Riverview Projects

Energy at Ginninderry

Snapshot and roadmap

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1. Introduction

1.1. The vision for energy at Ginninderry

Ginninderry was conceived as "a sustainable community of international significance in the capital region". Riverview Developments, in collaboration with the ACT Government and the NSW Government, is working to develop a project that will be sustainable over time, provide for the evolving state of infrastructure and regulatory mechanisms, and establish a best-practice blueprint for others to follow.

Riverview recognised that sustainable energy solutions would play a crucial role in realising these goals, and also held the added potential to provide ongoing economic and community benefits to Ginninderry residents and the wider region.

Not only is energy a rapidly increasing part of the cost of living, but the energy landscape is changing rapidly. The surge in rooftop solar generation, the emergence of batteries, and new technologies for managing energy, all point to the need to plan carefully for both the near future and for the lifetime of the Ginninderry community.

1.2. This report

With help from Beast Solutions, QED Energy, the ACT Land Development Agency, ActewAGL Distribution, and many others, Riverview set out for develop an energy strategy that would be cost-effective, realistic, future-proof, and would directly benefit the Ginninderry community.

This report describes the evolution of this strategy from its inception to the present day, and charts its course into the future stages of development at Ginninderry.

2. Where we are and how we got here

2.1. Introduction

The Ginninderry development team has stood by the concept of an integrated energy strategy as an inseparable part of its bold sustainability vision for the Ginninderry community. This vision has proved instrumental in achieving a 6-star "world leadership" Green Star Communities rating.

The energy concept we see today is the result of an extensive analysis of many options, scenario testing, and design iterations, undertaken since the early stages of the project. During the process we examined energy flows at the micro level, such as home appliances, and the macro level of interconnected and controlled energy flows across the entire Ginninderry development and the wider network. We investigated the behavioural patterns and opinions of homeowners, worked closely with the local electricity network provider ActewAGL. We also explored a wide variety of technologies, from simple rooftop solar photovoltaics to hydropower and community-owned solar farms.

2.2. The home energy concept

The home energy concept couples highly energy-efficient home designs with a range of carefully-selected packages of home appliances to further reduce energy demands.

The packages include energy efficient appliances, a rooftop solar photovoltaic (PV) system and an intelligent control system. The combination of these measures make the average Ginninderry home 'energy neutral', meaning that each year it is expected to generate as much energy from rooftop renewables as is consumed by the home itself. During periods of excess PV energy generation, surplus energy will be provided back to the grid for a feed-in-tariff, and used to supply other homes and businesses in the development.

The energy control system provided to each home will balance energy generation with energy demands to optimise performance and draw the greatest possible benefit from PV. For example, it can take advantage of periods of excess solar generation by switching on the electric hot water system, storing hot water for later use. Smart appliances can also be controlled using remotely-controlled sockets. The energy control system can also be linked to battery storage technologies to further improve the utilisation of PV and reduce energy bills.

2.3. The precinct energy concept

The precinct energy concept draws upon the collective power of the individual homes to create a 'microgrid' or 'virtual power plant'. In this model, the intelligent control systems in each home can work as one to create a far larger aggregated system comprised of dozens, hundreds, or even thousands of homes. When the Ginninderry development is completed, its aggregated PV generation capacity will be greater than that of the ACT's largest solar farm at Royalla. The precinct energy concept also provides for aggregated 'demand management', in which loads are actively reduced during periods of peak strain on the electricity networks, and energy stored in batteries can be released into the grid to provide additional stability. By actively balancing generation, demands, and storage resources across the development, the control systems provide for this future microgrid functionality in which the precinct can run as its own independent energy system under certain conditions, considerably enhancing resilience.

While many homeowners may elect to install battery storage systems in their own homes, the precinct energy concept includes spatial allocations for future neighbourhood-scale battery storage. These resources can provide high-volume energy storage during times of excess generation as well as grid stabilisation and demand management functions during peak periods. Larger-scale battery systems have the benefit of being more highly utilised, and may be owned by the community or a third party service provider, subject to approvals by energy regulators. By building in the option, the energy concept offers future flexibility and adaptability for a future microgrid.

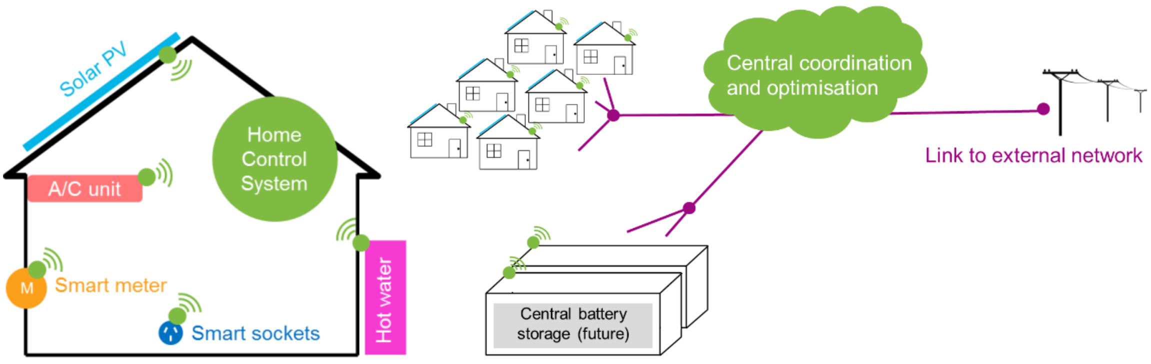


Illustration of the individual home energy concept (left) and the precinct microgrid (right).

