Energy, Transport, Waste and Water Demand Forecasting and Scenario Planning for Precincts.

Workshop 6 - The Development and Application of the ETWW Model Foundation Version 1.0 as a Prototype.

Authors	Nicholas Holyoak, Michalis Hadjikakou, Steven Percy, Ivan Iankov, He He
Title	Energy, Transport, Waste and Water Demand Forecasting and Scenario Planning for Precincts. Workshop 6 - The Development and Application of the ETWW Model Foundation Version 1.0 as a Prototype.
ISBN	
Format	
Keywords	Precinct, demand, forecasting, carbon, energy, transport, waste, water
Editor	
Publisher	
Series	
ISSN	
Preferred citation	

Australian Government
Department of Industry, Innovation and Science

Business Cooperative Research Centres Programme

Contents

List of Tables

List of Figures

Introduction

Forecasting for integrated demands and carbon impacts of a precinct in the ETWW (energy, transport, waste and water) domains will contribute to the assessment of policy scenarios for low carbon built environment futures. The development of an integrated tool for demand forecasting and scenario evaluation covering ETWW is in the process of being fully developed and implemented, with a final version due at the end of 2016. A major component of the framework under development includes the impacts of household behaviour change in demand forecasting. The approach also identifies commonalities in data requirements and model formulation between the four forecasting domains. In this way overall carbon impacts of urban developments or redevelopments can be assessed more accurately, effectively and efficiently.

As a result of the project's facilitated national workshops to date (with reports communicated through the CRC's website), researchers, project partners and industry interests have explored initial project issues, and established an approach for integrated ETWW demand forecasting and model specification, development and integration. In some cases, mature and well-researched models are utilised in forecasting routines and in other cases, new approaches have been developed. A focus of all modelling is on the household, however other land uses and activities that exists within a precinct are recognised and accommodated.

As the ETWW modelling framework applies forecast techniques to estimate carbon and associated impacts from precincts it is appropriate to define what this is. Newton *et al* (2013) defines a precinct as:

> *'a precinct can be represented an urban area of variable size that is considered holistically as a single entity for specific analyses or planning purposes, as well as in a contextual sense to represent the interactions that occur with elements of the surrounding urban area. It typically comprises land parcels occupied by constructed facilities (generally buildings), including open space, and often clustered in to urban zones that share some common characteristics (uses) and supported by physical infrastructure services to manage energy, water, waste, communication and transport as well as a range of social infrastructures related to health care, education, safety, retailing and entertainment'*

For an accurate assessment of the ultimate carbon impacts of the precinct, model applications consider not only the spatial location of the precinct but also the physical 'built' attributes and the population that reside and conduct activities within it. Interactions between the energy, transport, waste and water domains are also of importance to the model framework and to the overall assessment of forecast precinct scenarios. Forecasting routines can accommodate seasonal variations and climate change with links to existing external resources, including datasets, routines, surveys, climatic data and so on.

The Foundation Version.

The foundation version of the model platform is intended to be a working prototype of the finalised model version and will form the cornerstone for future developments throughout 2016. As a proof of concept, it should assist with industry and project partner interaction as the research team will seek comments and feedback on the model operation that can be progressed in the development of final model version. Core model operation is currently developed in Microsoft Excel, with reliance on modelling processes outside of this environment for the bulk of the forecasting tasks. Simpler modelling exists within the spreadsheet model. Some of the principal foundation model components that are detailed later in this report relate to scenario development, data input definitions, output data management and domain interaction specifications. Domain research developments to date are incorporated and demonstrate in the model with an application to the first forecast scenarios for the Lochiel Park precinct of Adelaide.

ETWW Model Components and Operation.

The ETWW model operation involves the definition of precinct variables, internal and external routines, data management and display environments and output summaries as depicted in Figure 1. Research conducted in the individual domains is producing much of the model 'engine' with integration between domains and feedback processing loops. A GIS environment is to be utilised for data management, processing and display purposes associated with input and output data archives, including the final demand and carbon impact results. The model also has potential pathways to connect with other CRC for Low Carbon Living research, particularly in terms of precinct data. Operation processes within the ETWW model are illustrated in the following figure with latter paragraphs detailing these core components.

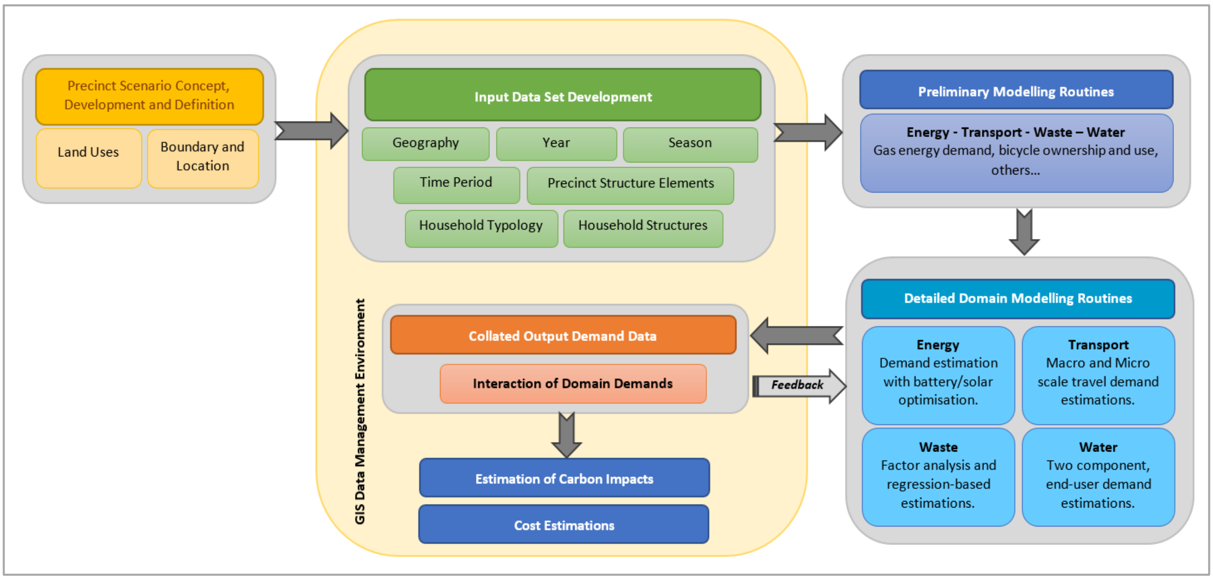

Figure 1 ETWW model operational flowchart.

Scenario definitions are the first step in the ETWW model operation with the need for details on the precinct 'concept' including land uses and household typologies involved with other land uses for education, retail, commercial, public space etc. Physical attributes of the precinct with respect to support infrastructures, the boundary definition or size of the precinct and location within Australia are required in preparation for the development of detailed input data sets.

