



**LOW CARBON LIVING
CRC**

Research Synthesis Report: A Research Agenda for Low Carbon Mobility



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ACRONYMS

BRT	Bus rapid transit
CRC	Cooperative research centre
CUTE	Comparative study on urban transport and the environment
EU	European Union
EV	Electric vehicle
GDP	Gross domestic product
GHG	Greenhouse gas
HSR	High speed rail
HTS	Household travel survey
ICEV	Internal combustion engine vehicle
ITS	Intelligent transport systems
LCL	Low carbon living
LCM	Low carbon mobility
LCT	Low carbon transport
LL	Living laboratories
LUTE	Land use transport environment
LUTI	Land use transport interaction
MRT	Mass rapid transit
PEV	Plugin electric vehicle
QOL	Quality of life
SP	Stated preference
TOD	Transport oriented development

INTRODUCTION

Context – Carbon, transport and urban precincts

Over 80 per cent of carbon dioxide emissions originate in urban areas (Grubler 1994, O'Meara, 1999), which occupy less than 2.4 per cent of the global land mass (Churkina 2008, Potere and Schneider 2007). The global rate of migration towards cities is three times greater than the rate of population growth (UN 2006). In 2007, for the first time in human history, more than half of the world's population was living in urban settings (UN 2007). Cities have been recognized as major contributors to global greenhouse gas emissions (International Energy Agency 2008, Grimm, Faeth and Golubiewski 2008), as well as a critical part of the solution in reducing these emissions (Chavez and Ramaswami 2011).

In the USA, studies have shown almost 40 per cent of total carbon dioxide emissions are associated with residences and cars, and that changing patterns of urban development and transportation can significantly impact emissions (Glaser and Kahn 2010).

In Australia we have one of the fastest growing populations for a developed country (Productivity Commission 2010) and one of the highest per capita carbon and ecological footprints in the world (Garnaut 2008, Global Footprint Network 2010).

Australian cities are typically composed of low density, dispersed suburbs, which are highly car dependent. This is resource and carbon emission intensive and therefore unsustainable in the long term (Rauland and Newman 2011). There is an immediate need for Australia to transition its cities to a low carbon alternative with more efficient form and function with respect to carbon emissions. A low carbon city must improve the energy efficiency of its buildings and transport system (Chavez and Ramaswami 2011). A key aspect of this transition is transportation.

Transportation systems guide our mobility, that is, our ability to move from one place to another in order to achieve our objectives. Transportation provides access to jobs, education and social interactions, for example, all of which are fundamental to human development (Donoso, Martinez and Zegras 2006).

Urban form can have a significant effect on the carbon intensity of travel, with some urban forms showing a greater capacity than others to reduce the rate of carbon emissions per capita. Newton et al (2012) underscore the importance of integrated land use and transport planning for growing cities, providing examples where transport planning and development planning have happened independently resulting in reliance on private vehicles or excessive pressure on public transport services. A major transformation in the way transport planning is carried out is required with a new approach toward environmental and liveability aspects and a focus on achieving carbon efficiency in transport and urban precincts (Hickman and Banister 2007).

Beyond reducing carbon emissions, changing the way we undertake urban and transport planning offers the potential to generate other important long term benefits, such as open space preservation, improved air quality and public health, and reduced infrastructure investments, leading to improved quality-of-life in urban areas (Donoso, Martinez and Zegras 2006).

Transport is a major source of carbon emissions in Australia, accounting for about 15.3 per cent of total GHG emissions in 2010 (DCCEE, 2012), 86 per cent of which came from road transport. Passenger cars were the largest single source of greenhouse gas (GHG) emissions from road transport. Analysis of the 2010 National Greenhouse Gas Inventory data indicates that urban transport accounted for some 73.6 per cent of the total road transport GHG emissions in Australia, or some 51.3 Mt CO₂-e per annum. Private car usage in urban areas was responsible for 55.5 per cent (39.7 Mt CO₂-e p.a.), i.e. 45.3 per cent of total transport GHG emissions and 7.3 per cent of total GHG emissions from all sectors

as recorded in the 2010 National Greenhouse Gas Inventory (DCCEE 2012).

Lenzen and Dey (2003) indicated that about 15 per cent of total household GHG emissions were attributable to the travel activities of the households.

Further, GHG emissions from the transport sector increased 32 per cent between 1990 and 2010, despite the considerable advances in vehicle, engine and fuel technologies over that period.

Passenger car usage in Australian cities is thus a significant source of GHG emissions, and one that can be directly related to the shape and form of the built environment.

Similar (if not worse) findings for other countries emerge from a scan of the international literature (e.g. Banister et al 2011, Nakamura and Hayashi 2012). One reason for this increase in transport emissions is the increase in travel that has occurred during the period. Reducing carbon emissions from the transport sector is becoming more difficult, not easier.

Researching low carbon mobility

Low carbon transport (LCT) or, more broadly in terms of urban planning and the built environment, low carbon mobility (LCM) have featured in many discussions in the Cooperative Research Centre (CRC) for Low Carbon Living (www.lowcarbonlivingcrc.com.au), particularly for Research Programs 2 (Low Carbon Precincts) and 3 (Engaged Communities). Indeed, as discussed later in this report, the CRC has specific milestones related to travel demand and transport activity. What has been missing is a research agenda to inform the CRC about relevant research topics on low carbon mobility which fit under its broad research strategy, especially in urban planning and urban design and the carbon emissions consequences of alternative plans and precinct designs, and which can provide outcomes that will assist the CRC to meet its objectives. As a consequence the CRC conducted a national workshop in Adelaide on 29-30 October 2013 to debate the issues and to develop a research agenda. The workshop participants included

CRC researchers and industry partners, as well as other interested parties. This report summarises the workshop proceedings and presents a research agenda developed from those proceedings and a review of the literature in the field.

Planning for personal mobility and the required transport infrastructure and service provision to meet mobility needs is an important component of precinct design in the built environment. Estimation and forecasting of transport demands are an integral part of a current research project in the CRC. Research issues already raised in the CRC include health co-benefits of active transport modes, utilisation of electric vehicles, travel behaviour change programs, urban form and land use-transport interaction, and travel substitution. These issues are best represented under the banner of mobility, as a significant subset of human activity within the built environment, and so this report focuses on research needs for LCM with special reference to urban areas.

The primary output from the workshop is this report, outlining a plan for potential relevant research on low carbon mobility by the CRC, over the period 2014-2019. The plan is based on a synthesis of the discussions in the workshop, informed by the keynote and background papers prepared for it and a review of the international literature. These resources provide a valuable secondary output of the project.

A special issue of the journal *International Journal of Sustainable Transportation* has been arranged. This will include selected papers from the workshop, a paper outlining the research agenda developed in it (as presented in this report), and other invited contribution. All papers in the special issue are subject to the normal peer review procedures of the journal.

The outcome of the workshop is thus a well designed research agenda for the CRC to pursue in the area of low carbon mobility, which should serve to inform and guide its research on low carbon precincts and engaged communities where transport dimensions are of importance. This will include precinct demand estimation

and precinct design, technologies and systems for low carbon living, land use-transport interaction in urban design, and voluntary behaviour change programs.

The final workshop report is to be circulated to all CRC members. It will also be distributed to the wider community through the CRC website. As such it will provide the basis for planning and scheduling of CRC research on low carbon mobility, and a resource for other researchers and end users in the field.

Potential research areas

There is an emerging international consensus that significant research on LCM is needed, largely because of the complexity of the topic. An optimum blend of technological development, infrastructure adjustment, innovative policy developments and community behaviour change is apparent. Givoni and Banister (2013) identified three possible ways to substantially reduce the carbon associated with mobility and transport, either individually or in combination:

- to change social norms,
- to follow an economic growth model not coupled with transport volumes, and
- to switch to a different transport system.

Each of those areas requires substantial research in its own right, and then the optimum combination needs to be explored. An initial indication was provided by Bristow et al (2008), who compared transport policy settings and developments in the UK with the national targets for carbon reduction to the year 2050. They concluded that even dramatic technological advances would not meet those targets without considerable behavioural change. Santos, Behrendt and Teytelboym (2010) considered a wide range of low carbon transport policy options, which they grouped into three categories:

- *physical policies*, concerning infrastructure and service provision,
- *soft policies*, aimed at bringing about behavioural change, and

- *knowledge policies*, emphasising the role of investment in R&D for future sustainable mobility.

They argued that policy integration was the key and that optimal blending of mutually reinforcing policies was essential. Banister (2011) discussed the concept of the sustainable mobility paradigm, which again required integrated, mutually supporting sets of policies. Banister and his colleagues then suggested a possible policy framework for LCM systems (Banister et al, 2011) but this still required determination of relevant policies sets. A major question is just what policies should be considered and how the policy settings can be optimised. Nakamura and Hayashi (2012) reviewed international developments on LCM policies and strategies and concluded that the specific development processes of individual cities significantly affected the feasibility and effectiveness of different policies.

Vehicle technology and vehicle ownership/access to vehicles, emerge as particular areas of concern for LCM, both in terms of actual carbon emissions and the propensity of people to use private motor vehicle transport (e.g. see Brand et al 2013). Again policy instruments – that affect vehicle selection and ownership, and vehicle usage – are important concerns, especially with regard to long term impacts (on government revenues in particular) and policy mixes.

Strategies to encourage, facilitate and maintain travel behaviour change are also important and may take a variety of directions (Taylor 2007, Line, Chatterjee and Lyons 2012) depending on the community or socio-demographic groups involved. Methods now exist for evaluating the short to medium term effects of voluntary travel behaviour change programs, and the potential for success of the programs is gaining better understanding (Zhang, Stopher and Halling 2013). A particular area of research interest for the CRC is in the potential health co-benefits for LCM, which is also the subject of international research (e.g. Mindell et al 2011, Mackett 2013).

Physical design of precincts is also recognised as a key area for LCM research, especially in design for

pedestrian movement and cycling to local facilities, and for access to public transport services. Dong, Dong and Wang (2011) describe the research issues well, in terms of 'last mile' movement, the access or feeder services to main line public transport.

Good planning practices will allow low carbon mobility to become a reality; however, prior to the workshop there has been no proposed CRC research plan for this area of urban activity. The purpose of the workshop was to indicate and map out the needs for LCM research by the CRC and to formulate a systematic research agenda on the topic, relevant to the objectives/milestones of the CRC and achievable within its initial lifetime of seven years.

The following information was provided to participants before the workshop as a starting point in developing the research agenda for:

- *LUTI (land use-transport integration)*, which remains the key concern in planning for the development and evolution of urban areas, including the spatial distribution of facilities, services, employment and residences, and how these are affected by and in turn influence travel patterns and transport systems and technologies. In a low carbon future where energy types and sources for both transport and facilities will be different, new insights are needed into the interactions.
- *LUTE (land use-transport-environment)*, which builds on the basic concerns in LUTI to consider the environmental impacts of urban development. For low carbon futures, the environmental issues need to also encompass energy usage, especially but not uniquely for transport systems. This includes alternative energy types, supply and availability. Environmental consequences are measured in terms of emissions, taking in both GHG emissions and air quality emissions. At the local (precinct) level air quality, especially in terms of total hydrocarbons, individual species of hydrocarbons, and particulate matter is of increasing concern as a public health issue. Three related sub-areas are:

- the energy supply infrastructure for alternative transport energy sources, with particular reference to the adoption of electric vehicles, and the potential impacts on land use and precinct design,
 - public health issues concerning the use of different transportation modes and the impacts of air pollutant emissions, and
 - the impacts of urban design details on individuals' travel behaviour choices.
- *Accessibility (of services and facilities, for enterprises and providers, and to services and facilities, for inhabitants and consumers)* is a key performance indicator for the operation of urban areas and their transport systems. How to measure and assess accessibility in a comprehensive way, accounting for local or precinct effects, is an area for new research. This will need to account for the availability of different transportation modes to households and individuals, include time-of-day effects, and consider virtual access alternatives to direct physical access. The development and selection of meaningful indicators of accessibility that can be interpreted and used by planners and policy makers is vital.
 - *Precinct design measures* that aid, improve and encourage pedestrian and bicycle movement, especially with regard to access to public transport stops, stations and terminals.
 - *Vehicle ownership and access* to vehicles, including considerations of the uptake of new and alternative vehicle types (e.g. electric cars, and electric bicycles), policy measures to influence both ownership and usage of private vehicles, and alternative models for vehicle availability (e.g. car pooling, car sharing, car clubs).
 - *The use and impacts of new technologies* for 'smart(er)' control of existing urban infrastructure systems, especially transport systems and energy supply and distribution systems. This includes both existing systems, with the objective of reducing carbon dependency and emissions, and new

systems based on low carbon dependency. One specific topic of interest for transport is the use of energy in urban areas and the impacts on that usage of traffic congestion.