2.4. The concept development process

The development of the energy concept has been an extensive process involving options analysis, scenario testing, stakeholder engagement and detailed discussions with technology manufactures and suppliers. The process encompassed the design and optimisation of individual homes and their aggregated impact on the precinct. It has included the establishment of a dedicated working party comprised of representatives from the ACT Government, project developer, electricity and gas utilities, to bring collective insights to bear in evaluating and validating the energy concept and its potential benefits.

The development process can be considered in terms of five key stages.

Stage 1: Review of project sustainability goals and early concept ideas

The process began with the foundational vision of "creating a sustainable community of international significance in the capital region", with specific goals relating to the delivery of long-term sustainability, responding to the local and global environments, providing for future beneficial change in infrastructure design and regulatory mechanisms, and providing a blueprint for future developments.

From early discussions, it was clear that the energy concept would be a key contributor to the achieving these visionary goals, and that truly innovative energy solutions would be required. A number of early concept ideas were created in pursuit of these energy goals, including the microgrid concept in place today.

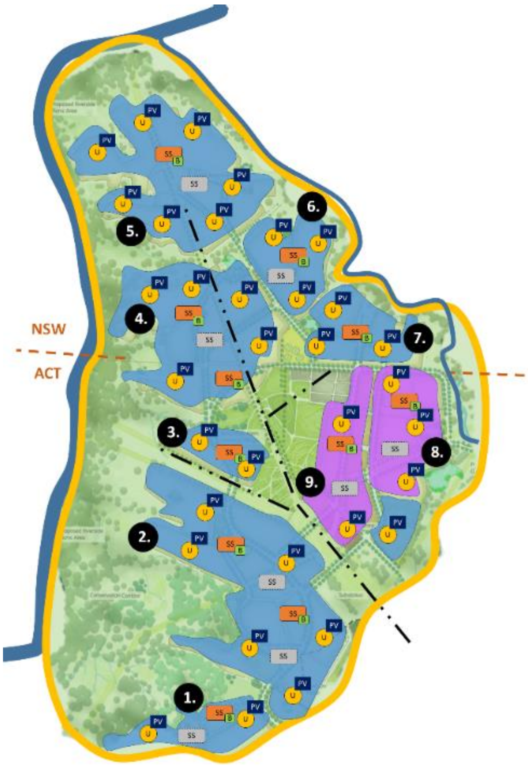


Illustration of the early Ginninderry microgrid concept.

Stage 2: Analysis of home energy flows and potential for precinct-scale measures

As housing mixes began to emerge from the project masterplan, a series of high-level analyses were performed to estimate the energy demands and carbon footprint of the development. These analyses included the potential impact of high-level home energy measures such as energy efficient home design, appliance selection, and rooftop solar thermal and PV systems. Non-residential building types such as schools, medical centres, and retail, commercial and industrial buildings were also included, as were elements such as street lighting.

These analyses enabled consideration of precinct-scale measures and where they could be located. These measures included a community solar farm, mini-hydropower plant, and battery storage systems. They were investigated with the assistance of ANU student researchers, offering a practical renewables research project and learning outcomes for participants.

A key goal of stage 2 was to investigate the potential to create an energy-neutral development, in which the total energy demands each year would be offset by renewable generation on site. This goal aligned with the both the project sustainability goals and the microgrid concept.

Stage 3: Detailed analysis of home energy concept and benefits to residents

The development of early home designs enabled a more detailed analysis of home energy options, including the relative system costs and benefits to residents. We developed nine home energy options, ranging from a simple business-as-usual home design featuring a gas hot water system, evaporative cooling system, gas heating system and no renewables technologies, through to a high energy-efficiency home design featuring an electric heat-pump hot water system, energy efficient reverse-cycle air conditioning system, rooftop solar, battery storage and a home energy control system.

The nine home energy options were made up of various combinations drawn from the following:

- Heating and cooling
    - gas ducted heating with evaporative cooling
    - 4-star reverse-cycle air conditioning

    - 5-star reverse cycle air conditioning
- Hot water system
    - gas
    - solar with electric boost
    - electric heat pump
- Rooftop PV
    - Not present
    - present, sized according to house type
- Home energy control
    - not present
    - present
- Home energy efficiency rating
    - EER 6 stars
    - EER 7 stars
- Battery system
    - not present
    - in-home battery
    - batteries shared by many homes.