Input data required by model components is compiled for all precinct forecast scenarios, as required by all of the forecasting domains. Some data may be specific to individual domains (such as the transport network configuration), with other core inputs (such as number of household residents), having multiple domain applications. Greatest attention is paid to defining the household in detail with other inputs for non-household related land uses that are regarded as precinct structure elements such as green space and commercial land uses. Timing components including the forecast year/s, the season and forecast period (which may be a day or a peak during the day) are defined. Household typologies align with Mosaic household typologies developed by Experian and household structures relate to the physical attributes of the household such as number of bedrooms and solar generation capacity.

Preliminary modelling routines exist as simpler internal models mainly for the purpose of data preparation or support procedures for the detailed domain modelling applications. Simplified calculations that add to domain-specific forecasting routines include household gas consumption and bicycle ownership estimation with processes such as application of linear regression equations or factor matrices. Much of the preliminary modelling therefore occurs before the domain modelling processes which are more detailed in nature and can reply on external processes to complete the modelling duties. Detailed domain-specific forecast models are for:

- Energy demand - demand forecast process combined with battery solar optimisation model,
- Water demand - water demand forecasting model with end use components,
- Transport demand - macro and nano-scale model representations for internal and external precinct-travel,
- Waste production - regression and factor analysis based forecasts.

Forecast demands from the detailed domain models are collated and assembled as precinct consumption and production estimates. Again, the focus is on the households and household typologies with other land uses also accounted for in a more aggregate fashion.

Output datasets are collated within the ETWW model environment from domain-specific routines to define the consumption and production or overall demand profile of the precinct. The ETWW model then specifies the relationships that can potentially exist between the domains with relationships within the precinct demand forecasts, a process which is very much a result of the initial scenario specification. Potential relationships are initially reported in the Workshop 3 report on model specification, development and integration and now exist within the ETWW modal as:

- Use of electric vehicles by household
- Telecommuting/shopping/activities and in-household activity
- Wasted time in congestion
- Waste removal vehicles
- Waste water

- Water supply including desalination
- Distribution networks,
- Waste water collection networks
- Water utilised in energy generation
- Embodied energy
- Recycling/reuse
- Congestion caused by burst water mains, transport of water, stormwater and the coincidence of water and transport networks, flooding
- Biofuels

Other behavioural interactions resulting in domain demand interactions that are represented are:

- Increased recycling behaviour
- Reduced waste production behaviour
- Increased work-form-home behaviour
- Increased shop-from-home behaviour
- Reduced water consumption behaviour
- Reduced energy use behaviour
- Reduced transport demand behaviour
- Mode shift behaviour

The ETWW model processes the domain interaction with resulting changes to demands as appropriate. An example of an interaction is that which exists between the transport and energy domains in an electric vehicle scenario. Transport demands that include the use of electric vehicles must first be established in order to estimate the electrical energy required to fully or partially charge the electric vehicle batteries required for a day's travel. This additional energy requirement from the precinct household can then be incorporated into the energy demand model with supply of this energy possible from mains or solar produced power. Revised demand profiles then bring about the need for model re-estimations, with updates of modelling inputs supplied by the feedback routine.

Feedback routines between the collated data allow for demand interactions and their influence the forecasting process. Re-estimations of domain forecasts will now account for the influence of other domains on consumption and production profiles to reflect scenario definitions. Following this process, final demand profiles can be submitted to carbon and cost estimation routines. Carbon and particularly cost estimations based on the demand profiles is an area of the ETWW model requiring further investigation. For the transport domain, PhD research associated with this project has determined detailed estimation routines with other approaches required for the energy, waste and water domains. Initially, simple estimations will be permitted however the extent of carbon and cost estimation is yet to be determined. The research team will look to industry feedback and involvement to refine this further and also related CRC research such as the 'Economy-Wide Carbon Accounting' framework.

For the transport domain, current project-related research into emission forecasting domain involves the development of generic emission rates for light vehicle traffic loads that are highly applicable to Australian conditions. The emission rates are user friendly and can be used in long term forecasting studies. A sound and robust statistical methodology is used for predicting the expected variance of the emission rates and they are reported as confidence intervals. The user of the emission rates can assess risk when forecasting road transport greenhouse gas emissions. Research has also determined the uptake of fuel efficient technologies, including Hybrid electric vehicle (HEV), Plug-in hybrid electric vehicle (PHEV), Battery electric vehicle (BEV), Fuel cell vehicle (FCV) in the future light vehicle fleet.

Foundation Model.

The development of the foundation model allows for the forecasting abilities to be demonstrated with frameworks for:

- input data types required,
- preliminary and detailed modelling processes that are performed, currently existing both within the foundation model and externally,
- output demand data collation,
- the domain interactions possible,
- re-estimation of domain demands following on from interactions,
- initial estimations of carbon impacts and potential for estimation of costs

Scenario Development.

Any reliable forecasting tool needs to be driven by an ensemble of credible scenarios. Given that the main focus of the ETWW project is carbon emissions quantification and the identification of possibilities to achieve savings, the most relevant parameters to be considered in this case are the variables of climate change, electricity mix and the potential for climate, behavioural and technological changes. The Mosaic mix can also be varied, allowing the model to predict carbon emission for a range of different household shares and configurations in a given precinct. Figure 2 shows an example of how to construct multiple future scenario possibilities combining various assumptions about climate (sourced from CSIRO, 2015), electricity mix (based on Wolfram et al., 2016), as well as possible technological solutions and behavioural changes.

Major Australian urban centres have seen unprecedented growth in recent decades, with the urban built environment contributing significantly to the nation's greenhouse gas emissions (Bunning et al., 2013). The present study aims to build on previous research that has quantified energy use, greenhouse gas emissions and potential carbon savings associated with different future housing scenarios for Melbourne (Fuller and Crawford, 2011; Newton and Tucker, 2011). Housing size, style, and location have all been identified as principal factors which determine carbon emissions from the residential sector (Fuller and Crawford, 2011). Scenarios therefore need to consider various possibilities in terms of these three key parameters. In this project, a high socioeconomic segmentation of different household types is achieved through the use of the Mosaic dataset (Experian, 2013), which allows the characterisation of different household types on the basis of multiple criteria, including but not restricted to, housing size, style and location.

Studies on urban energy use also widely acknowledge the role of consumer behaviour (Faiers et al., 2007; Masoso and Grobler, 2010; Poortinga et al., 2004). The use of appliances, time spent in the shower, amount of heating or cooling used and also transport and vehicle choices are all important components of carbon emissions in an urban setting. Technological or engineering solutions are thus not sufficient in reducing the energy requirements of residential housing. Government intervention and other incentives encouraging more sustainable occupant behaviour, in addition to the use of renewable technologies to generate electricity and hot water, are necessary complementary actions (Fuller and Crawford, 2011; Newton and Tucker, 2011). For this reason, the scenario analysis and the model consider potential changes and relative influences of all the above variables.