- *Systems and infrastructure* for the 'refuelling' of alternative technology vehicles and fuels, including biofuels stations, recharging facilities for electric vehicles, and the interactions between the transport energy supply system and other infrastructure systems.
- *Mechanisms for decoupling GDP and transport GHG* and the development of LCM policies that do not inhibit economic development.
- *Programs for voluntary travel behaviour change* and their applicability to different groups in the community.
- In terms of methodological considerations, *modelling, interpretation* and *visualisation* tools need to be defined and examined, and their roles in decision support outlined.

Using this information as a guide the workshop was conducted in five sessions with the themes of:

- Land use-transport integration and urban design,
- LCM policy and behaviour change,
- Systems and infrastructure,
- New Technology and new approaches, and
- Modelling, measuring and visualising.

Workshop approach

The workshop aimed to establish the needs for CRC research on low carbon mobility and set a potential research agenda for the CRC. Day 1 focussed on general aspects of LCM, including policy formulation, co-benefits of LCM initiatives, active transport modes, land use-transport interaction (including urban accessibility planning and travel substitution) and travel behaviour change. Day 2 focussed on related areas such as alternatives for vehicle ownership and access, transport

technologies, electric vehicles, alternative fuels and infrastructure implications.

The workshop was conducted as an active event in which all attendees participate in discussion and debate in small groups, and in plenary session and panel session. Short formal paper presentations were made at the beginning of each session to inform the discussion and debate between participants. Rapporteurs for each workshop session collated the findings from the workshop groups and reported back to the workshop as a whole at the end of each day. The rapporteur summaries form the basis of the following session summaries.

Appendix A shows the workshop program and Appendix B lists the workshop participants.

WORKSHOP SESSION SUMMARIES

Keynote Session Summary: International perspectives

The workshop began with presentations from two eminent international researchers in the field, Professors Yoshitsugu Hayashi (Nagoya University) and Guenter Emberger (Vienna University of Technology), to provide an international context and perspectives on research and research needs in low carbon mobility. The topics of the presentations were:

- Drastic visioning and backcasting to leapfrog to low carbon transport in growing Asia (Yoshitsugu Hayashi)
- Low carbon transport strategy in Europe – a critical review (Guenter Emberger)

Seeking low carbon outcomes for rapid urbanisation in Asian cities

Professor Hayashi considered the rapid urbanisation occurring in Asia, the formation and growth of a significant set of megacities in that continent, and potentially profound impacts on global greenhouse gas emissions. He proposed a visionary planning strategy for urban development which he described as 'backcasting to leapfrog to a low carbon society', as a means to both reduce per capita carbon emissions in developed countries and prevent the rapid increase of those emissions in developing countries as their economic development took them closer to the conditions of the developed world. Figure 1 provides a schematic view of the 'backcasting and leapfrogging' vision for urban futures. The essence of backcasting is to develop a preferred vision of the future and then seek policies and initiatives directed at fulfilling that vision.

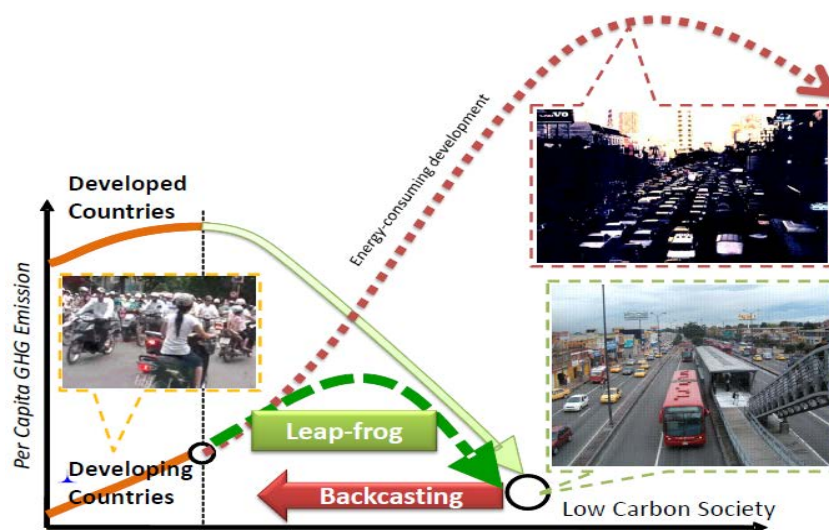


Figure 1: Risk of rapid growth in CO₂-e emissions in the developing countries of Asia and the backcasting and leapfrogging vision
[source: Hayashi (2013)]

To achieve the low carbon transport and low carbon society scenario described in the vision, Professor Hayashi recommended the adoption of a systematic planning methodology termed the Comparative Study on Urban Transport and the Environment (*CUTE*) – see Nakamura, Hayashi and May (2004) – which is based on three parallel planning objectives: *Avoid*, *Shift* and

Improve. Policy and technological options for improved GHG emissions performance can then be described and compared in terms of the *CUTE* matrix, as exemplified in Table 1.

Table 1: Example CUTE matrix of policy/technology options for urban policy development (from Nakamura, Hayashi and May (2004))

Strategy Means	AVOID	SHIFT	IMPROVE
Technologies	<ul style="list-style-type: none"> • Transport oriented development (TOD) • Polycentric development • Efficient freight distribution 	<ul style="list-style-type: none"> • Railways and BRT development • Interchange improvement among railway, BRT, bus and paratransit modes • Facilities for personal mobility and pedestrians 	<ul style="list-style-type: none"> • Development of electric vehicles • Development of biomass fuels • ‘Smart grid’ development
Regulations	<ul style="list-style-type: none"> • Land use control 	<ul style="list-style-type: none"> • Separation of bus/ paratransit trunk and feeder routes • Local circulating services • Controls on driving and parking 	<ul style="list-style-type: none"> • Emissions standards • ‘Top runner’ approach
Information	<ul style="list-style-type: none"> • Telecommuting • Online shopping • Lifestyle change 	<ul style="list-style-type: none"> • ITS public transport operation 	<ul style="list-style-type: none"> • ‘Eco-driving’ • ITS traffic flow management • Vehicle performance labelling
Economy	<ul style="list-style-type: none"> • Subsidies and taxation to location 	<ul style="list-style-type: none"> • Park and ride • Cooperative fare systems among modes 	<ul style="list-style-type: none"> • Fuel tax/carbon tax • Subsidies and taxation to low-emission vehicles

Hayashi then indicated how the ‘avoid, shift and improve’ paradigm can then be applied to develop a backcasting framework for the development of urban land use and transport policies that both account for broader trends in society (e.g. economic development, population aging and technological innovation) and aim for the realisation of a low carbon city. The approach is indicated in Figure 2. This indicates that societal trends provide the basic driving forces for socio-economic development that then influence lifestyles, consumption and production and lead to the development and use of urban land use-transport systems. Transport and land use policies follow, as governments at all levels attempt to manage urban and regional growth and its impacts on society, the economy and the environment.

Policies aimed at the realisation of low carbon cities need to be cognisant of the relationships between the trends and their impacts on urban development, so that policies and initiatives that encourage low carbon development can be formulated and applied. The primary consideration in Hayashi’s approach is the need for transport policies that demand the early introduction and provision of mass rapid transit (MRT) in developing

cities, as the means to avoid if not prevent the onset of mass motorisation that leads to high carbon outcomes, as exemplified in the modern cities of the developed world. Secondly, Hayashi argues for economic policies that are ‘sufficiency seeking’, and perhaps then seek moderation (but still continuation) of economic development, as opposed to ‘efficiency demanding’ policies based on aggressive economic growth. Figure 3 illustrates this decomposition of the vision of urban transport systems into low carbon strategies using the ‘avoid, shift and improve’ paradigm.

Figure 3 suggests that the outcome of the low carbon city can be achieved through multiple paths regarding economic development, but that strong policies and planning strategies, including the imperative to invest strongly in transit infrastructure and services are essential elements of the adopted process.

On the basis of his study of several of the Asian megacities (including Tokyo, Bangkok and Shanghai) and regions (such as the Greater Mekong region of SE Asia), Hayashi concluded that:

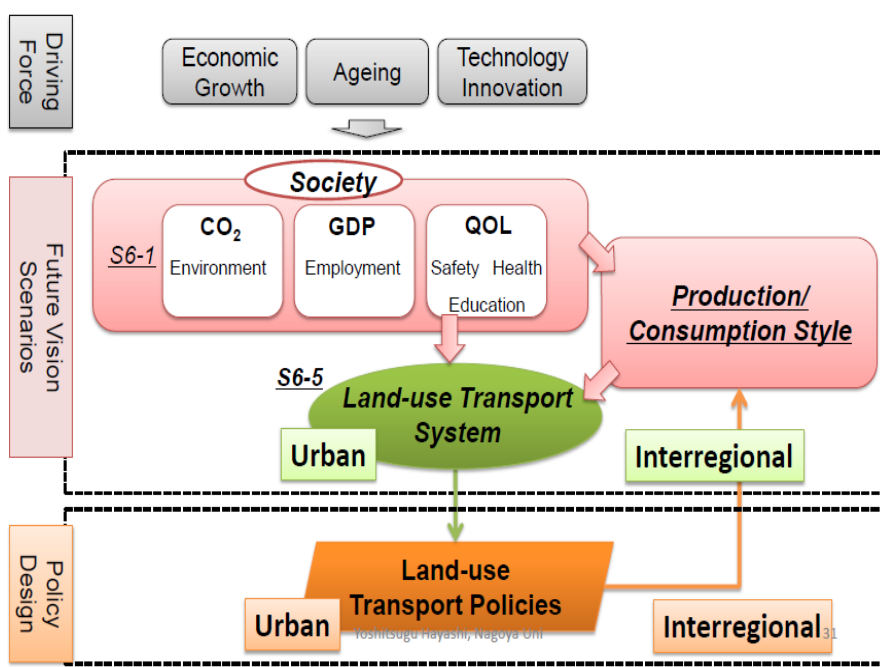


Figure 2: Framework for the backcasting approach to the development of a low carbon city [source: Hayashi (2013)]

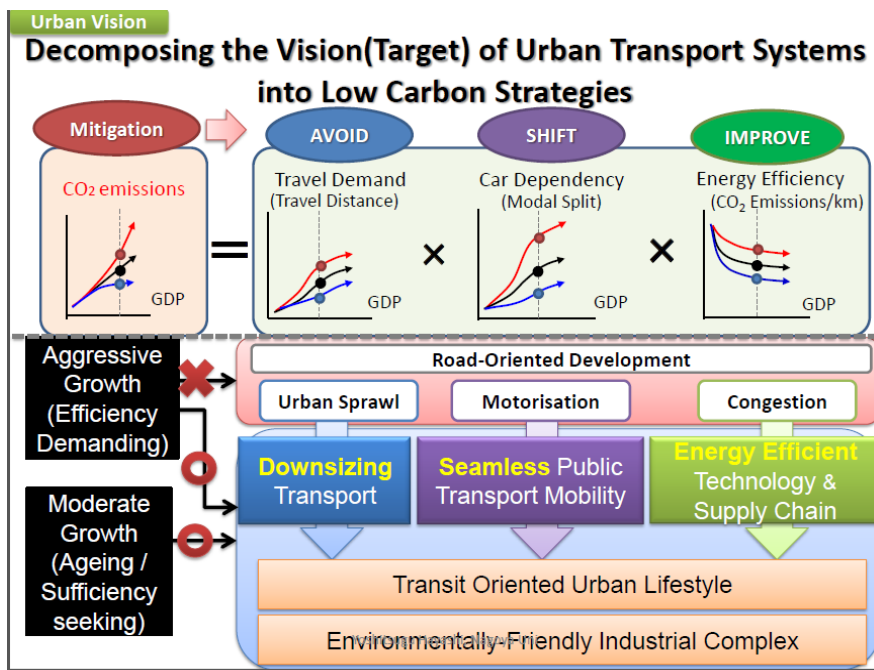


Figure 3: Decomposing the vision (target) of urban transport systems into low carbon strategies [source: Hayashi (2013)]

- compact city development with mainstreaming of rail and water transport can meet diversifying passenger transport demands and growing freight transport demand, and
- 40-60 per cent reductions in CO₂-e emissions could be achieved through policies for compact city development and the early implementation of urban MRT systems (with high speed rail (HSR) development for intercity travel).