The analysis involved modelling hourly energy demands, generation, and controlled load shifting and storage for several different housing types, using current electricity and gas tariffs to determine the annual energy bills and carbon footprint for each option. The results of the energy bill analysis were then compared against the required upfront costs, replacement costs and maintenance costs to calculate the whole-of-life costs and investment performance metrics for each option.

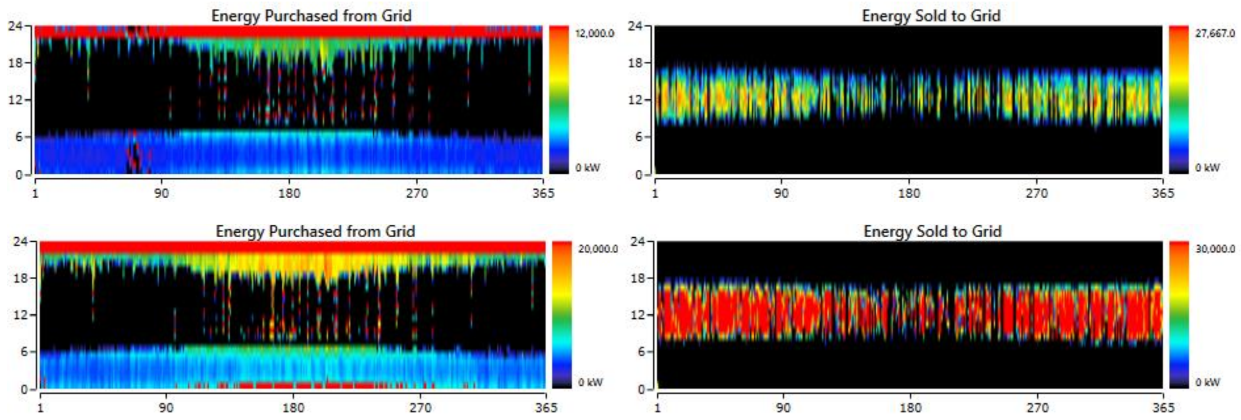
Stage 4: Exploration of the precinct microgrid concept and its regulatory implications

We explored the microgrid concept further by modelling of how different microgrid configurations would perform in terms of their renewable energy utilisation, control strategy, grid independence, stability under stress, and cost-benefit outcomes.

Different microgrid ownership models were also explored, such as a community ownership, private investment, utility partnerships and hybrid models. We also looked at the constraints and opportunities presented by the regulatory environment, liaising with the Australian Energy Market Commission (AEMC), the Australian Energy Market Operator (AEMO), the Australian Energy Regulator (AER) and the Independent Competition and Regulatory Commission (ICRC).

Crucial to this stage was how the microgrid may evolve over time, adapting to the growing infrastructure and energy demands of the precinct, future technology change and the expected modernisation of the regulatory landscape.

In the early stages of Ginninderry, insufficient energy demands, a cost-prohibitive regulatory pathway and technology cost barriers would preclude the realisation of a full microgrid, but this situation is likely to rapidly improve. The first stage of homes will be 'microgrid ready', including the necessary controls, compatible appliances and land allocations to link in to a future microgrid. While technology change is sometimes difficult to predict, attention was given to avoid locking in technologies and considering the future impact of new technologies such as electric vehicles.