According to Bunning et al. (2013) and Newton et al. (2013), designing low carbon cities must focus on instigating change at the precinct level ,where the highest potential for delivering low-carbon outcomes within the built environment has been demonstrated. Energy, transport, water and waste are all modelled at the precinct scale in our scenarios. Lochiel Park, a sustainable residential development in Adelaide hailed as a model low-carbon precinct (Berry et al., 2013; Berry et al., 2014; Saman, 2013), has been chosen as a case study. Lochiel Park serves as an example of a highly efficient energy precinct for Adelaide and South Australia. Meanwhile, low-carbon efficient BASIX-certified households fulfil the same role for Sydney and New South Wales (NSW Government, 2013).

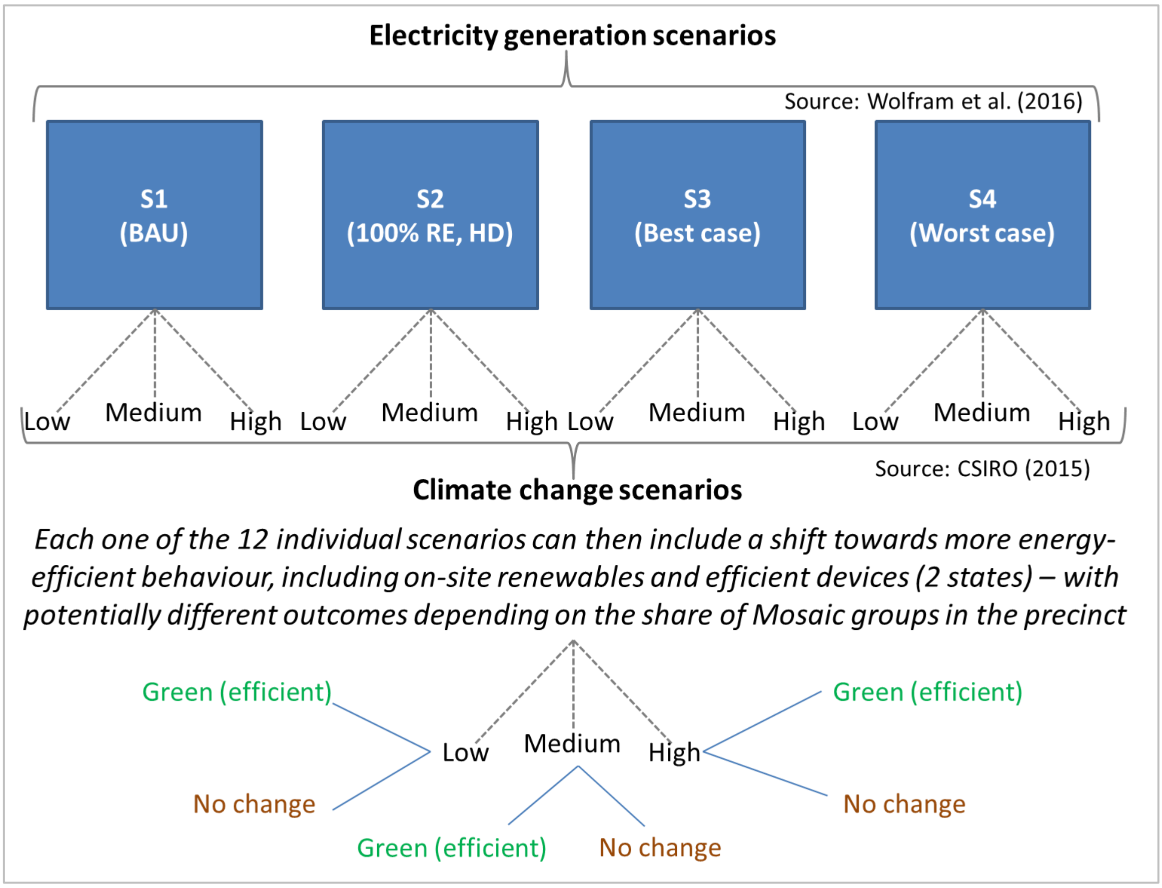

Figure 2 Illustration of the scenario analysis tree showing multiple possible variants based on choice of emissions scenario, electricity mix and technological/behavioural changes.

In Figure 2, S1 represents business-as usual electricity mix, while S4 represents a worst case scenario where fossil fuels still make up a significant share of the electricity mix in 2050. S2 and S3 assume widespread deployment of renewable, S2 with high demand and S3 (best case) with low demand. The greenhouse gas intensity of grid electricity (in kg CO2-e/kWh) for each of these scenarios has been calculated on the basis of supplementary data in Wolfram et al. (2016). With respect to the climate change scenarios, Low represents a B1 emissions scenario, Medium represents the most commonly used A1B emissions scenario, while high represents the A2 emissions scenario. Green (efficient) technology assumes efficient technologies and devices at the household level while no change assumes average present conditions.

Foundation Scenarios.

The foundation model is applied to 2 forecast scenarios, both based on Adelaide's Lochiel Park precinct, located approximately 8 kilometres North-East of the Adelaide CBD. The two scenarios detail a 'current' condition in 2015 and a future forecast condition in 2035 with specific attributes to demonstrate domain interaction. Both scenarios forecast daily demand profiles during the Spring.

The 2015 forecast or 'Scenario A' reflects current precinct with 106 households with 2015 Mosaic classifications (Table 1) and no other land uses. The current climate prevails with existing transport network connections, waste collection operations, household technologies etc., much of which is detailed by Experian's assessment of current household attributes. Scenario B relates to a 2035 forecast with the precinct expanded to 256 households adjusted proportions of Mosaic types to reflect possible population change over 20 years. Additional simple land uses with small retail space and secondary education are also present and forecast climatic conditions prevail. In addition to the modified household profile of the precinct, Scenario B involves a secondary school with 300 enrolments and 15 staff and a small retail outlet employing 5 persons.