This suggested two areas for strategic consideration: the 'leap frog' that is required to shift from high-carbon road-oriented mobility and supply chains to transit-oriented urban lifestyles and rail-oriented industrial development in Asian cities, and policies to encourage broader changes in lifestyle and production processes that would be favoured by these transport sector reforms.

A critical review of Europe's low carbon transport strategies

Professor Emberger described the current European initiatives on low carbon transport, as represented by the European Community's White Paper on Transport (EU, 2011) and the subsequent policy brochure 'Towards low carbon transport in Europe' (EU, 2012). These documents discuss the recent trends in transport activity and on environmental impacts, provide forecasts of the impacts of European transport systems on greenhouse gas emissions, and outline policy instruments intended to produce low carbon outcomes. Notwithstanding this substantial endeavour, there were a number of significant issues revealed in a critical review of the European Union's (EU) low carbon transport strategy, which could result in less effective outcomes than originally envisaged. Professor Emberger was then able to suggest new and additional policies and actions that could assist in the realisation of the EU's stated goals on low carbon transport.

The EU's vision is for a competitive and sustainable transport system growing transport activity and supporting mobility while reaching its 60 per cent emission reduction target by 2050 (with respect to 1990) in the transport sector through:

- 1) improving transport efficiency
- 2) energy efficiency, and
- 3) alternative fuels and propulsion systems.

The first point to note though, is that curbing mobility is not part of the options set under this vision.

In the broader area of GHG emissions reduction, the EU is a proactive force in the international arena in contributing to agreements on GHG emission reduction, and has a commitment to '20-20-20 targets' for 2020 in climate and energy policy:

- 20 per cent reduction in greenhouse gas emissions on 1990 levels and 30% reduction if other developed countries make comparable reduction commitments (still 8% above 1990 level)
- 20 per cent increase in renewable energy – wind, solar and biomass – of total energy production (currently 8.5 per cent)
- 20 per cent reduction in energy consumption in projected 2020 levels by improving energy efficiency.

In terms of the transport sector's contributions to GHG emissions, presently 23 per cent of the total emissions in the EU come from transport. As in Australia, the trend is for the transport sector to continue to grow as a proportionate contributor to total GHG emissions: if present trends continue the transport will be responsible for 50 per cent of the EU's emissions by 2050 or, in a worst case scenario, earlier (by 2030). See Figure 4, taken from EU (2012) – the transport sector stands out from all others.

EU (2012) indicates that of the EU27 GHG emissions from the transport sector, road transport is responsible for the large majority (70.6 per cent of transport emissions), with the next two largest contributors being international maritime transport (14.4 per cent) and international aviation (10.6 per cent). Domestic aviation, domestic navigation and rail make up almost all of the remaining emissions, in roughly equal proportions (about 1.2 per cent each).

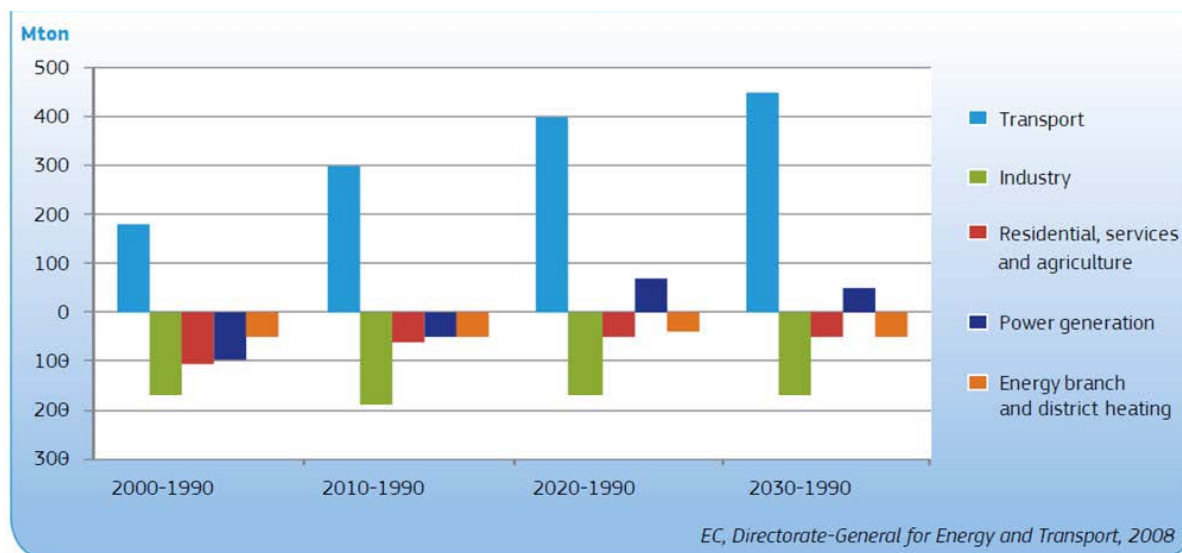


Figure 4: Historical and projected changes in CO2-e emissions in the EU by sector [source: EU (2012)]

The three initiatives in the EU vision a competitive and sustainable transport system (improving transport efficiency, energy efficiency, and alternative fuels and propulsion systems) were cited above. For each initiative, the EU has set out specific policy directions, but there are some deficiencies in each area.

For *improving transport efficiency*, the EU indicates that:

- making transport infrastructure and services throughout Europe more efficient should lead to reductions in GHG emissions
- 'better' infrastructure planning should facilitate a shift from road to rail and inland waterways
- overall transport efficiency can be reached through ITS (intelligent transport systems).

These directions are discussed in detail in EU (2011). The major deficiency is that there is little indication that the policies for improved transport efficiency will lead to any changes in behaviour, so that substantial decreases in emissions may not be realised.

For improved *energy efficiency*, in transport, technological innovations should raise vehicle energy efficiency, and new technologies and engines can result in clean and energy efficient road transport. These directions are mainly orientated towards individual

vehicles, and may offer little for total traffic impacts. Again, there must be questions about their ability to lead to behavioural change, and indeed the opportunity for rebound effects, by which travellers use the new technologies to increase the amount of travel they undertake, should not be ignored.

For the direction involving *alternative fuels and propulsion systems*, there is a substantial need for extensive research to enable a shift from fossil fuels to decarbonised transport, involving the likely market uptake of such systems in the general community. Research and policy interventions are required to assess the potential impacts. Once again, impacts of behaviour change and rebound effects are not obvious. In addition, there is a need to consider whether there is real opportunity for alternative fuels, such as bio fuels, to be made available in sufficient quantities to have a significant impact on transport behaviour. Research is also needed on the opportunities for non-transport alternatives (such as e-mobility) to replace physical movement (of people) to such extents that significant reductions in GHG emissions could occur.

In short, Professor Emberger summarised the present LCT strategy in Europe in the following terms:

- The EU wants to increase economic growth

- With that growth they want to finance technology improvement *and* market penetration of the technologies, so that the technologies can be used as the main means to reach the emission targets
- With the development of technology they would like to generate the necessary economic growth.

The potential flaws in this approach are:

- Decoupling of economy and energy consumption (resources) – is this possible?
- Where will the ‘next’ limiting factors be (energy, crops for biofuel, space, urban sprawl, Lithium, others,)
- What happens if there is no economic growth?

The general problems in the process are thus:

- Decision making and implementation within 28 countries, and the inevitable time delays in full adoption and implementation of overall policies)
- The influence of global companies (e.g. the current debate on GHG emissions of the vehicle fleet in Europe)
- Global perspective, with the EU depending also what others will do (e.g. lower standards in other countries or regions may lead to lower economic growth in Europe and thus less opportunity for emission reductions based on economic growth and technological innovation)
- Considerations of people who may not be able to afford the ‘new’ technologies.

Consequently, Professor Emberger concluded that:

- The EU LCT strategy is based on economic growth
- There is no plan ‘B’ if growth does not take place
- Also with growth the targets of GHG reduction are very unlikely (export of dirty industries, urban sprawl, decoupling, etc.)
- GDP is not the right indicator when talking about sustainability

- Potential can be found in the reorganisation of transport in cities
- Car (motorised individual transport) is not sustainable
- Understanding human behaviour (body energy vs external energy; changes of modal split without reducing trip numbers or increasing travel times)
- Higher car and motorcycle speeds increase the attractiveness of their use
- One important solution for urban transport problems is the organisation and availability of parking space
- Responsible transport planners have to provide infrastructure for sustainable means of transport – pedestrians, cyclists (the ‘active’ modes) and public transport (see case study)
- The Priority Order towards sustainability should be:
 - 1) Walking
 - 2) Cycling
 - 3) Public transport
 - 4) ...
 - 5) ...
 - 6) Private motorised transport.

Case Study

Emberger presented a solution for transport problems through the re-organisation of parking spaces and highlighted the responsibility of transport planners to provide infrastructure for sustainable means of transport with priorities centred around walking, cycling and public transport. He highlighted this using the example of the city of Eisenstadt where a change in transport planning and policy resulted in a vibrant city centre, rather than a congested road thoroughfare with no social value (Figure 5).



Figure 5: Eisenstadt (left) in the 1980s compared to (right) today

Session 1 Summary: Land use-transport integration and urban design

This session included two starter presentations:

- Land use-transport integration in the decarbonising city (Jan Scheurer)
- Improving local mobility through increased local public transport and citywide network planning (Leigh Glover)

Scheurer described the use of the *Spatial Network Analysis for Multi-Modal Transport Systems* (SNAMUTS) method in an analysis of the performance of the public transport system in inner Melbourne under existing conditions and future scenarios, with a focus on the interaction between land use and transport operations.

Glover considered local mobility in urban areas, with a focus on local public transport services which he believed had been neglected in previous considerations of mobility. He provided five directions required for improved mobility:

- greater innovation and flexibility at the local scale, through new and emerging models of urban mobility
- maximising networking and integration, through joint consideration of public transport modes and the active transport modes
- greater clustering of services and destinations
- optimising road space for public transport and active transport

- new generation active transport measures and insights, including links to research on related public health issues).

Appendix C1 contains a consolidated summary of the group discussions.

Session 2 Summary: LCT policy and behaviour change

This session included two starter presentations:

- Low Carbon Transport in a Walkable Polycentric City (Cole Hendrigan)
- Voluntary Travel Behaviour Change- what is it and what can it achieve? (Belinda Halling).

The presentations raised two of the many possible policy-oriented research responses to high car-dependency and the strong institutionalisation of car-oriented planning in Australian cities over many decades.

The first looked at use of graphics and 3D models that could help the public and policy makers to understand the physical capacity and redevelopment yields from intensified settlement in nodes around rail. This study used Perth as a case study due to the very high level of automobile ownership combined with a very low population density. The purpose of the presentation was to develop ways to demonstrate through models and graphic illustration the interaction of land capacity, redevelopment yields, and policy options.

The second presentation outlined the community programs undertaken by the South Australian Dept. for Planning, Transport and Infrastructure to encourage behaviour change with respect to car use. The presentation provided evidence of positive long-term behaviour outcomes from trials of travel behaviour change through direct engagement and provision of information in various forms. This presentation described the data on travel behaviour that has been collected using GPS loggers.

Appendix C2 contains a consolidated summary of the group discussions.

Session 3 Summary: Systems and Infrastructure

This session included two starter presentations:

- Electric vehicle integration (Iain MacGill)
- The use and applicability of EVs (Rocco Zito).

McGill began by providing a background on the challenges facing the use of Electric Vehicles (EVs) as a means of reducing GHG emissions. A range of background research papers were introduced relating to the deployment; potential (for emissions reduction); economic issues; and integration of EVs within urban transport systems. He then reported on a UNSW study 'CEEM Project on Integration', which modelled data from the Sydney Household Transport Survey and explored the relationship between charging rates and a number of charging distribution scenarios: residential only; residential and commuter off-street; and universal off-street. Two key findings were reported:

- charging infrastructure availability is a key variable which effects marginal and average emissions from charging; and the flexibility to move charging load
- a trade-off is observed between the economic interests of the electricity industry and emissions.

Zito began by highlighting how EVs are used differently to internal combustion engine vehicles (ICEVs). EVs are applicable to urban travel i.e. most daily travel by people in

urban regions is less than 100km. What is important is the perception of EV; this is the issue of behaviour change to enable the adoption of EVs. He then talked of the issue of *range anxiety* and highlighted the importance of the relationship between the placement of charging stations, the perception of drivers and the patterns of everyday travel. The location of charging stations needs to be considered with future accessibility modelling. He concluded by noting the importance of the use a common methodology to evaluate carbon emissions.