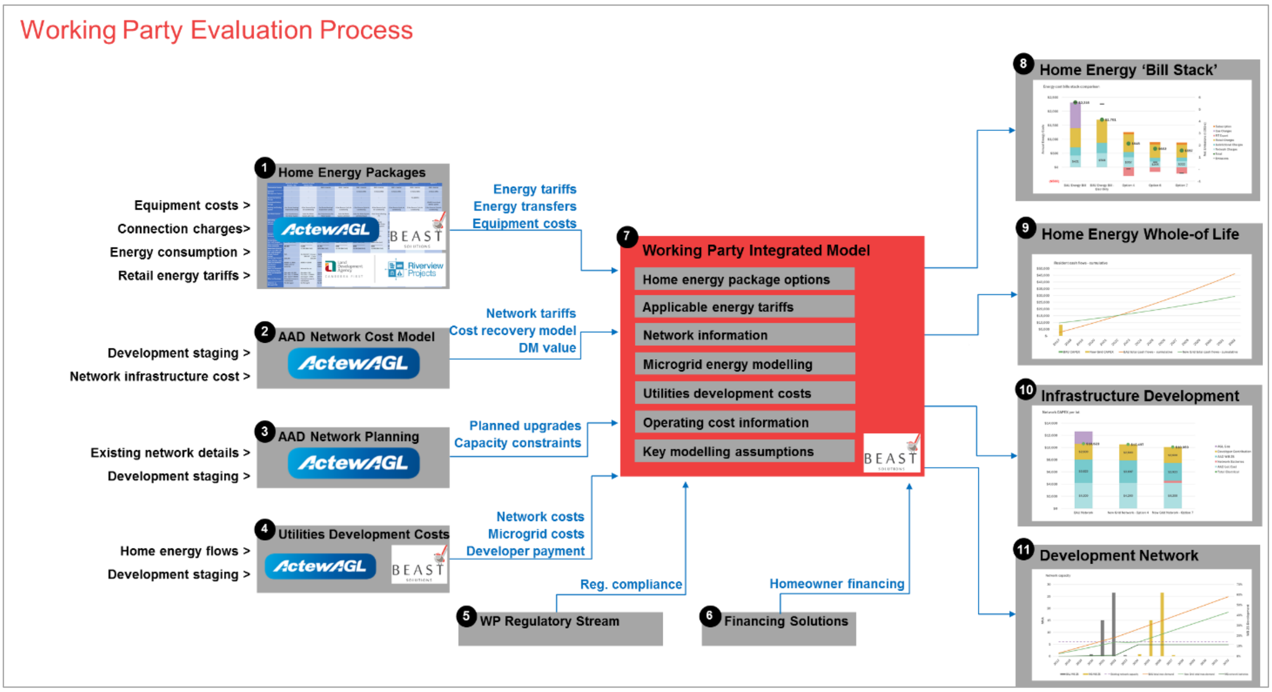


Examples outputs from early-stage energy modelling of concept microgrid scenarios. The outputs show energy purchased and sold to the external network during each hour of the day (vertical axes) and each day of the year (horizontal axes).

Stage 5: The project working party

This stage involved the formation of a project working party comprised of representatives from the ACT Government, Riverview Projects, ActewAGL electricity and gas and ActewAGL Distribution. The working party brought the collective experience of all key stakeholders to bear, allowing the group to refine the home energy options and microgrid concept using insights from prospective home owners, energy benchmarking, equipment pricing, technical advice and inputs for modelling.

With the guidance of the working party, an integrated technical and economic model was developed to assess how each of home energy package options might affect homeowners and utility networks, and examine the potential for the full development of the microgrid in the future.



Blueprint of the working party process, highlighting the numerous contributors, inputs and outputs.

2.5. Results

Developed with the guidance of the working party, the integrated technical and economic model examined several aspects of the energy strategy, including the following key outcomes:

- the effect on homeowner's energy bills and carbon footprint
- the total costs and benefits to homeowners over time
- the effect on the electricity network.

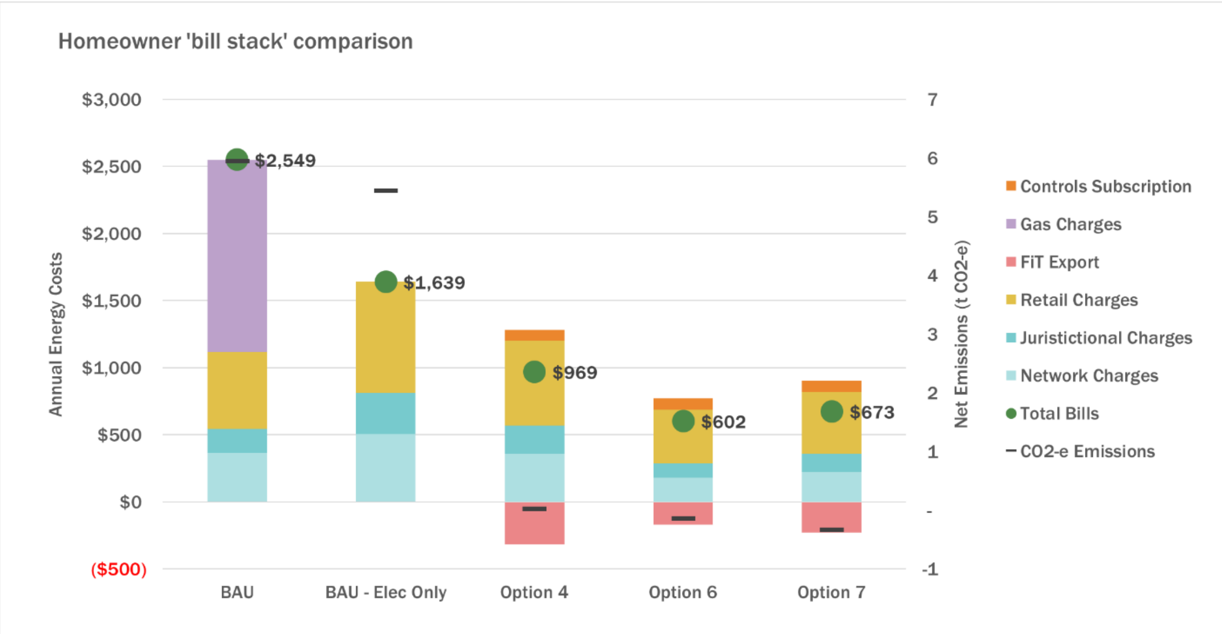
Home energy bills and carbon footprint

The figure below compares an average home's 'bill stack' (the various components that make up a home energy bill) for five of the nine home energy options:

- 'BAU', a business-as-usual home with standard electrical and gas appliances
- 'BAU – Elec Only', an all-electric version of the BAU home with solar hot water
- 'Option 4', an all-electric home with reverse cycle air conditioning, heat pump hot water, PV and a control system
- 'Option 6', similar to option 4 but with an in-home battery system
- 'Option 7', similar to options 4 and 6 but with a large battery system shared between many homes.

All of the electric-only packages are cheaper for the average home than the BAU package that includes gas heating, hot water and cooking. Because natural gas is a relatively low-carbon fuel the CO_2 emissions for the all-electric BAU case are not much less than for the plain BAU case, but emissions reduce drastically when solar PV comes into play in options 4–7, which are carbon neutral or carbon positive.

While option 6 gave in the lowest annual bill, the extra cost of batteries may be beyond the means of many buyers, and would be difficult to mandate or incentivise. The working party was most interested in option 4, which significantly reduces energy bills, maintains flexibility for a future microgrid, and does not rely on batteries.



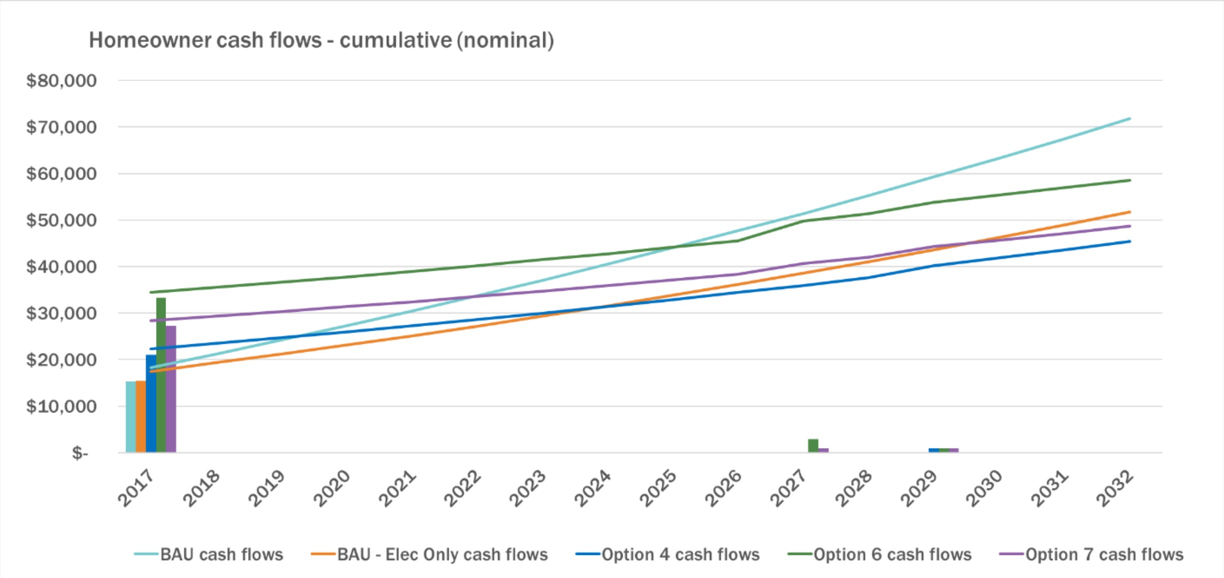
Bill stacks of home for five energy packages showing CO_2-e emissions, total annual bill amount, and all the contributing bill elements.

Homeowner costs and benefits over time

The figure below compares a homeowner's cash flows over 25 years, bringing together the annual energy bills above, up-front purchase costs, replacement costs and maintenance allowances for the five options listed above.

The BAU and electric-only BAU homes naturally require the lower up-front costs, but this advantage is outweighed by high energy bills in the long term. Option 4 requires a greater upfront investment but represents the lowest cost over time.

Options 6 and 7 provided for the lowest energy bills (above), but the increased up-front costs make these options more expensive than option 4 over time; a situation that may change depending on how fast and how far battery prices reduce in the coming years.