Mosaic Code	Type	Detailed Description	Households	House Structure Type
Scenario A - 2015				
B05	Educated Savers	Informed and educated wealthy families in desirable suburbs on city perimeters.	10	Larger Detached
C13	Professional Views	Apartment dwellers with a social outlook living on the fringe of the inner city.	36	Apartment
D16	Ageing Gracefully	Empty-nester couples living in large houses in sought after outer metropolitan suburbs.	60	Medium Size Detached
Scenario B – 2035				
B05	Educated Savers	Informed and educated wealthy families in desirable suburbs on city perimeters.	13	Apartment
B06	Maturing Assets	Educated, maturing family households located in outer metropolitan suburbs.	38	Apartment
B08	Multicultural Wealth	Multicultural adult households with good incomes in inner and outer city suburbs.	13	Apartment
B09	The Good Life	Older couple households with simple needs living in suburbs that are more affordable.	51	Larger Detached
C12	Wireless and Wealthy	Social young careerists in affluent city central suburbs.	13	Larger Detached
C13	Professional Views	Apartment dwellers with a social outlook living on the fringe of the inner city.	38	Medium Size Detached
D16	Ageing Gracefully	Empty-nester couples living in large houses in sought after outer metropolitan suburbs.	26	Medium Size Detached
F21	Family Connections	Mixed family forms with substantial incomes located in new suburban estates.	13	Medium Size Detached
H31	Extended Ethnicities	Extended families and home-sharers of diverse backgrounds living within easy access of major cities.	26	Medium Size Detached
I34	Roaring Twenties	Singles at university or in early stages of their career in apartment outside of city centre environs.	5	Medium Size Detached
K40	Community Conservatives	Elderly couples and singles with traditional values and low expenses in metropolitan areas.	20	Apartment

Table 1 Household resident types present in the Lochiel Park precinct scenarios.

Physical attributes of household structure types are defined as the three possible households of apartments, medium and larger size detached houses. Table 2 provides a breakdown of the attributes for these house types present in both Scenarios A and B.

House Structure Type	1	2	3
General Description	Apartment	Medium Size Detached	Larger Detached
Roof Area/home (sqm)	45	190	240
Connected roof coefficient	0.9	0.8	0.7
Rainfall Collection/home (kL)	19111	71727	79277
Rainwater tank size (kL)	1.0	3.0	4.5
Panels/home	10.0	12.0	15.0
Bedrooms	2.0	3.0	4.0
Bathrooms	1.0	2.0	2.0
Parking allocation off-street	1.0	2.0	2.0
Parking allocation on-street	0.5	1.0	1.0
Plot Size (sqm)	150.0	300.0	300.0
Outdoor green space (%)	0	10	10
Elec - TV's	1.0	2.0	2.5
Elec - Cooking	1.0	1.0	1.5
Elec - AC	1.0	2.0	3.0
Elec – Hot Water	1.0	1.0	2.0
Elec - Washer	1.0	1.0	1.0
Elec - Dryer	1.0	1.0	1.0
Elec - Fridge	1.0	1.0	2.0
Gas - Cooking	0.0	0.0	0.0
Gas - Heating	0.0	0.0	0.0
Gas – Hot Water	0.0	0.0	0.0
Water - Showers	1.0	2.0	2.0
Water - Toilets	1.0	2.0	3.0

Table 2 Household structure type attributes.

Other specifications relating to Scenario B including the electric vehicle type, waste truck specifications, solar efficiency and so on are detailed within the ETWW foundation model spreadsheets. The combined domain interactions for the forecasts are specified to only occur in Scenario B and are as follows:

- Energy and transport domains through the presence of electric vehicles,
- Waste, transport and energy domains through the physical pick-up and disposal of precinct waste,
- Water and energy from renewables and the energy used in the supply of water,
- All domains based on work-from-home behaviour, ie. spending the day in the precinct rather than at the work location.

Forecasting.

Core components of the ETWW foundation model exist within a Microsoft Excel spreadsheet environment. This allows for a flexible working environment and for transparent development of the model with inclusions (as individual sheets) within the spreadsheet for:

- INPUTS: defining the attributes of the domain, focussing on the households, resident population and other land uses, this spreadsheet defines the detail of the scenarios developed for Lochiel Park (commented on later in this report),
- HHoldStructure_Ref: defining a household physical structure and attributes including appliances and technology within the house,
- Transport_Ref: transport domain specific reference material,
- MosaicGIT_Ref: Mosaic’s ‘grand index table’ lookup reference,

- BOMWeather_Ref: historic Bureau of Meteorology data sourced from the BOM website,
- Thorntwaite_Ref: forecast Thornthwaite Index reference data sourced from the TMI spreadsheet model,
- HTS_Ref: household travel survey extracts, de-identified and sourced from the HTS database,
- CPI_Ref: historic consumer price Index data reference data,
- Bicycle Modelling: household bicycle ownership estimation routine with operational data de-identified and sourced from the HTS database,
- OUTPUTS_Demand: collated demand profiles or integration and re-estimation as well as final version of the forecast outputs, sourced from domain modelling routines operating externally to the spreadsheet.

Domain forecasting routines that operate externally with input-output data connections to the ETWW spreadsheet model include the current developed forecasting routines. These are reported in detail in the Workshop 5 report and summarised in the following:

Energy

Current research in the energy domain involves the implementation of an Adaptive Boost Regression Tree algorithm to forecast electricity demand at 1 hour intervals and applied linear programing to model the impact of solar and battery systems on residential demand, capturing divisions of energy costs to reduce emissions. The model allocates an optimum system capacity and control operation for each home in the precinct with implementation of a demand model that applies three large demand datasets and Mosaic codes to predict residential electricity demand.

Transport

Current research in the transport demand forecasting domain involves establishing forecasting procedures in the Metropolitan Adelaide Strategic Transport Model (MASTEM) established for strategic-level precinct-to-external demands. Intra-precinct demand in the Commuter software is under development, with the incorporation of household types and behaviour through Mosaic and datasets also under development. For other capital cities, relevant strategic transport planning tools will be engaged.

Water

Current research in the water demand forecasting domain involves setting up a two component water demand forecasting model with end use component. Mosaic data socioeconomic characteristics are currently used to estimate likely water demand based on empirical relationships established from previous Australian studies. Ongoing work on model calibration (subject to data from Sydney Water, SA Water and Lochiel Park) and forecasting under future water supply and energy scenarios (in development).

Waste

Current research in the waste production forecasting domain involves applying a time series model and multivariable linear regression model in terms of the characteristics of data in order to forecast the municipal waste generation. The information of human behaviour at the Lochiel Park had been collected, and the work at the city of Marion is ongoing and factors based on the information from the Lochiel Park are analysed to show how factors influence the municipal waste generation, and the research of connecting human behaviour with associated quantity of municipal waste generation is carried out.

Continued Model Development.