A number of questions followed:

- the first related to the integration of cleaner energy such as solar, wind into the charging infrastructure for EVs. It was noted that the electrical energy for EVs will most likely come from a diverse range of sources
- the second question related to the potential for EV uptake in fleet vehicles
- the third question introduced the idea of EVs changing the ownership structures or perception of the need to own one, two or three cars.

Appendix C3 contains a consolidated summary of the group discussions.

Session 4 Summary: New technology and new approaches

This session included two starter presentations:

- New Technologies for Low Carbon Mobility (Jason Miller)
- Lighter-than-cargo vehicles (what price mass?) (Peter Pudney)

Miller discussed the need for new technologies for low carbon mobility and how they can be achieved. Miller proposed the use of the 'innovation funnel' to accelerate the adoption of these new technologies by systematically using this framework to match needs to the design through the product planning process. The new technologies discussed included: EV technology, cyber cars, autonomous cars, pod cars and air rail transit.

Pudney characterized vehicles by their mass and its impact on fuel efficiency, and argued that lighter vehicles are the future due to their high energy efficiency for a given speed. However, the safety infrastructure needed for this new technology is an important area of debate.

Appendix C4 contains a consolidated summary of the group discussions.

Session 5 Summary: Modelling, measuring and visualising

This session included two starter presentations:

- Measuring and modelling low carbon transport (Vinayak Dixit)
- Estimating greenhouse gas emissions by private vehicles (John Moore)

Dixit discussed the need for a methodical, multi-disciplinary approach to modelling aspects of electric vehicles at the demand, supply and technological levels as outlined in Figure 6 below. Dixit also advocated the need to take theory and lab based experiments into the field where there are many uncontrollable factors.

Moore discussed the work Adelaide City Council had undertaken to estimate the carbon emissions generated by vehicle trips with an origin or destination within the council boundaries. This work used a standardised method based on easily available data to estimate the carbon emissions that could be similarly applied in other locations.

Appendix C5 contains a consolidated summary of the group discussions.

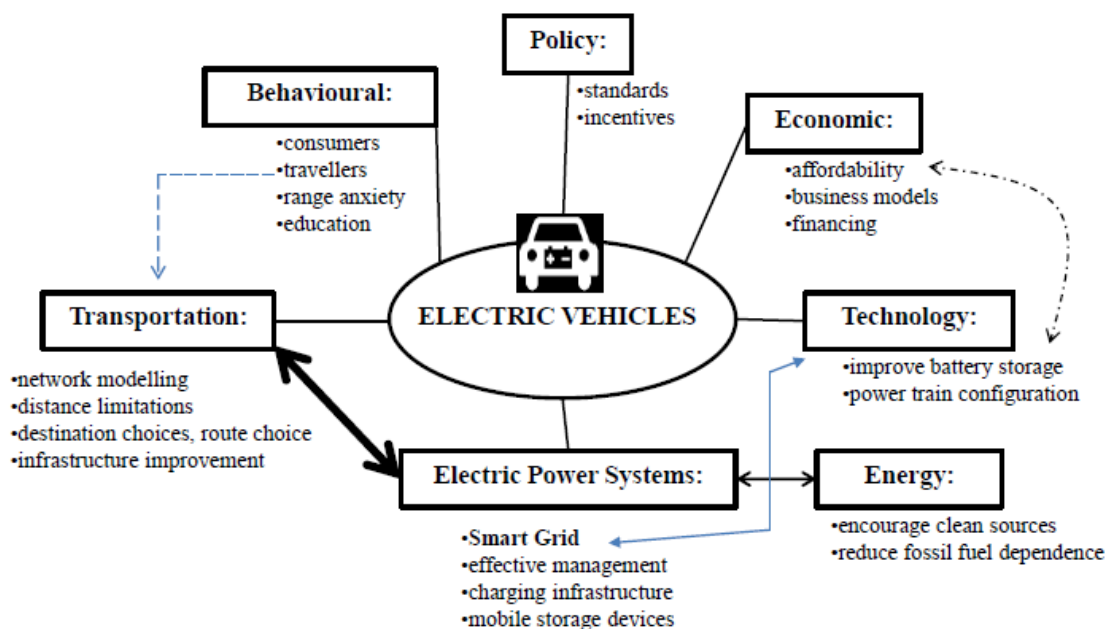


Figure 6: Modelling aspects required for consideration with respect to electric vehicles

RESEARCH SYNERGIES & SYNTHESIS

Identifying Research Synergies

A review of the session summaries allowed several key research areas to be identified across the various themes of the workshop. These can be generalised under the following topics:

- Data
- Integration
- Evaluation
- Urban design and planning
- Technology, and
- Safety.

The following paragraphs discuss the current state and the future requirements, as evidenced from current literature and the workshop discussions, for research for low carbon transport under these headings.

Data

Data issues were a recurrent theme through the workshop discussions. Reliable data was identified as being essential in proving the value of low carbon transport options, understanding why and how people travel in the manner that they do and further identifying how to promote increased transition to low carbon transport options. Several data issues were raised relevant to furthering research regarding low carbon transport.

The first data issue relates to data collection. Developing a reliable, standardised method for travel data collection, employing a less resource intensive method than current techniques, was identified as important in the future of LCT research.

Conversely, there is also a requirement to better understand the data that has already been collected and

realise its full potential application. For example, many travel behaviour studies have been undertaken across Australia. A repository for travel data from these studies would be useful to many researchers, and more in depth analyses across a wide number of studies may allow new insight into travel behaviour. Using the data we have to its full capacity would reduce the burden of new data collection. For instance, most major cities have substantial Household Travel Survey (HTS) databases which include activity-travel diaries of individuals in households. These data sets could be subject to more in depth analysis to indicate household mobility patterns, e.g. as done for trip chaining by Primerano et al (2008). Perhaps even more importantly, the extensive (longitudinal) data sets collected in evaluations of large scale travel behaviour change programs, such as the Perth 'Individual Marketing' program and the Adelaide 'Travelsmart' program (Zhang, Stopher and Halling 2013) contain much in depth data on personal mobility, attitudes to travel, and individual mobility trends over time, that have never been fully analysed. In the Adelaide case several waves of data were collected from a survey panel over an eight year period. These data include household socio-demographics and travel behaviour, the latter measured using GPS devices and thus providing a high level of detail and accuracy about travel. The relationships between personal mobility and the usage of services and facilities at different locations relative to place of residence could be explored in some detail using these existing data sets, a most effective and efficient way to gain greater understanding of behaviour and the opportunities for low carbon mobility policies and programs. This is an important area for future research by the CRC.

In addition, new data sources are emerging with the widespread implementation of new technologies for transport services. For example, 'smartcard' fare payment systems for public transport – as now operating in most of Australia's capital cities – are providing an ongoing source of data on public transport usage, collected routinely in the operations of the public transport system. These data can be made suitable for research and investigation on travel behaviour and the

propensity to use public transport. With suitable research and development the data can be linked to the socio-demographic and locational characteristics of the card users (subject to necessary privacy constraints). Opportunities for research on the utility and application of these data sets for information on access needs to public transport (and hence precinct design) and on service provision in suburban areas need to be fully explored by the CRC.

Modern advances in the use of stated preference (SP) methods and discrete choice modelling (Hensher, Rose and Greene 2005, Rose et al 2008) and the coupling of advanced discrete choice models with GIS analysis (Meng, Taylor and Scrafton 2014) are providing enhanced opportunities for the exploration of the factors influencing people's life style, location and travel decisions, the identification of relevant target groups in society (including geographical locations), and the formulation of policies and plans to suit the needs of and influence specific groups. Modern SP sampling and data collection methods offer far greater efficiency in new data collection, and when coupled with advanced choice models offer powerful new tools for informed policy and planning decisions.

Integration

The research theme of integration relates to how low carbon mobility can be integrated into existing infrastructure, behaviour, and policy making. These research areas are discussed in the following sub headings.

Integrating LCM and Infrastructure

In order to successfully and efficiently transition to a low carbon transport future it is important to consider how and where LCM technology can be integrated into existing supporting infrastructure to improve low carbon mobility. Two examples are provided here from the literature.

Singh and Strømman (2013) analysed the potential for reducing the global warming potential from the passenger vehicle transport sector in Norway through

the large scale transition to electric vehicles. The potential benefit was found to be between three and fifteen per cent when the complete life cycle of the vehicle type was considered. However, as hydropower, a low carbon energy source, was the primary energy source for electric vehicles (EVs) in Norway, the benefit was more pronounced. For countries such as Australia electricity used to charge EVs is predominantly sourced from high carbon sources such as coal, gas or oil, perhaps significantly reducing the potential benefits of EV transition. In these countries, an important consideration for the transition towards LCM will be what can be done to integrate EVs with the existing infrastructure in order to maximise the potential benefits. Taylor et al (2010) analysed the potential GHG impacts of EVs in Australia, accounting for the sources of electrical energy (i.e. power generation technologies) in different states and regions, finding significant differences across the nation depending on the source of the electrical energy.

Traut et al (2013) provide a second example regarding the interaction between LCM transport options and infrastructure. Traut et al found one potentially significant limiting factor for any significant growth in Plug-in Electric Vehicles (PEV) numbers in the USA was the ability of households to charge vehicles at home. Less than half of US vehicles have reliable access to a dedicated off-street parking space at an owned residence where charging infrastructure could be installed. This fact is important for two key reasons. Firstly, consumers were found to be less likely to purchase PEVs if they do not have at home charging. Secondly, off-peak electric load times take place overnight, so more people charging during the day if they have access at their workplace will increase pressure on the existing electrical infrastructure.

Considering the best practice methods to allow the integration of LCM options within existing infrastructure restraints will be important in the transition to a low carbon urban future.

Integrating LCM and Travel Behaviours

Givoni (2013) states high carbon mobility is more of a social problem than a technological one, and so technology alone cannot fix it. As such we need to understand how and why people travel in various ways and what is needed to transition to low carbon mobility options.

Public awareness and perception are two major barriers for the transition to low carbon transport. Banister (2013) emphasises the need to understand the importance of time and how people want to use time in travel compared to other activities. Aditjandra, Mulley and Nelson (2013) suggest residents have to be well informed of the available opportunities for them to pursue sustainable travel choices. Hackbarth and Madlener (2013) found that despite the fact that most European Union countries have implemented programs to accelerate the diffusion of alternative fuel vehicles, predominantly electric vehicles, German car buyers are still very reluctant toward these vehicle types. Jensen, Cherchi and Mabit (2013) investigated changes to individual preferences and attitudes after individuals experienced an EV in their daily life. Whilst the results showed that individual preferences do change after exposure to the EV, driving range is a major concern. One of the key findings of their study was that the concerns individuals had about driving range were not due to misconceptions, but a true mismatch between the range they thought they required in their daily life and what the EVs provide.

The future of low carbon mobility relies on determining how we go about breaking down people's perceptions, misconceptions and barriers to change.

Furthermore, traditional behavioural framework models may not provide the best fit for behaviour related to low carbon transport options. Hensher, Greene and Chorus (2013) found people's behaviour with respect to decisions surrounding LCM options fit alternative behavioural framework models better than those traditionally used. Alternative models may provide a better predictive framework with respect to non-traditional transportation options.

Integrating LCM with Policy Making

Policy interventions are required in order to achieve a LCM future. The complex nature of the interaction between transportation and other urban systems, and the life cycle of transport related infrastructure means that traditional static planning practices may not achieve the desired outcome for reducing carbon emissions. Ramjerdi and Fearnley (2013) highlight the importance of adaptive and flexible policy-making frameworks, favouring methods of dynamic planning where decisions are made continuously and based on a steady flow of new information. A widely popular and accepted trend found to increase the success of policy implementation is the formulation of integrated policy packages, rather than policy measures that are considered and deployed in isolation (May and Roberts 1995, Banister et al 2000, Feitelson 2003, OECD 2007, Justen et al 2013a, Justen et al 2013b, Givoni et al 2013, Taeihagh, Bañares-Alcántra and Givoni 2013). Justen et al. (2013a) supports the use of policy packaging where there is a lack of public acceptability. For example, they discuss how urban road pricing schemes may be theoretically effective in encouraging modal shift from private car travel to public transport, but generally receive significant opposition from motorists. Policy packaging options to reduce opposition to the scheme could include public transport improvements, or directing revenue from the scheme to other road improvements.