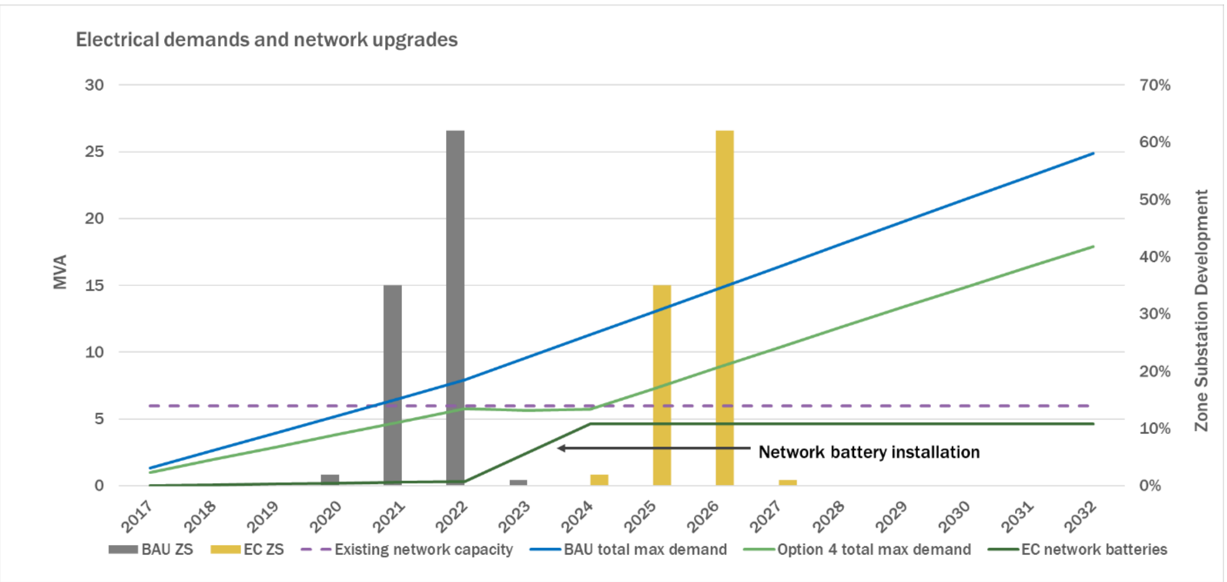


Comparison of an average homeowner's cash flows (positive numbers are costs) for five home energy packages. Capital costs and replacement costs are shown as columns, and cumulative cash flows as lines. Cash flows are not discounted and include allowances for energy price escalation.

Implications for the electricity network

The next figure illustrates the electricity network implications for one many microgrid scenarios. The figure charts the existing network capacity in the area as well as the increasing expected demands of the Ginninderry development as it grows under a BAU scenario or an energy concept ('EC') scenario. Once the growing demands of each scenario exceed the existing network capacity, the need for a new zone substation ('ZC') is triggered, which is developed over four cost stages represented by the columns. Deferring the substation to later years will result in substantial cost savings. The zone substation can be deferred for longer with the use of network batteries.

ActewAGL Distribution assisted the team in understanding how the energy concept might yield cost savings for the network. While the figure shows a single case, many scenarios were considered including all five home energy options above, using alternate shared storage and demand management options, and analysing the potential impact of electric vehicles.



Example of electrical network implications of different home energy options and potential network battery installation. The model explores how the costs of the future zone substation ('ZS') could potentially be reduced through infrastructure deferral.

2.6. The first 300 homes

The learnings from the working party process paved the way for the design of the first 300 homes, representing the first stage of the Ginninderry development and the first step towards a future microgrid.

Ginninderry Stage 1 is comprised of approximately 350 dwellings including approximately 300 homes and 50 multi-unit dwellings. The 300 homes include a mix of types ranging from compact affordable housing types to large detached homes.

The working party considered option 4 the most reasonable option for the first stage. It offers a reduced energy bill and long-term financial benefits at reasonable cost, contains elements that can be easily incentivised or mandated, and is adaptable to a future microgrid.

The adoption of option 4 means that the first the 300 homes will be designed with:

- a minimum home energy efficiency rating (EER) of 6 stars
- 4-star reverse cycle heating and cooling
- electric heat pump hot water systems
- rooftop PV sized according to house type, from 2kW to 5kW
- home energy management systems.

These inclusions will be mandated to support the energy concept and the achievement of important sustainability targets such as Green Star Communities. The home energy control system is an important element, because it will allow for participation in a future microgrid, virtual power plant, or distributed energy exchange (see section 3). Since the performance of option 4 does not depend on batteries, residents may choose whether or not to own one.

The home energy package above does not utilise gas for heating, hot water generation or cooking, so gas connections to these homes will not be required in principle. At the request of Riverview, the ACT Government is currently considering an amendment to the Estate Development Code under the Territory Plan removing the requirement for the mandatory provision of mains gas in new estates. If successful, this would mean substantial savings in infrastructure. The team hopes to include only a gas trunk main to provide future flexibility and gas supply to future stages, particularly for commercial and industrial applications.

To provide the home energy package to Ginninderry residents at a reduced, bulk-purchase cost, a tender process was used to extract competitive rates from providers and installers. The response from suppliers, builders and installers has been very positive and supportive of the home energy concept.