Model developments into 2016 will seek to develop and refine the forecasting structure and routines, incorporate modelling elements internally where possible and strengthening linkages to external components where necessary. Output representations for demands, carbon and costs will develop with GIS and mapping applications where possible. Industry input and guidance will be sought on a range of aspects related to the model refinement and application. Other items for progressing include:

- collation of data from a range of sources, including CRC for LCL projects operating in Program 2 and industry partners,
- assembly and incorporation of domain researcher outcomes, who are at various stages of research development and differing completion dates.
- Note : PhD research will continue until July 2017. The contributions of the two PhD students in the energy and waste domains are key contributions to the overall integrated forecasting model. Sufficient time is required to allow for inclusion of reasonably mature versions of their domain-specific sub-models,
- collaboration and synergies with other CRC projects and industry partner led research directions,
- additional domain researcher workshops to integrate developed methodologies, share research outcomes and incorporate industry partner feedback,
- production of additional reporting material including an interim report,

- production of a foundation version of the model that allows for the future integration of detailed domain research outcomes,
- integration of combined research outcomes, testing and production of a final report in December 2016.

Application scenarios beyond Lochiel Park will further demonstrate the carbon impact forecasting abilities of the model. At this stage, the precinct sites of Bowden and Tonsley in Adelaide are earmarked for model applications.

Selected Scenario Results

The following provides a brief summary of selected scenario outcomes presenting the overall influence of forecast scenarios on the carbon production attached to the precinct. Estimation processes allow for detailed estimations at a household and individual land-use level.

Electric Vehicles

The electric vehicle scenario sees the introduction of electric vehicles to all household types for the Lochiel Park precinct in the year 2035, and assumes a growth of the precinct from 106 households in 2015 to 256 in the year 2035, along with other land uses as described previously. Travel over a complete day is considered and so this includes return trips as part of the journey. In this scenario the use of electric vehicles is for work-trips from, and returning to, the home. The following table presents the 2015 and 2035 travel and carbon productions.

	2015		2035	
	Travel (km)	CO2 (kg)	Travel (km)	CO2 (kg)
Car - Conventional	18,071	3,397	58,093	10,921
Car - Electric	-	-	15,893	-
Public Transport	1,262	189	4,908	736
Bike	53	-	310	-
Walk	28	-	554	-

Table 3 Lochiel Park precinct multimodal travel and carbon impact for scenarios.

The 2035 scenario produces an overall growth in car travel of 55,915km with 15,893km of this attributable to electric vehicles. There is also substantial relative growth in travel from other modes which in not only related to an increase in home-based travel but also due to the presence of a secondary school and retail space. The introduction of electric vehicles in 2035 for work-based travel sees a saving in CO_2 of 2,988kg on a typical day if electricity is sourced from renewable sources such as solar.

As a result, the precinct requires a total of 2,861 kilowatt hours of electrical energy to power the daily electric vehicle needs. The ETWW foundation model allows the deeper investigation of this energy in terms of average energy per household within each household classification to power an electric vehicle, per home.

Mosaic Classification	kWhr required for electric vehicle travel
B05	6.0
B06	7.4
B08	6.7
B09	7.5
C12	4.1
C13	5.0
D16	6.9
F21	7.2
H31	9.2
I34	5.6
K40	4.7

Table 4 Daily household power required for electric vehicle travel by house classification in 2035.

Energy

The energy demand scenario investigates precinct energy demand for 2015 and 2035. For both scenarios we first determine the raw demand profiles, based off hourly outside temperature, information about the occupants and the homes. We then investigate the impacts of reducing demand, and CO_2 emissions, through the installation of solar and battery systems and how this effects the hourly demand profile shapes. Two demand reduction scenarios have been considered: 1) the reduction in grid reliance by 50% and, 2) the lowest cost energy supply solution. Table 5 summarises the yearly CO_2 emissions and the 25 year net-present-value cost of energy, this cost includes the infrastructure costs of the solar and battery system, cost of energy imported from the grid and a small profit from energy exported to the grid; a discount rate of 5% was used. This table shows that there is only a small increase in lifetime energy costs to reduce grid reliance by 50%. Furthermore, the lowest cost scenario shows that both emissions and energy costs can be reduced by installing a solar panel only system.

	Grid only		50% grid reliance reduction scenario				Lowest cost scenario			
Mosaic Group	Total cost of Energy from the grid ($)	Total Yearly CO_2 (TCO_2e)	Total cost of energy	Total Yearly CO2 (TCO_2e)	CO2 offset from Export (TCO_2e)	Net impact (TCO_2e)	Total cost of energy	Total Yearly CO2 (TCO_2e)	CO2 offset from Export (TCO_2e)	Net impact (TCO_2e)
C12	$ 12,744.81	1.63	$ 13,319.88	0.88	2.87	-2.00	$ 10,891.30	1.29	1.31	-0.03
C13	$ 7,629.41	0.53	$ 6,915.95	0.29	0.81	-0.51	$ 6,611.21	0.38	0.50	-0.12
I34	$ 12,744.81	1.63	$ 13,319.88	0.88	2.87	-2.00	$ 10,891.30	1.29	1.31	-0.03
F21	$ 13,478.63	1.45	$ 11,127.25	0.82	2.22	-1.40	$ 10,556.83	0.98	1.43	-0.44
B05	$ 15,894.44	2.19	$ 15,527.68	1.18	3.41	-2.23	$ 13,068.35	1.67	1.30	0.37
B06	$ 11,773.57	1.23	$ 10,132.85	0.69	1.78	-1.09	$ 9,505.44	0.86	1.05	-0.20
B08	$ 11,918.96	1.49	$ 12,493.59	0.79	2.77	-1.97	$ 10,262.30	1.17	0.96	0.21
H31	$ 11,321.01	1.29	$ 10,974.70	0.70	2.12	-1.42	$ 9,567.62	0.98	0.82	0.16
D16	$ 17,480.43	2.30	$ 15,257.97	1.26	3.71	-2.44	$ 13,664.06	1.64	1.97	-0.33
B09	$ 7,867.59	0.57	$ 7,123.56	0.32	0.81	-0.50	$ 6,789.75	0.40	0.54	-0.14
K40	$ 7,629.41	0.53	$ 6,915.95	0.29	0.81	-0.51	$ 6,611.21	0.38	0.50	-0.12

Table 5 CO_2 Emissions and 25 year lifetime cost of energy.

Energy-Transport Interactions

An initial investigation of the interaction between the Energy and Transport domains has been considered by adding the electric vehicle daily charging requirements, from Table 4, to the base load profiles for each Mosaic Group. When generating the new profiles it was assumed that the charging of the electric vehicle is spread over the off peak pricing times, from 11pm – 6 am every day. Figure 2 shows a sample of the demand profiles produced by the model, the impact of electric vehicles can be seen by the increase in precinct demand during the off peak periods. The battery and solar optimisation model has been applied to these new profiles to analyse the impact of solar and battery systems on the precinct demand with electric vehicles. The 50% grid reliance scenario, shown by the blue line has increased the demand shape complexity significantly; this could have negative impacts on the electricity network.