However, it is not always clear what the 'correct' option is and which of methods and tools can be used for which purpose and at what stage in the process of policymaking (Justen et al 2013b, Ramjerdi and Fearnley 2013). Whitehead (2013) discusses an example from Stockholm, Sweden where a congestion charging scheme was introduced with an exemption for low emission vehicles, in conjunction with the introduction of financial incentives for the purchase of low emission vehicles. As the number of low emission vehicles increased, the effectiveness of the congestion reduction charging was severely diminished. As such, the exemption policy was phased out less than 18 months after being introduced. Ramjerdi and Fearnley (2013) raise several questions with respect to the

uncertainties and risk with transportation policies, including:

- What are the 'correct' sets of policies?
- How should the policies be phased in and out?
- How should the government address the choice among technologies?
- What are the variables/factors that need to be taken into consideration for decision making?
- What is the right time to take a position on a necessary regulatory framework?

Taeihagh, Bañares-Alcántra and Givoni (2013) have developed a virtual environment for the exploration and analysis of different configurations of policy measures in order to build and assess alternative policy packages. Packages such as these and decision support systems are required to assist policy makers to develop effective policies with respect to low carbon mobility.

Evaluation

A major concern raised throughout the LCT workshop was the current focus on the economic side of evaluation related to low carbon transport schemes. It was suggested in the workshop that based on economic merits alone, LCT schemes often do not perform well enough to garner support to be instituted. This opinion is also supported in current literature. Akyelken (2013) states that the empirical evidence from past transport projects demonstrates how the lack of sustainability elements in current project appraisal methods requires significant attention, and that the application of existing assessment methods may yield misleading conclusions for future developments.

Ramjerdi and Fearnley (2013) summarise the issues associated to taking a purely economic perspective as being related to trying to distil the complexity of the transport system into relatively simple existing economic models, resulting in certain aspects being lost. Often it is the societal and environmental costs and benefits that get lost in this process.

Recent research in New Zealand has shed new light on this topic. Wedderburn (2013) examined the available evidence on interventions that could improve the integration of public transport with walking and cycling, in order to provide decision makers with a robust basis for the appraisal of measures, using cost-benefit analysis. The project provides a review of the available international evidence of public transport access and egress behaviour. Where evidence was available, analysis of trip chains from the New Zealand Household Travel Survey highlighted patterns of public transport access and egress and, importantly, provided an indication of the mode shift and trip generation impacts of improved access to public transport. The research project also developed an evaluation framework for estimating the cost-benefit analysis of integrating public transport with walking and cycling.

Social inclusion and public health are two major benefits that could potentially outweigh the results of purely economic assessments of low carbon transport schemes. For example, subsidies for public transport might be disputed from an economic perspective, but may provide social benefits, such as social inclusion and accessibility that can outweigh the loss of revenue (Justen et al. 2013a). Active transportation modes such as walking and cycling are widely recognised for their zero carbon impact and the co-benefits associated with them with regard to public health. Many studies have investigated the impact of these transportation modes on public health (Giles-Corti and Donovan 2002, Sallis et al 2004, Wen and Rissel 2008, Woodcock et al 2009, and Hickman 2013). The task remains to find an effective way to evaluate these benefits.

Justen et al (2013b) found that monetising benefits for cost benefit analysis, or establishing impact weightings for multiple criteria analysis, two methods traditionally used in the evaluation of transport schemes, can be a source of conflictive debate and prove difficult where there is a lack of empirical evidence. Lopez-Ruiz et al (2013) attempted to explore the impacts and effects that different urban measures may have in planning for transportation sustainability on a European wide level.

The major challenge attempted by the study was to clearly identify the common elements in each planning measure in order to develop a general scoring template that normalized scores coming from various sources.

GHG emissions are also a relevant externality in the transport sector, especially when evaluating LCM schemes. Nocera and Cavallaro (2013) found that feasibility assessments do not always take these effects into account due to the difficulty and uncertainty in reliably estimating unitary CO₂.

Future research needs to consider how to establish a framework for the evaluation of low carbon mobility plans and furthermore be able to report this in terms of carbon metrics. The current CRC project RP2007 'Integrated carbon metrics (ICM) – a multi-scale life cycle approach to assessing, mapping and tracking carbon outcomes for the Built Environment' should provide a firm basis for this proposed framework, but further research will be needed to encompass the specific features inherent in urban travel demand analysis and urban transport systems.

Urban Design and Planning

The travel decisions people make have been found to be significantly associated with built environment factors such as density, location, mix of land uses and precinct design (Hickman 2013). Changes are starting to occur in the structure of cities, as the cities are reaching a limit to car use growth and there are shifts away from traditional urban culture and economic paradigms (Newman, Kenworthy and Glazebrook 2013). As such there exists the potential for urban design and planning to play a major part in establishing a low carbon transport future.

Many theories exist regarding the ideal layout for low carbon cities, however there has been found to be a huge gap between theory and practice (Hickman 2013). The current understanding is that urban form and layout set the 'envelope of possibilities' for travel, and residential layout and supporting facilities have a complex relationship with resident attitudes, preferences and perceptions (Aditjandra, Mulley and Nelson 2013, Hickman 2013). The 'compact city' approach attempts to

bring activities closer to residents so that they can fulfil their needs and using low carbon options such as active travel or public transport (Aditjandra, Mulley and Nelson 2013). The problem exists in maintaining quality of life and space in high population density environments, and what options for built environment interventions are available where high density living is not feasible. Aditjandra, Mulley and Nelson 2013 found that the specific layout of towns and cities in a low carbon world was as yet unclear.

Research is required to establish the combination of factors in urban planning that are supportive of low carbon transport modes and the built environment interventions that are capable of achieving this in our future city structures.

Technology

Technological improvement of vehicles and the way they are operated is a direct way to reduce the carbon emissions from the transport sector. However, are these technological advances enough to negate the continued increase in the volume of vehicles on our roads? Radical technological and operational innovation is required to increase efficiency, but the improvements to carbon emissions will be generally limited to the long term due to consumer behaviour, fleet turnover, physical infrastructure constraints, regulations and long term industry practices (Bishop 2013).

There are two general paths future innovations may take in order to realise a low carbon future. Firstly, improvements of current technology focused on meeting current travel demands in alternative ways. Secondly, the development of new technology to which future users, owners and operators will have to adapt new behaviours toward their use and function.

Safety

Safety is an ongoing issue for all transportation modes. Commonly the move towards a low carbon transportation future is visualised through zero carbon active transport styles such as walking or cycling, or with

low mass transportation modes such as e-bikes and smart car type vehicles (Martens 2004, Tight et al 2011, Jones and Azevedo 2013, Jones et al 2013, Luo et al 2013). The safety concerns involved with these mode shifts is often involved with the interaction with traditional motor vehicles i.e. cars, truck and buses, where there is traditionally a high mass, high speed relative to the low carbon alternatives (Wegman, Zhang and Dijkstra 2012, Schepers et al 2013). Ideally there would exist a physical separation between these mode types, however this is not always feasible and interactions between the traditional and low carbon transport options will occur (Luo et al. 2013). Effective methods to maintain public safety whilst using low carbon transportation options is a significant research requirement for the future of LCM and transportation in cities.

Future Research Priorities

As indicated in the introduction to this report, the National Greenhouse Gas Inventory (DCCEE, 2012) identifies transport as a major contributor to carbon emissions in Australia, second only to electrical power generation. Further, the significance of private car usage in areas as the source of 45.3 per cent of total transport GHG emissions (i.e. urban road transport is 7.3 per cent of total GHG emissions from all sectors as recorded in the 2010 National Greenhouse Gas Inventory, with a total emissions output of 39.7 Mt CO₂-e p.a.) clearly indicates the importance of that activity in an carbon emissions reduction strategy.

The shape and form of our built environment along with lifestyle choices strongly influence the use of the private car in urban areas. Newton and Newman (2013) addressed this issue in their consideration of the carbon benefits that can accrue from more compact urban forms where public and active transport modes can be of most benefit. They considered the need for urban design innovation in Australia, largely focusing on energy demands in housing and transport, and available alternative energy technologies and fuel types. The 'post war' suburbs, i.e. those areas of our cities first developed in the latter half of the twentieth century,

which are heavily car dependent, provide the most challenges in transitioning to lower carbon cities.

Newton and Newman (2013) developed a model framework for low carbon technology interventions in urban and suburban forms of the built environment, based around the consideration of appropriate low carbon technologies applied to housing and transport in suburban and inner urban areas of our cities. This framework is presented in Figure 7. Given the known trade off between housing type and location, with resulting impacts on demand for transport which are largely met at present by the private car for suburban locations, strategies to reduce the carbon emissions of our cities need to be directed at providing substantial alternatives to that mode, based around greater use of the active modes and public transport. To make this direction feasible will require indepth consideration of built form, land use-transport interaction, land use mixes, the location and intensity for services and facilities and the supporting infrastructure, and precinct planning and design including the relationships between neighbouring precincts and between precincts and major activity centres such as the CBD.

The Newton-Newman framework identifies key differences in consideration between higher density urban regions and suburban developments. In a subsequent paper Newton (2013) stressed the need for urban precinct design assessment tools and clearly defined benchmarks for low carbon urban developments, noting that variability in housing and transport attributes of different suburbs leads to variations in carbon emissions by as much as 50 per cent (see also Newton et al 2012).

The significant contribution to carbon emissions by private car usage in urban areas (see above) suggests that this is an area of particular scope for carbon reductions, and that precinct planning and design, with the potential for redevelopment and reorganisation of activity-facility locations could play a substantial role in this. A set of sensitivity tests were conducted using the data from the 2010 National Greenhouse Gas Inventory, supported with other information from the metropolitan

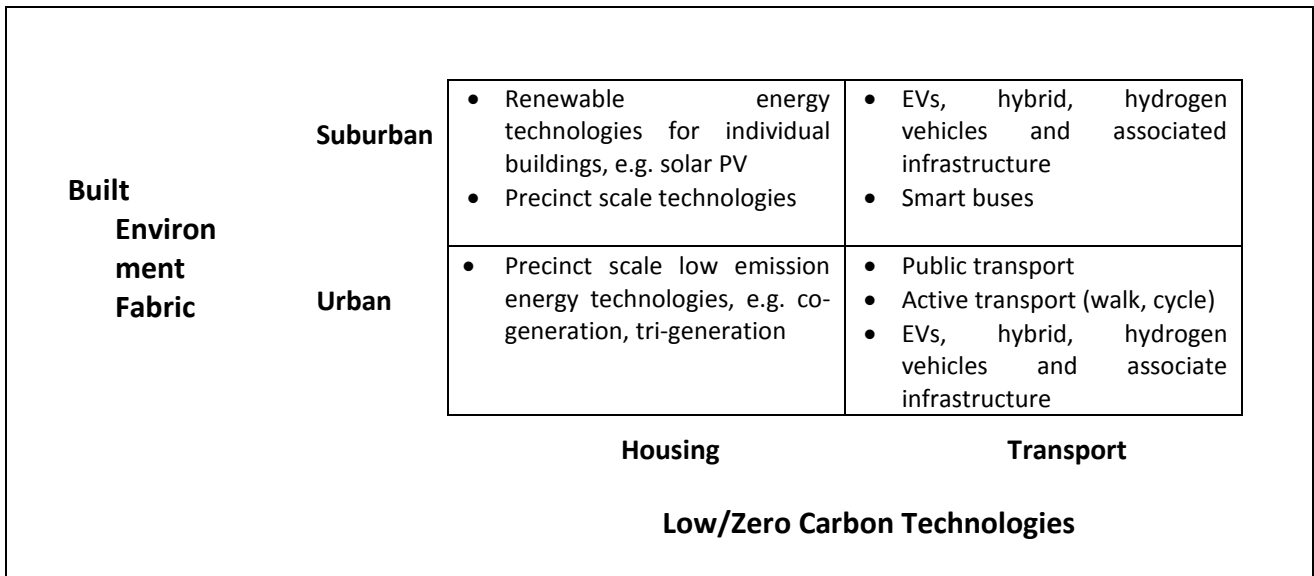


Figure 7: The Newton-Newman model framework for low carbon technology interventions in urban and suburban forms of the built environment [source: Newton and Newman, 2013]

areas travel demand (household travel survey) databases (e.g. BTS 2013)., to provide some broad indications of the potential reductions in carbon emissions from some different planning initiatives.