2.7. Lessons learned so far

Some valuable lessons have been learned along the journey to developing the energy concept we see today. These lessons concern almost all aspects of the process, and can be summarised as follows.

The energy concept would not have been possible without the progressive sustainability vision of the Ginninderry development team and their unfaltering commitment to achieve the project sustainability goals, despite many challenges.

The formation of the working party and valuable contributions offered by its participants provided a high degree of robustness to the energy concept and its implementation. The insights offered by the working party were instrumental in bringing together this multifaceted concept and making it a reality.

The technical solutions behind the early energy concepts were built upon and refined with the valuable collaboration of the ActewAGL Distribution team. This collaboration proved to be a valuable part of the development process, and enabled solutions which better integrated with electrical networks and drew out greater benefits for all stakeholders.

The regulatory exploration process identified several requirements and rules to be navigated within the current regulatory environment to fully realise a microgrid. Existing regulations were not initially designed for such next-generation energy concepts, leaving many aspects open to interpretation. This was highlighted by the range of opinions and interpretations among regulatory bodies themselves as well as expert advisors. Ultimately, it was determined that regulatory bodies are still responding to the new phenomenon of next-generation energy concepts such as microgrids, and that the regulatory pathway would likely improve over the coming years.

The precinct-scale analysis showed the importance of greater home numbers and aggregated energy demands on microgrid function and economic benefits. With increasing scale, fixed cost elements reduced proportionately and the ability to provide network stability increased significantly. This contributed to the strategy to develop stage 1 as 'microgrid ready' awaiting lower technology costs and a critical mass of participating homes.

The process involved the evaluation of numerous technology options, and design optimisation for many development and network scenarios. The process highlighted the broad impact that changing technologies, utilities energy prices, regulatory implications etc could have on performance, particularly over the 40-year development timeline. Because of this, the energy concept has been designed with careful attention for flexibility for the future.

3. Roadmap to 1000 homes

3.1. Learning from the first 300 homes

Both the technical modelling and the ARENA-backed community consultation process gave the team the confidence to carry through with the all-electric home energy packages, and to design the first 300-home neighbourhood to be microgrid-ready. The success of the energy strategy is ultimately determined by the Ginninderry community, so the team will draw on the experience of residents to ensure that the next stages respond to their needs as well as the technological, regulatory and economic changes that may happen in the meantime.

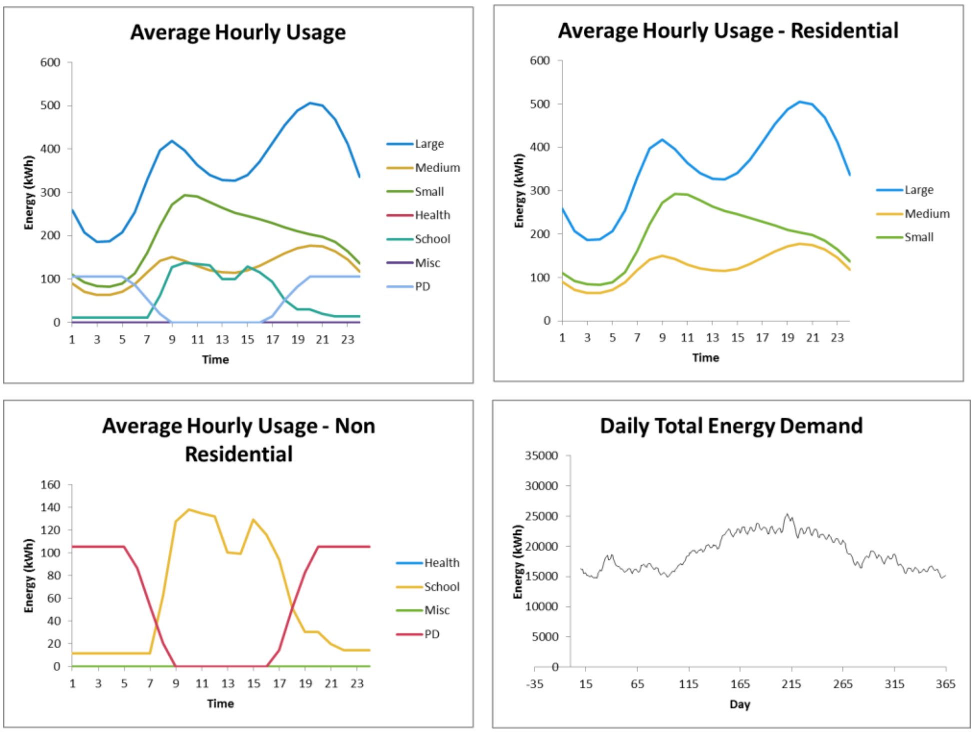
To supplement the subjective experience of the community, the energy management systems, solar inverters and other equipment to be installed in the first neighbourhood are capable of measuring, logging and (with permission) sharing data on energy consumption, solar generation, battery use and so on.