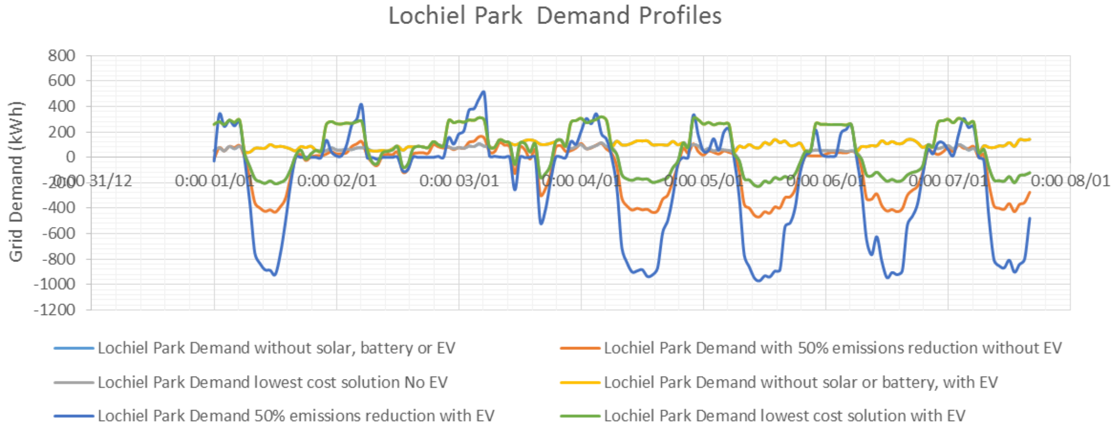

Figure 3 Sample of the precinct demand scenarios.

Table 6 shows the solar and battery capacities defined in the optimisation model. It can be seen that, no battery system has been defined for the lowest cost scenarios, this could change as battery prices reduce in the future.

	[redacted]				With Electric Vehicle			
	[redacted]		Lowest cost scenario no EV		[redacted]		Lowest cost scenario with EV	
Mosaic Group	Solar Capacity (kW)	Battery Capacity (kWh)	Solar Capacity (kW)	Battery Capacity (kWh)	Solar Capacity (kW)	Battery Capacity (kWh)	Solar Capacity (kW)	Battery Capacity (kWh)
C12	3.52	1.83	1.67	0.00	4.80	4.08	1.67	0.00
C13	1.04	0.35	0.67	0.00	2.98	3.10	0.67	0.00
I34	3.52	1.83	1.67	0.00	5.23	4.92	1.67	0.00
F21	2.85	0.67	1.95	0.00	5.96	4.47	1.95	0.00
B05	4.32	2.12	1.87	0.00	6.78	5.38	1.87	0.00
B06	2.32	0.72	1.47	0.00	5.34	4.72	1.47	0.00
B08	3.35	1.64	1.29	0.00	5.68	5.36	1.29	0.00
H31	2.65	1.21	1.16	0.00	5.95	6.33	1.16	0.00
D16	4.68	1.59	2.68	0.00	7.27	5.30	2.68	0.00

Table 6 Optimised system capacity.

Table 7 summarises the yearly CO_2 emissions and the 25 year net-present-value cost of energy when the homes have electric vehicles. An increase in emissions from the grid and energy costs can be observed in all scenarios. Since charging only occurs at night, to meet a grid reliance percentage of 50%, a large battery system is required to shift the solar generation from the day time to the night time to reduce the vehicle charging demand from the grid. This large battery accounts for the higher cost of energy for this scenario.

	Grid only		50% grid reliance reduction scenario				Lowest cost scenario			
Mosaic Group	Total cost of Energy from the grid ($)	Total Yearly CO2 (TCO2e)	Total cost of energy	Total Yearly CO2 (TCO2e)	CO2 offset from Export (TCO2e)	Net impact (TCO2e)	Total cost of energy	Total Yearly CO2 (TCO2e)	CO2 offset from Export (TCO2e)	Net impact (TCO2e)
C12	$15,014	2.44	$19,952	1.32	3.78	-2.45	$13,161	2.18	1.31	0.87
C13	$10,397	1.53	$15,234	0.84	2.32	-1.48	$9,378	1.47	0.50	0.98
I34	$15,844	2.74	$22,480	1.49	4.07	-2.58	$13,991	2.51	1.31	1.20
F21	$17,463	2.88	$22,090	1.61	4.74	-3.13	$14,541	2.56	1.43	1.13
B05	$19,215	3.38	$25,228	1.84	5.37	-3.53	$16,389	2.98	1.30	1.69
B06	$15,869	2.70	$21,985	1.50	4.18	-2.68	$13,601	2.48	1.05	1.42
B08	$15,627	2.82	$23,555	1.53	4.51	-2.98	$13,971	2.64	0.96	1.68
H31	$16,412	3.12	$26,418	1.71	4.63	-2.92	$14,660	2.99	0.82	2.18
D16	$21,299	3.67	$25,964	2.02	5.71	-3.69	$17,483	3.15	1.97	1.19
C12	$12,018	2.06	$19,749	1.14	2.98	-1.84	$10,940	2.05	0.54	1.51
C13	$10,230	1.47	$14,713	0.81	2.21	-1.40	$9,212	1.41	0.50	0.91

Table 7 Energy and Electric vehicle CO_2 Emissions and 25 year lifetime cost of energy.

Waste Disposal

The ETWW foundation model allows for the estimation of household waste production the transport needs for waste removal and disposal/recovery with associated carbon impacts. Forecasting for both the 2015 and 2035 scenarios assume that the on-road distance from Lochiel Park to recycling and dumping facility at Wingfield is 14.5km with *landfill* waste collection weekly, and bin capacity 140 litres; *organic and recycling* waste collection fortnightly and alternating with bin capacity of 240 litres.

Calculations are performed by waste type and again disaggregated by Mosaic household classification and reported here on a weekly basis. Transport based CO2 production is from the collection vehicle emissions with waste generated from landfill and organic is only from the decomposition of materials. Forecasts do not account for embodied CO2 or CO2 production from the recycling process. This requires further investigation.

	2015		**2035**	
	Transport Based CO2 (kg)	**Waste Generated CO2 (kg)**	**Transport Based CO2 (kg)**	**Waste Generated CO2 (kg)**
Landfill Garbage	112.6	365.2	337.9	915.6
Organic Waste	90.1	386.3	180.2	968.5
Mixed Recycling	90.1	0.0	180.2	0.0
Total	**292.9**	**751.6**	**698.4**	**1884.0**

Table 8 Weekly generation of CO2 associated with Lochiel Park precinct waste disposal for both scenarios.

Evident from Table 8 that that in both scenarios transport is a significant component of carbon production associated with waste disposal, accounting for close to 27% of the total in both forecast scenarios.