The analysis of the 2010 National Greenhouse Gas Inventory data indicated that the average GHG emission for all travel (driver and passenger) by private car in urban Australia is 212.2 g(CO₂-e)/person-km. Taylor et al (2010) indicated that a generic figure for per capita emissions by public transport passengers in Australian cities is 124.1 g(CO₂-e)/person-km. A ten per cent switch of person-km by car to public transport could therefore yield a reduction in carbon emissions of 0.78 Mt CO₂-e p.a., based on the National Greenhouse Gas Inventory analysis. A more significant impact could be achieved by a reduction in average car trip length, for instance a ten per cent reduction in car trip length in urban areas could yield a 2.78 Mt CO₂-e p.a. reduction – a more substantial result and one that may be easier to achieve given current travel preferences (e.g. see McCarney 2013) and the proper attention to precinct planning and design that could result from CRC research on low carbon precincts including low carbon mobility.

Identified research needs on LCM

The outcomes of the October workshop coupled with the reviews of the research literature suggest a rich agenda for essential research on LCM. Further, as indicated below, much of this agenda falls within the realm of the CRC for Low Carbon Living, particularly for its research programs on low carbon precincts and engaged communities.

Areas identified for LCM research are:

- Urban design and land use-transport integration (LUTI)
- Low carbon mobility policies and behaviour change
- Opportunities for new technology and its application, including requirements for systems and infrastructure, and
- Analysis and tools for informed decision making, including modelling, measurement and assessment, and visualisation.

The following topics span these research areas;

- Data, with both availability and reliability of relevant data emerging as key concerns

- Integration, enabling considerations of LCM in the context of infrastructure, behaviour, and policy making
- Evaluation, with the need to consider how LCM initiatives may be better considered within existing evaluation frameworks (which may often seem biased towards short term factors) and the development of new but still rigorous evaluation frameworks
- Urban planning and design, to seek better integration of land use and transport, through factors including intensity, location and mix of land uses and precinct design, and considering the potential wider benefits of integration (e.g. in public health and economic productivity and well as environment)
- Technology improvement, including the system wide impacts consequences of the adoption of new technology and implications for urban planning and impacts on congestion and the environment, and
- Safety issues related to the wider adoption of more vulnerable transport modes (e.g. walking and cycling).

CRC LCL research programs, work packages and milestones

The CRC has three research programs:

- 1) Integrated building systems
- 2) Low carbon precincts
- 3) Engaged communities,

for which research on LCM fits largely within Program 2 (Low carbon precincts) and impinges on Program 3 (Engaged communities). Some aspects of LCM related to the supply and operation of infrastructure and buildings (e.g. charging facilities for electric vehicles) could also fit in Program 1 (Integrated building systems). In addition the CRC is developing a set of Living Laboratories (LCL-LL) which can provide testbeds for

application of design, analysis and assessment tools developed in its research and as focal points for data collection and monitoring.

The research agenda identified in this report is of most reference to Program 2, with some important links to Program 3.

The Low Carbon Precincts research program seeks to develop new knowledge and tools for the design of, and stimulate the markets for, low carbon infrastructure at the precinct scale, and is therefore much concerned with urban planning and urban design, including assessment and evaluation, in the provision of new low carbon infrastructure development (greenfield sites) and the redevelopment/ retrofitting of existing precincts, whether brownfield or greyfield sites. The program is also interested in co-benefits of low carbon initiatives, including such areas as health and productivity.

The proposed workflow structure for the *Low Carbon Precincts* program is indicated in Figure 7. It includes six related work packages, which also connect to the other programs in the CRC.

Work package 1 is concerned with the development of a precinct-focused data model (PIM, the Precinct information Model) to facilitate and support the data collection, monitoring, design and assessment tasks of the other work programs.

Work package 2 considers the development of assessment and design tools, for eco-efficiency performance assessment and prediction of precinct development and redevelopment, to:

- 1) Develop an assessment model for precinct design, embodied in software applications based on the PIM technology
- 2) Develop a comprehensive, integrated tool set that enables measurement and assessment of precinct performance based on PIM technology, forecasts demand at precinct level, and assesses the co-benefits of low carbon living

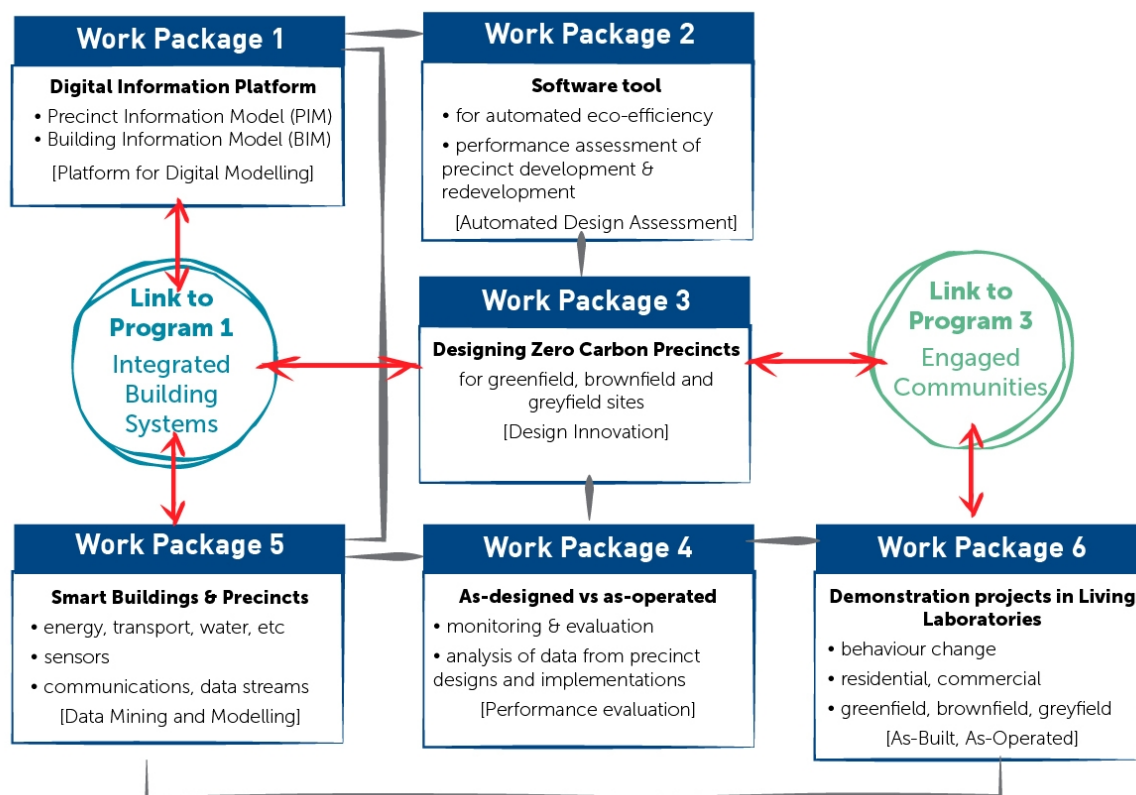


Figure 8: Workflow structure for *Low Carbon Precincts*

3) Develop a suite of co-benefit calculators suitable for different stakeholders (government regulators, developers, precinct planners and designers and community end users) based on rigorous research to identify measurable metrics derived from a PIM that models planned precinct developments.

Work package 3 focuses on the design of zero carbon precincts, for greenfield, brownfield and greyfield sites. Its function is to develop decision support tools for the integrated design of low carbon precincts, and then apply these tools in the design of prototype low carbon precincts.

Work package 4 is concerned with evaluation and assessment, and particularly on the comparison of ‘as-designed’ versus ‘as-operated’ precincts. Monitoring and evaluation are key considerations in this work package, along with the analysis of data from precinct designs and implementations. The Living Laboratories of the CRC are important sites for use in the CRC’s research in this work package.

Work package 5 involves the processes of data collection and monitoring of buildings and precincts, including the CRC-LL sites. It is concerned with the observation of performance in respect to energy, water, transport, waste, etc from the sites through the establishment and operation of sensor networks and facilities for communications and data streaming, and in database management and use.

Work package 6 focuses specifically on the demonstration projects to be undertaken in the living laboratories, taking in precinct and buildings performance for both residential and commercial precincts. It is involved with greenfield, brownfield and greyfield sites and with behaviour change. It thus requires substantial integration with research projects in Research Programs 1 and 3. In particular, it is intended to provide tools, techniques and technologies for use in the assessment and evaluation of low carbon precincts as undertaken in Research Program 3 (Engaged communities).

A seventh work package, not shown in Figure 7, covers research training through higher research degree studies and advanced skills development for urban professionals in the broad area of urban precinct planning and design. This work package embraces all of the first six work packages of the program.

The CRC has sets of contracted milestones in each research program. The milestones cover both research activity and utilisation of research outputs from CRC research projects. The full set of milestones for Program 2, allocated to the program's work packages, is provided in Appendix D. Program 2 milestones of relevance for LCM research, noting that Program 2 research milestones are designated as R2.x.x and utilisation milestones are designated as U2.x.x, and the (Program 2) work packages they belong to (WP), as identified in this report, include:

- R2.2.3 Software prototype of automated **precinct assessment** tool, including visualisations that clarify assessments for different user categories, developed (WP2)
- R2.2.4 Book documenting *Best Practice Approaches to the Design of Zero Carbon Low Consumption Communities* published (WP2, WP3, WP4, WP5, WP6)
- R2.3.2 Creation, assembly and testing of prototype tools for demand forecasting in each of energy, water and **travel**, building on knowledge of existing tools and available data (WP2)
- R2.3.4 Case studies selected and designed for model testing, addressing greenfield, greyfield and brownfield settings, plus differing household demands linked to dwelling/household types, distributed generation and **electric vehicle** scenarios (WP2, WP3, WP4, WP5, WP6)
- R2.3.5 Results of case study testing known, with consequential refinement of the set of **demand tools** (WP2, WP4, WP5, WP6)
- R2.4.2 Base line survey of current levels of **active transport usage**, including understanding of the environmental and human health benefits in the studied communities (Living Labs) plus constraints on the uptake of those practices completed (WP2)
- R2.4.3 Economic incentives/advantages for government and community end users of adopting a co-benefits framework to justify and promote **active transport** identified (WP2, WP3)
- R2.4.4 Prototype **co-benefits calculator** developed (WP2)
- R2.4.5 Trial adoption of incentives embodied in the **co-benefits framework** to test and evaluate their impact on the uptake of **active transport** in living laboratories commenced (WP4, WP5, WP6)
- R2.4.6 Review and evaluations of impacts, leading to the final development of the **co-benefits tool** that will provide an integrated evidence base for policy development, together with community incentive schemes commenced (WP4)
- R2.4.7 Suite of **co-benefit calculators** delivered (WP2)
- U2.2.3 Performance assessment of [automated **precinct assessment**] tool in use across all jurisdictions in Australia completed (WP2, WP3, WP4)
- U2.3.1 Trials of prototype **demand forecasting tools** participated in by utility partners in CRC (WP2)
- U2.3.2 Utility partners would be making use of the new **demand forecasting tools** and are able to identify benefits of early access (WP2, WP3)
- U2.3.3 Broad adoption of the **forecasting tools** across non-partner utilities and infrastructure

companies (40% uptake) (WP2, WP3)

U2.4.2 Communities to work with **co-benefits calculator** (living laboratories) identified (WP4, WP5, WP6)

U2.4.3 Prototype of the **co-benefits calculator** for different government, developer and community users launched (WP2, WP3, WP4)

U2.4.4 **Co-benefits calculator** piloted in government policy, including initial evaluation of results – used in specific policy interventions in the Living Laboratories (WP3, WP4, WP5, WP6)

U2.4.5 **Co-benefits calculator** piloted in private sector (for developers), including initial evaluation of results – used in specific precinct plans to demonstrate low carbon living in selected Living Laboratories (WP3, WP4, WP5, WP6)

U2.4.6 **Co-benefits calculator** across all three domains (government, private sector, community) completed (WP3, WP4, WP5, WP6)

U2.4.7 **Co-benefits calculator** adopted as mainstream tool for government, private sector decision making and community incentivisation for **active transport** implementation (WP3, WP4)

- Methods for ‘greening’ suburban travel, given the current strong dependence on private car usage for suburban based travel
- Relating potential health benefits and precinct evaluation and design evaluation methods
- Provision and operation of infrastructure for electric vehicles
- Experimentation and pilot testing of community options such as electric vehicle share scheme trials in the CRC-LLs
- Broadening and deepening our understanding of travel and related behaviours, using existing sources such as the activity-travel records held in the Household Travel Survey databases, the data previously in the evaluations of large scale travel behaviour change programs, and use of new data collection opportunities such as Smartcard data from public transport usage
- Scientifically designed stated preference surveys on travel behaviour, energy and water consumption, and waste generation, in CRC-LLs – such surveys would provide better understanding of the interactions between types of consumption at household and precinct levels and would improve the design of demand forecasting tools.