Work From Home

The work-from home scenario only considers impacts related to the 2035 forecast scenario and assumes that a selection of household types will effectively 'work from home' and hence not contribute to commuting travel on the road. The following table presents the car-based travel and carbon saving disaggregated by mosaic household type.

Mosaic Classification	Households	Work From Home?	Car travel saved (km)	CO2 saved (kg)
B05	13	All	5,332	1,002
B06	38	All	1,413	266
B08	13	All	860	162
B09	51	None	-	-
C12	13	All	249	47
C13	38	All	881	166
D16	26	None	-	-
F21	13	None	-	-
H31	26	None	-	-
I34	5	None	-	-
K40	20	None	-	-

Table 9 Work-from-home 2035 scenario car-based travel and carbon savings.

In total 8,734 kilometres of travel are removed from the roads as the selected cohorts do not commute, resulting in a reduction in carbon of 1,642 kg CO2.

Water

The following is a comparison of current (2015) versus potential future (2035) scenarios in relation to water use for the Mosaic types at Lochiel Park. Current totals for Lochiel Park (2015) (see below for model assumptions):

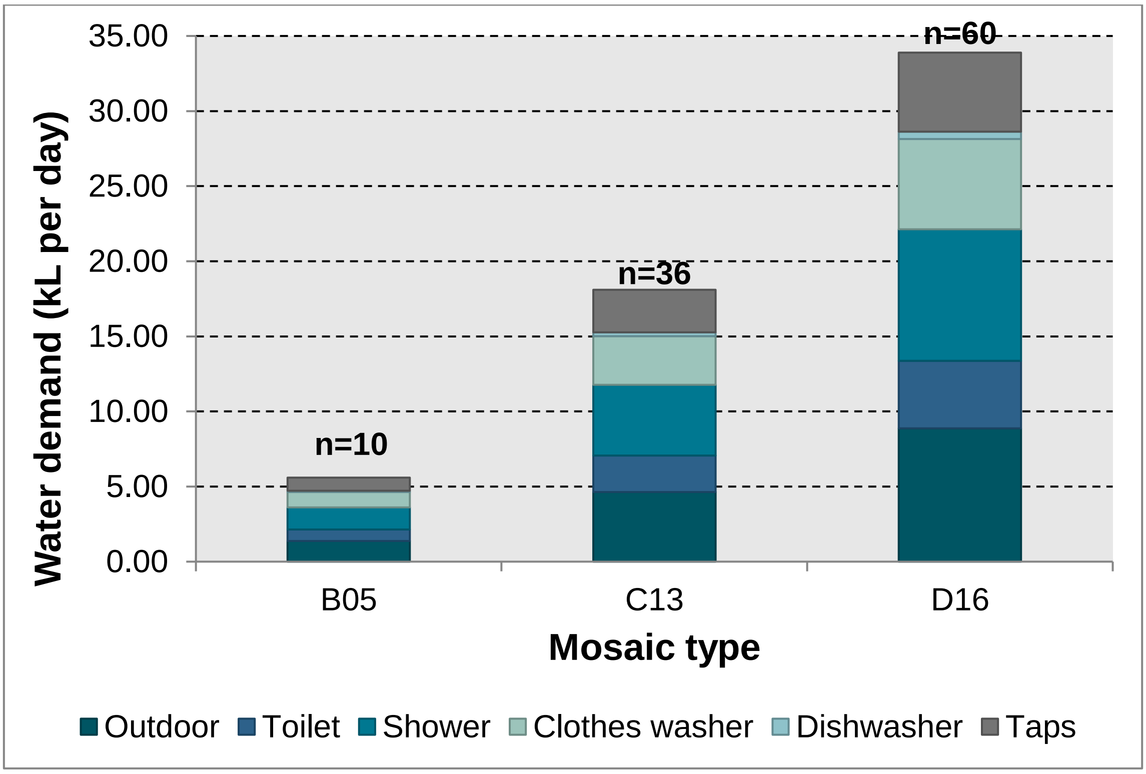

Figure 4 Estimated end use for each of the households types currently found in Lochiel Park.

Mosaic Classification	Households	Average daily water use (l)	Average daily wastewater (l)	Daily household GHG emissions (kg CO_2-e)	Total precinct GHG emissions (kg CO_2-e)
B05	10	450	338	0.57	5.70
B06	-	-	-	-	-
B08	-	-	-	-	-
B09	-	-	-	-	-
C12	-	-	-	-	-
C13	36	280	207	0.38	13.7
D16	60	340	252	0.43	25.8
F21	-	-	-	-	-
H31	-	-	-	-	-
I34	-	-	-	-	-
K40	-	-	-	-	-

Table 10 Daily water use profile and GHG emissions based on present consumption patterns.

Mosaic Classification	Households	Average daily water use (l)	Average daily wastewater (l)	Daily household GHG emissions (kg CO_2-e)	Total precinct GHG emissions (kg CO_2-e)
B05	13	530	398	0.55	7.20
B06	38	580	441	0.61	23.1
B08	13	470	357	0.49	6.40
B09	51	530	398	0.55	28.1
C12	13	310	226	0.32	4.10
C13	38	340	252	0.35	13.3
D16	26	410	303	0.42	11.0
F21	13	380	300	0.41	5.30
H31	26	610	482	0.65	16.9
I34	5	500	350	0.50	2.50
K40	20	350	228	0.34	6.80

Table 11 Daily water use and GHG emissions based on future climate projections for 2035.

Mosaic Classification	Households	Average daily water use (l)	Average daily wastewater (l)	Daily household GHG emissions (kg CO_2-e)	Total precinct GHG emissions (kg CO_2-e)
B05	13	530	398	0.33	4.30
B06	38	580	441	0.36	13.8
B08	13	470	357	0.29	3.80
B09	51	530	398	0.33	16.8
C12	13	310	226	0.19	2.50
C13	38	340	252	0.21	8.00
D16	26	410	303	0.25	6.60
F21	13	380	300	0.24	3.10
H31	26	610	482	0.39	10.1
I34	5	500	350	0.30	1.50
K40	20	350	228	0.20	4.10

Table 12 Daily water use and GHG emissions assuming 50% renewable energy in 2035.

Discussion:

Current water use is a function of household size, lot size and seasonality influence (temperature and precipitation), the latter mostly having an influence on irrigation. The amount of wastewater generated is based on the indoor to outdoor ratio from the literature (Arbon, N., et al., 2014). Current energy use related to water supply and wastewater supply is based on Adelaide's current energy and water supply mix.

Future water use is a function of projected climatic change. Behavioural or technological changes have not been simulated here but these certainly have the potential to reduce the GHG intensity of water supply. The influence of rainwater tanks will also be added in future simulations. The future GHG projections also assume a higher share of water coming from desalination. That also partly accounts for significant increases in GHG emissions.

It is nevertheless clear that a combination of a grid with a high share of renewable energy has the potential to aid greatly in the reduction of GHG emissions from water use and wastewater treatment.

Model setup and assumptions:

Model results are based on multiple linear regression of primary data from two households at Lochiel Park (one D16 and one C13 type) in addition to precipitation from two BOM stations (Felixstowe and Greenacres) and temperature (Kent Town). The current water demand forecasting model automatically locates and the nearest weather stations and can then download relevant precipitation and temperature data directly from the BOM website, thus allowing such relationships to be ascertained for any precinct in Australia. For the other Mosaic types the relative differences between Mosaic types obtained from Sydney Water data are inferred. Future water use is simulated by assuming increase in temperature and decrease in precipitation as dictated by the Thorntwaite Index.

End use was simulated on the basis of previous findings for different household types and sizes (Arbon et al. 2014, Makki et al. 2013 and Makki et al. 2015). This can be improved with more specific data from the households at Lochiel Park or from data provided by SA Water as the implications for energy and the potential interaction with the energy model are important, especially with regards to hot water use and appliance use.

Carbon emissions were simulated on the basis of 2009/10 data with regards to the energy supply mix (DOE, 2014) and water supply mix (Cook and Gregory, 2012) in Adelaide. Current assumption for future energy and water use has been based on Cook and Gregory (2012) but further scenarios could explore transitions to renewable energy, in line with the South Australian government's emission reduction aspirations.

Necessary improvements:

- Water demand data from other Adelaide households (outside Lochiel Park) – this includes data on lot size, household size.
- Spatially-specific wastewater and water supply energy intensity data
- Additional data from households in Lochiel Park to improve regression coefficients
- Simulating possible interaction with energy, especially hot water use and end use by appliances such as dishwashers and washing machines
- Future scenarios combining behavioural and technological changes alongside impacts of climate change and renewable energy
- Weekend versus weekly water use dummy variables

References

Arbon, N., et al., 2014. Understanding and Predicting Household Water Use for Adelaide, Goyder Institute for Water Research Technical Report Series No. 14/15: Adelaide, South Australia.

Berry, S., Davidson, K., Saman, W., 2013. The impact of niche green developments in transforming the building sector: The case study of Lochiel Park. Energy Policy 62, 646-655.

Berry, S., Whaley, D., Davidson, K., Saman, W., 2014. Do the numbers stack up? Lessons from a zero carbon housing estate. Renewable Energy 67, 80-89.

Bunning, J., Beattie, C., Rauland, V., Newman, P., 2013. Low-carbon sustainable precincts: An Australian perspective. Sustainability 5, 2305-2326.

Cook, S., H. M., and A. Gregory, Energy use in the provision and consumption of urban water in Australia: an update. 2012, Prepared for the Water Services Association of Australia.: CSIRO Water for a Healthy Country Flagship, Australia.

CSIRO, 2015. Climate Change in Australia: Technical Report. Commonwealth Scientific and Industrial Research Organisation Canberra.

DOE, 2014. National Greenhouse Accounts Factors, Commonwealth of Australia, Department of the Environment (DOE): Canberra.

Experian, 2013. Experian Mosaic Guide. Retrieved from: http://www.experian.com.au/consumer-segmentation/mosaic-segments.html. Experian Marketing Services.

Faiers, A., Cook, M., Neame, C., 2007. Towards a contemporary approach for understanding consumer behaviour in the context of domestic energy use. Energy Policy 35, 4381-4390.

Fuller, R.J., Crawford, R.H., 2011. Impact of past and future residential housing development patterns on energy demand and related emissions. Journal of Housing and the Built Environment 26, 165-183.

Makki, A.A., et al., 2015. Novel bottom-up urban water demand forecasting model: Revealing the determinants, drivers and predictors of residential indoor end-use consumption. Resources, Conservation and Recycling, 95(0): p. 15-37.

Makki, A.A., et al., 2013. Revealing the determinants of shower water end use consumption: enabling better targeted urban water conservation strategies. Journal of Cleaner Production, 60(0): p. 129-146.

Masoso, O., Grobler, L.J., 2010. The dark side of occupants' behaviour on building energy use. Energy and buildings 42, 173-177.

Newton, P., Marchant, D., Mitchell, J., Plume, J., Seo, S., Roggema, R., 2013. Performance Assessment of Urban Precinct Design: A scoping study. CRC for Low Carbon Living, Sydney, Australia.

Newton, P.W., Tucker, S.N., 2011. Pathways to decarbonizing the housing sector: a scenario analysis. Building Research & Information 39, 34-50.

NSW Government, 2013. BASIX outcomes - 5 year summary. NSW Government. Available from: www.basix.nsw.gov.au, Sydney, Australia.

Poortinga, W., Steg, L., Vlek, C., 2004. Values, environmental concern, and environmental behavior a study into household energy use. Environment and behavior 36, 70-93.

Saman, W.Y., 2013. Towards zero energy homes down under. Renewable Energy 49, 211-215.

Wolfram, P., Wiedmann, T., Diesendorf, M., 2016. Carbon Footprint Scenarios for Renewable Electricity in Australia. Journal of Cleaner Production doi:10.1016/j.jclepro.2016.02.080.

Appendix A

The following CRC Commonweatlh milestones are addressed by this project as identified below:

> ***Milestone U2.2.1 Prototype CRC partner tools trialled by State, local government, NGO agencies and private sector.***
>
> ***Milestone U2.3.1 Trials of prototype demand forecasting tools participated in by utility partners in the CRC.***

As part of recent project developments the research team has developed a prototype or 'foundation' version of the model and applied it to scenarios based around the Lochiel Park development in Adelaide. This work assessed scenarios that were developed with industry guidance and were discussed at project steering committee meetings and researcher workshops.

To communicate the results of this prototype tool application this report has been developed with the researcher team also inviting all industry partners to individual presentation sessions. The purpose of these sessions (held during March, Aril and May of 2016) have been to discuss the prototype model approach and to receive industry feedback and guidance on these outcomes and directions for future developments including model inclusions, output types, case study locations and scenario types. Industry partners for the project included in this process are:

- AECOM,
- SA Department for Planning Transport and Infrastructure (DPTI)
- SA Department of Environment, Water and Natural Resources (DEWNR)
- SA Water
- Sydney Water
- Renewal SA
- CSIRO
- University of NSW

And beyond these partners:

- University of SA
- Sustain SA

> ***Milestone 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.***

The project team has developed this report which describes the development and assessment of an electric vehicle component of the application scenario. Specifically the following sections refer to the impacts of household electric vehicle use:

- Electric Vehicles (pg14)
- Energy and transport interactions (pg15)

The report addresses detailed household electric vehicle demand with use, energy requirements, energy provision and carbon impacts.