A more systematic overview can also be considered, taking account of the research areas identified for LCM research and the research topics applying to those areas, as identified in the section *Identified research needs on LCM* (see above). Table 2 provides indications of the research relevance and importance of the identified LCM research areas across the research programs of the CRC.

CRC research and LCM

The analysis presented in this report suggests that many facets of low carbon mobility are appropriate areas for CRC research that can contribute strongly to the attainment of the CRC’s stated objectives for low carbon living. At the precinct level, the interplay between energy consumption in housing and transport as identified by Newton and Newman (2013) is a key consideration. Some of the immediate research topics identified in the report are:

Table 2: Systematic view of relevance and importance of identified areas for low carbon mobility (LCM) research

Research area: Topic:	Urban design and LUTI	LCM policy and behaviour change	New technology and infrastructure	Analysis and tools for informed decision making
Data				
Integration				
Evaluation				
Urban Planning and Design				
Technology				
Safety				

Key:

CRC Program 1		some importance		important		very important
CRC Program 2		some importance		important		very important
CRC Program 3		some importance		important		very important

Table 2 may be taken as a summary of the potential relevance of LCM research to the research and objectives of the CRC for Low Carbon Living. There is considerable scope and opportunity for research on LCM with respect to urban design and LUTI, and LCM policy and behaviour change. Data analysis and modelling tools to enable informed decision making in these areas also requires research effort that falls within the domain of CRC LCL. Evaluation and assessment, and suitable tools to address these key issues in precinct planning and design, is also of high priority. Technological

developments cannot be ignored, but technological change – on the basis of the review of the international literature and the deliberations in the CRC workshop – of itself is insufficient to provide the necessary reductions in carbon emissions. Technology change in compass with behaviour change – involving heightened emphasis on land use-transport integration – is the key to a low carbon future for mobility in our cities.

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APPENDIX A: WORKSHOP ON A RESEARCH AGENDA FOR LOW CARBON TRANSPORT (LCT)

Workshop program

Venue: Radford Auditorium, Art Gallery of South Australia, North Terrace, Adelaide (access from the north (university) side of the gallery)

Day 1 – 29 October 2013		Day 2 – 30 October 2013	
9:00	Registration		
9:30	Opening and welcome Prof Deo Prasad (CEO, CRC LCL) & Prof Michael A P Taylor (UniSA) Keynote address: Prof Yoshitsugu Hayashi (Nagoya University), 'Drastic visioning and backcasting to leapfrog to low carbon transport in growing Asia' Keynote address: Prof Guenter Emberger (Vienna University of Technology), 'Low carbon transport strategies in Europe – a critical review'	9:00	Workshop session 3: Systems and infrastructure Background papers: 'EV integration' (Iain MacGill, UNSW) & 'Use and applicability of EVs' (Rocco Zito, UniSA) General Q & A Breakout discussions
11:00	Morning tea	10:30	Morning tea
11:30	Workshop session 1: Land use-transport integration and urban design Background papers: 'Land use-transport integration in the decarbonising city' (Jan Scheurer, Curtin University) & 'Improving local mobility through increased local public transport and citywide network planning' (Leigh Glover, University of Melbourne) General Q & A Breakout discussions	11:00	Workshop session 4: New technology and new approaches Background papers: 'New technologies for low carbon mobility' (Ajay Kapoor & Jason Miller, Swinburne University) & 'Lighter-than-cargo vehicles' (Peter Pudney, UniSA) General Q & A Breakout discussions
13:00	Lunch	12:30	Lunch
13:45	Workshop session 2: LCT policy and behaviour change Background papers: 'Decoupling GDP and GHG' (Cole Hendrigan & Peter Newman, Curtin University) & 'Travel behaviour change programs, what they are, and what they can achieve' (Belinda Halling, SA DPTI) General Q & A Breakout discussions	13:30	Workshop session 5: Modelling, measuring and visualising Background papers: 'Measuring and modelling low carbon transport' (Travis Waller, UNSW) & 'Carbon emissions from transport in the Adelaide CBD' (John Moore & Nicholas Nash, Adelaide City Council) General Q & A
15:15	Afternoon tea	14:45	Afternoon tea
15:30	Day 1 wrap-up session Reports by session rapporteurs General discussion	15:00	Day 2 wrap-up session: An LCT research agenda Reports by session rapporteurs on Day 2 Panel session, chaired by Gareth Evans (SA DPTI) Closure
17:00		16:30	

APPENDIX B: WORKSHOP PARTICIPANTS

Name	Affiliation
Dr Andrew Allan	University of South Australia
Mr Courtney Babb	Curtin University
Mr Daniel Bennett	Hassell
Mr Christian Bodé	AECOM
A/Prof Hussein Dia	Swinburne University
Mr Andrew Dickson	SA Department for Manufacturing, Industry, Trade, Resources & Energy (DMITRE)
Dr Vinayak Dixit	University of New South Wales
Mr Gerard Drew	Zero Carbon Australia Transport Project
Prof Guenter Emberger	Vienna University of Technology
Mr Gareth Evans	SA Department of Planning, Transport and Infrastructure (DPTI)
Dr Leigh Glover	University of Melbourne
Ms Sherree Goldsworthy	SA Department of Planning, Transport and Infrastructure (DPTI)
Ms Belinda Halling	SA Department of Planning, Transport and Infrastructure (DPTI)
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Mr Patrick Hearps	Zero Carbon Australia Transport Project
Mr Cole Hendrigan	Curtin University
Dr Nicholas Holyoak	University of South Australia
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Mr Ivan Iankov	University of South Australia
A/Prof Iain MacGill	University of New South Wales
Mr Jason Miller	Swinburne University
Mr Graham Mills	University of New South Wales
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APPENDIX C: SUMMARIES OF WORKSHOP PARTICIPANT DISCUSSION SESSIONS

The following notes provide a consolidated summary of the discussions from the table groups by session.

Appendix C1 Session 1 Summary: Land use-transport integration and urban design

Precinct planning:

- retrofitting walking and cycling
- a research priority – accessibility indicators to encourage access to everyday facilities by walking and cycling, including both local destinations and main public transport routes
- better considerations of appropriate public transport and active transport modes in development planning
- current urban environments are unfriendly to the active modes. There should be a new focus on pedestrian movement in CBD areas and cycling and walking in inner city and suburbs. New priorities over motorised modes should be considered, as should the use of road space
- improved methods for consideration of active modes in cost-benefit analysis for Australian cities
- legal factors in considerations of increased usage of active modes.

Benefits:

- current decision making is skewed towards economic benefits of transport system improvements, which largely reflect estimated savings in travel times
- a research priority – seek evidence based impacts, especially with respect to social, environmental and public health issues
- a research priority – develop evaluation models for social, environmental and health outcomes (see also precinct planning and metrics)
- examine economic benefits of walkability
- property value beneficiaries from public transport improvements – what mechanisms are there for value capture?
- understanding of benefits of public transport developments – needs analysis.

Post review:

- Not enough research on post implementation/as operated performance (what works and what does not).

Role of pricing signals:

- considerations of political factors in Australian markets
- include parking fees, city access/congestion factors, tolls, etc.

Taking the people with us:

- how to describe benefits of pedestrian precincts vs car based areas to stakeholders, especially local businesses (e.g. those who rely on kerbside car parking outside their businesses)

- understanding of changing and future demographics needs
- leadership/consistency by governments
 - political courage
 - nonpartisan
 - government vision, action and commitment
 - what is good/bad government in the context of sustainable transport
- conflicting policies, and how to deal with these.

Integrating public transport:

- Spatial Network Analysis for Multimodal Urban Transport Systems work
- benefits of bus/train coordination at activity centres
- network effects
- are services up to scratch?

Metrics:

- walkability indices
- assessment tools that explicitly consider walkability over standard traffic metrics (move beyond '400 m to nearest bus stop').

Visualisation:

- representation of possible outcomes/scenarios
- build on complex data sets (e.g. Australian Urban Research Infrastructure Network opportunities).

Use of road space:

- alternatives to existing road engineering focus, with more emphasis on pedestrian flows and low speed environments
- improved/changed use of existing infrastructure.

Data:

- mode shares (use Household Travel Surveys as well as ABS census data)
- mobility profiles and styles of individuals and households
- quality of life and wellbeing
- a research project – translate survey data into publicly available mobility profiles
- a research project – case studies on pioneers of low carbon lifestyles
- more relevant data for policy, planning and investment, including origin-destination information, trip length, latent demands, etc.
- need good data on people *and* freight.

Transit Oriented Development and Polycentricity:

- implications of polycentricity for transport networks and services
- a research project – how does the 'line of confrontation' over sustainable transport improvements shift over time?
- how can Transport Oriented Development (TOD) be encouraged
- what are the optimum sizes of activity centres and TOD developments.

Demographic change and aging of cities:

- adaptive design methods.

Appendix C2 Session 2 Summary: LCT policy and behaviour change

- there is potential to use data collected by various programs to better understand travel behaviour associated with households with different characteristics – and through this to improve the inputs to various traffic models
- we need to better understand the changes in attitudes existing residents in locations of intensified development to see if the typical patterns of uneasiness and opposition are maintained over time once the development is complete
- attitudes and travel behaviours of new residents in previously engaged communities should be monitored
- we need data and case studies to support traders in better understanding the economic benefits of a shift to transit as the priority for use of contested street space
- we need to break the intergenerational transmission of habitual attitudes favouring car use.

Appendix C3 Session 3 Summary: Systems and Infrastructure

Market up-take:

- what incentives are needed for the up-take of EV? This questions needs to be asked of both consumers and manufacturers.
- what are the barriers to the affordability of EV? (Issue of equity of access to new EV technology)
- what possibilities are there for the development and use of purchasing comparison tools?
- what means is best employed for informing the public when buying EV?
- there is a need for the comparison of the flexibility of hybrid models and pure EV.

Energy implications:

- green power- there is a need to ensure that electricity sources for EV are sustainable.
- how does the time of use (charging) influence emissions profiles?
- there is a need to better understand the life cycle costs of EVs.
- (in regards to fleet vehicles) there is a need to understand the decreasing efficiencies over time i.e. understanding the life cycle of vehicles and long-term impacts on fleet turn over.
- is there potential for energy source agreements for EV consumption?
- Green Power Purchaser Agreement

- how can the distribution network impacts be minimized?

Use of EV including behaviour:

- there is a need to understand and address the issue of *range anxiety*- i.e being stranded and not having access to a charger.
- there is the potential for research into user friendly technology to reduce range anxiety. For example, can there be more accurate visualizations of energy consumption to reflect issues like terrain using GPS.
- there is a need to educate the public as to the efficient use of EVs- educating people to avoid particular behaviours in order to improve efficiencies.
- one comment was made that EVs can be perceived to be good for geeks not for techno-phobes. There is a need for behavioural research into these different types of technology users.
- what are the implications for EVs in an emergency situation, i.e. during black-outs due to events such as bushfires and storms? What is the impact on evacuation processes? Are EVs reliable in these situations?

Regulation:

- is there scope for a national registration scheme based on emissions not engine size?

Land Use/ Built form:

- what are the implications for using Plug in EVs when retrofitting old infrastructure- new building requirements?
- how can EV mobility be integrated into a precinct scale transport system- what is the impact on a precinct?
- is there potential to expand Lochiel Park (Bowden, Tonsley (link with Flinders))?
- what are the household issues associated with EV load i.e. household Electricity load and household travel behaviour?
- will EV uptake change land use? Or alternatively will EV fit existing land use model? Does EV take-up mean BAU for land use development? Should we be thinking about how EV fits within alternative land use future scenarios- TOD; activity centres; and activity corridors?

Relationships with other transport modes:

- what will be the role of EV in an alternative transport future?
- what change in EV vehicle usage profile is possible/probable?
 - with change in public transport uptake
 - with active travel (e-bike) increase
- what is the potential for e-bikes? – to extend the active travel profile
- there is the potential for backcasting future transport composition and new profile for vehicle use.
- investigation of hybrid energy for public transport services
 - Diesel/electric battery hybrids
 - Battery/pantograph bus service.

Fleet Vehicles:

- taxi, fleets, transport and delivery applications- can targeted use scenarios be developed?
- what is the appropriate business model to accommodate use and convenience of EV fleet vehicles?
- should there be independent verification of longevity, life cycle, of fleet vehicles?

Alternative ownership models:

- do EVs allow us to think of private car ownership differently?
- do EVs provide the opportunity to develop or increase uptake of alternative ownership models- e.g. car share; smart parking schemes.

Appendix C4 Session 4 Summary: New technology and new approaches

Electric Bicycles:

- feasibility of electric vehicles (e-bikes etc.), are they really an option? A comprehensive life cycle analysis is needed?
- better standard for electric bikes with respect to:
 - speed limits or alternatively energy/power limits
 - safety standards
- how far do people ride on bikes?
 - how far would they ride with electric assist?
 - cargo potential for electric assist
 - example Australia Post bike
- alternatives for bikes and vehicles as community mobility providers
 - what infrastructure is required
 - TOD applications link with traditional public transit
 - Bike facilities at public transit interchanges
- safety vs. weight vs. bike safety
- service level of public transport (PT) can be improved by providing better links to stops via community bikes.

Innovation Tunnel:

- design products to meet actual needs
- look at all different transport needs
- look at what types of transport services should we have for various needs vs. wants instead of designing cars to meet all of them
 - such as local neighbourhood shared car schemes
 - quantifying the types of travel best suited to PT

- trade and business transport requirement
- working with the community to gain support for ultra-light vehicles (& legislation to support)
- requiring new infrastructure for new technology?
- new safety standards?
- what happens when new technology is mixed with current vehicles?
- is retrofitting old vehicles and option?
- one car + community car model for car ownership would provide better car ownership
- taxis – supply constraints, able to provide a higher level (e.g. Car store) of service if we have less cars.
- network usage:- allocate roads by vehicle type or by residential area
- multiple type of vehicle ownership per household: role of car share/ car hire for high capacity long distance use.
- what responsibility does government have in incentivizing clean vehicle usage?

Behavioural:

- don't rely on people having to actively make choices, instead limit choices. We need to shape infrastructure to impose hard physical limits on things we don't want, and make the things we do want to be more attractive, so that people's choices in such a framework is natural.
- understand the elasticity of car travel vs. public transit vs. bikes under different fuel price regimes
- how do people adopt new technology?
- users are very adaptable: trip purpose vs. flexibility of travel, mode split change
- social acceptability of new vehicle technology
- perceptions with respect to new technology are an important barrier.

Research Questions:

- what are the various travel demands and how can they be met through various technologies?
 - e.g. what types of travel demand can be mode-shifted with a radically improved public transit system?
 - of the residual what does the demand look like and how much of it could be met by alternatives to private vehicle ownership (e.g. car share)
 - how much opportunity is there to provide separate network requirements (e.g. rail lines, dedicated road lanes for different vehicle types, bike lanes) while utilising existing infrastructure and avoiding unnecessary duplication:
- 'what the market wants?' vs. 'what society needs to look like to achieve a low carbon society'

Appendix C5 Session 5 Summary: Modelling, measuring and visualising

Data:

- it is important to understand how people travel, this can be achieved through further application of GPS or Bluetooth monitoring, and up-to-date household travel survey data

- issue of verifying the usefulness of the data collected
 - development of screening tools for application to GPS or Bluetooth data
- issue related to the privacy of participants
 - more detailed data could mean participants are reluctant to have their movements tracked
 - development of an appropriate app. Users have to agree to the terms and conditions when purchasing and using an app. Currently many apps also track the location of users as a background part of the programming. A similar app could therefore be developed for data collection in mind, where there is a separate utility available to the user while their movements are tracked in the background.
 - developing a methodology to strip identifying features from data collected.

Modelling:

- the need for a standardised framework for transport modelling and planning
 - reduction of carbon emissions is an objective in order to get low carbon transport outcomes.
 - specified for models on the macro, meso and micro scale
- the boundary issue surrounding carbon. Where do we draw the line when considering carbon impact within a fixed area?
 - suggested methods for emissions ownership included assigning them spatially based on location, or the assignment to individuals such that everyone has a 'carbon number'.

Measuring:

- defining the term 'low carbon'
- when is a particular type of transport considered low carbon?
- what is the yard stick we are using to define low carbon?
- comparisons are possible based on geography, transport mode, technologies and many other factors.

Visualisation:

- how do we communicate and demonstrate to a general audience the magnitude of carbon emissions or their reduction and the importance associated with this?
- black balloon advertisements broadcast on Australian television circa 2006 provided a visual measure for people to get a better understanding on their GHG emissions related to household energy use
- potential for similar schemes related to transport
- standardised emission estimation reporting for local councils using a method such as that undertaken by Adelaide City Council could also be used to develop a series of carbon maps.

APPENDIX D: RESEARCH AND UTILISATION MILESTONES FOR CRC LCL RESEARCH PROGRAM 2 ‘LOW CARBON PRECINCTS’

Table D 1: Research milestone completion dates for Program 2

Completion date	Research milestone no	Description	Program 2 work package
30 June 2013	R2.1.1	Analysis of the information needs of CRC stakeholders leading to an agreed information model schema that extends work already completed in a previous ARC Linkage project (LP0776642) completed	WP1
	R2.3.1	Detailed functional specification of the demand forecasting tools produced, including definition of performance metrics, on the basis of an international review and subsequent stakeholder feedback	WP2
	R2.5.1	10 HDR students enrolled (7 PhD and 3 Masters)	WP7
30 June 2014	R2.1.2	Initial implementation and testing of a database conforming to the proposed schema, with sample data sets provided by CRC partners completed	WP1
	R2.2.1	International survey of current neighbourhood assessment studies (e.g. Community Green Rating Tool, PRECINX, LEED-US, etc.) and stakeholder reviews of performance requirements, metrics, benchmarks completed	WP2, WP4, WP5, WP6
	R2.2.2	Functional specification finalised and Precinct Information Data Model plus connection to distributed databases that contain input data for assessments implemented	WP2, WP3
	R2.4.1	Audit of current Australian policies (national, state, metropolitan and regional urban planning and health policies) to examine whether they adopt a co-benefits framework and the potential to do so completed	WP2
	R2.4.2	Base line survey of current levels of active transport usage, including understanding of the environmental and human health benefits in the studied communities (Living Labs) plus constraints on the uptake of those practices completed	WP2
	R2.5.2	Further 5 HDR students enrolled (4 PhD and 1 Masters)	WP7
	R2.5.3	4 Masters by research students completed	WP7
30 June 2015	R2.1.3	Information exchange protocols that support the performance metrics identified from projects within the CRC developed	WP1
	R2.1.4	Seek international endorsement of the [PIM] model schema at the building SMART International Technology Meeting, proposing inclusion as an extension of ISO/PAS 16739	WP1
	R2.2.3	Software prototype of automated precinct assessment tool, including visualisations that clarify assessments for different user categories, developed	WP2
	R2.3.2	Creation, assembly and testing of prototype tools for demand forecasting in each of energy, water and travel, building on knowledge of existing tools and available data	WP2
	R2.3.3	Integrating shell for incorporation of component tools as fully integrated tool set based on PIM data designed and implemented	WP2
	R2.4.3	Economic incentives / advantages for government & community end users of adopting a co-benefits framework to justify and promote active transport identified	WP2, WP3
	R2.4.4	Prototype co-benefits calculator developed	WP2
	R2.5.4	Further 6 HDR students enrolled (4 PhD and 2 Masters)	WP7

Completion date	Research milestone no	Description	Program 2 work package
	R2.5.5	Preliminary drafts of 1 set of training material delivered and pilot professional development workshops completed in collaboration with activities within Research Program 3	WP7
30 June 2016	R2.1.5	The [PIM] schema will have been implemented and tested using prototype databases, with exchange protocols that interface to the tools under development in other activity areas at that time	WP1
	R2.3.4	Case studies selected and designed for model testing, addressing greenfield, greyfield and brownfield settings, plus differing household demands linked to dwelling/household types, distributed generation and electric vehicle scenarios	WP2, WP3, WP4, WP5, WP6
	R2.4.5	Trial adoption of incentives embodied in the co-benefits framework to test and evaluate their impact on the uptake of active transport in living laboratories commenced	WP4, WP5, WP6
	R2.5.6	Final 6 HDR students enrolled (5 PhD and 1 Masters)	WP7
	R2.5.7	Further 6 HDRs completed	WP7
	R2.5.8	Final versions of first set of training material available	WP7
30 June 2017	R2.1.6	The [PIM] schema will have been implemented and tested using prototype databases, with exchange protocols that interface to the tools under development in other activity areas at that time	WP1
	R2.4.6	Review and evaluations of impacts, leading to the final development of the co-benefits tool that will provide an integrated evidence base for policy development, together with community incentive schemes commenced	WP4
	R2.5.9	Two more sets of training material for professional development programs delivered	WP7
	R2.5.10	Further 5 HDR students completed	WP7
30 June 2018	R2.1.7	The [PIM] schema will have been implemented and tested using prototype databases, with exchange protocols that interface to the tools under development in other activity areas at that time	WP1
	R2.3.5	Results of case study testing known, with consequential refinement of the set of demand tools	WP2, WP4, WP5, WP6
	R2.4.7	Suite of co-benefit calculators delivered	WP2
	R2.5.11	Two more sets of training material for professional development programs delivered	WP7
	R2.5.12	Further 6 HDR students completed	WP7
30 June 2019	R2.1.8	By the end of the life of the CRC, the PIM schema will be a mature, applicable entity that is able to support information exchange across the range of tools and applications developed in support of the low carbon objectives	WP1
	R2.2.4	Book documenting <i>Best Practice Approaches to the Design of Zero Carbon Low Consumption Communities</i> published	WP2, WP3, WP4, WP5, WP6
	R2.3.6	Book/manual describing the <i>Use and Application of the Integrated Tool Set</i> published	WP2, WP4
	R2.5.13	Final set of training material for professional development programmes delivered	WP7
	R2.5.14	Further 6 HDR students completed	WP7

Table D 2: Utilisation milestone completion dates for Program 2

Completion date	Utilisation milestone no	Description	Program 2 work package
30 June 2013			
30 June 2014	U2.4.1	Policies (national, state and local) where the co-benefits calculator can be used identified	WP2
	U2.4.2	Communities to work with co-benefits calculator (living laboratories) identified	WP4, WP5, WP6
30 June 2015	U2.1.1	Prototype information repositories based on the evolving PIM schema in use across several Living Laboratories to test the emerging tools and community engagement models	WP1
	U2.2.1	Prototype tool trialled by state, local government, NGO agencies and private sector	WP2, WP3
	U2.3.1	Trials of prototype demand forecasting tools participated in by utility partners in CRC	WP2
	U2.4.3	Prototype of the co-benefits calculator for different government, developer and community users launched	WP2, WP3, WP4
30 June 2016	U2.1.2	By this time, the PIM schema will have been defined and we would expect that it would be used as a core technology across the range of tools and information management processes adopted by the CRC	WP1
	U2.4.4	Co-benefits calculator piloted in government policy, including initial evaluation of results – used in specific policy interventions in the Living Laboratories	WP3, WP4, WP5, WP6
30 June 2017	U2.2.2	Formal national workshopping of [automated precinct assessment] tool will be completed, forming a basis for formal adoption in national planning scheme	WP2, WP3
	U2.3.2	Utility partners would be making use of the new demand forecasting tools and are able to identify benefits of early access	WP2, WP3
	U2.4.5	Co-benefits calculator piloted in private sector (for developers), including initial evaluation of results – used in specific precinct plans to demonstrate low carbon living in selected Living Laboratories	WP3, WP4, WP5, WP6
30 June 2018	U2.4.6	Co-benefits calculator across all three domains (government, private sector, community) completed	WP3, WP4, WP5, WP6
30 June 2019	U2.1.3	We expect to see precinct information models in use across many major urban regions in Australia and overseas	WP1
	U2.2.3	Performance assessment of [automated precinct assessment] tool in use across all jurisdictions in Australia completed	WP2, WP3, WP4
	U2.3.3	Broad adoption of the forecasting tools across non-partner utilities and infrastructure companies (40% uptake)	WP2, WP3
	U2.4.7	[Co-benefits] Calculator adopted as mainstream tool for government, private sector decision making and community incentivisation for active transport implementation	WP3, WP4