Together, this data will allow the team to calculate the cost-benefit balance for homeowners, and then to tune and predict the equation for the residents, businesses and schools that will be the users of the following stages.

The team also hopes to do more work with researchers and students from Canberra's major tertiary education institutes: the ANU, University of Canberra, and CIT. We foresee several research projects that will help analyse the data from the first 300 homes, and understand the changes that need to happen for the next stage on the journey to a microgrid.

3.2. New elements

The first stage consists of around 300 homes, but the following stages will become more diverse from an energy point of view. It is likely that a school, some retail, light commercial and other new elements will feature in the next stage. While the concept-stage planning allowed for the full mix of development, much detailed work will need to be done to clarify the details of the strategy for these new users.



Early concept planning for the combined energy demand profiles of both residential and non-residential buildings.

3.3. Industry changes

In the last few years, the word "revolution" has often featured in articles and conferences about the energy industry. At the precinct and household scale, this revolution manifests as a rapidly changing suite of products, commercial models and mechanisms for energy management, generation and storage. Planning for the next stages of Ginninderry will need to take all of these into account, against an evolving landscape of increasing renewable content and lower carbon in the ACT electricity grid.

Home energy management

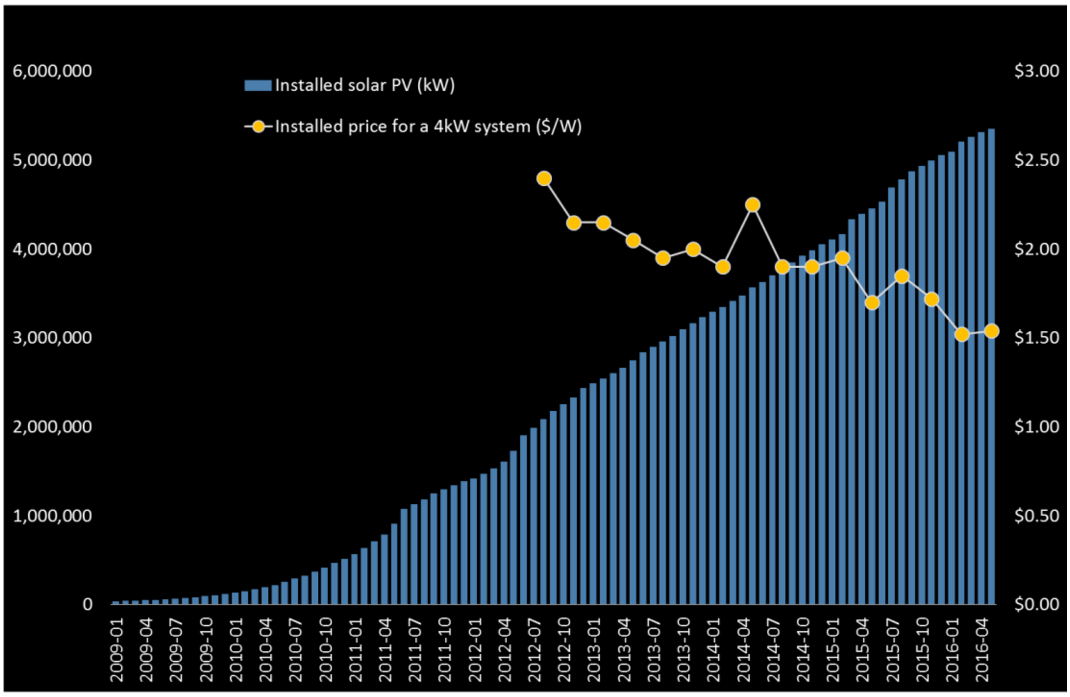
The market for home and precinct energy management systems is growing rapidly, with many products competing for market share. The next few years may see some consolidation as leaders emerge and companies either fall away or are merged into others. A consolidation of product functions is already happening: some high-end solar inverters, for example, now offer many of the features of dedicated home energy management and monitoring systems.

Generation

It is common knowledge that the price of solar PV has fallen significantly and consistently for many years. Competition in the market has also driven a general increase in quality for a given price, and greater incentives for suppliers to cut overheads and add value by packaging solar with energy management systems, maintenance deals and so on. Competition in a crowded market has driven the price for home solar installations very low indeed: the lower limit is now set by labour costs rather than equipment. In the past few years, new, fast mounting and framing systems have also driven labour costs down.

The cost of owning solar will also continue to fall as new products start to carry longer warranties and efficient methods for maintenance arise: both drone-mounted imaging and panel-cleaning robots are already being trialled, for example.

Nobody seems to know where these trends will end, but various opinion pieces predict a further 30% reduction in cost-per-unit-energy by 2020.



The national installed capacity of household solar PV (bars) and price for a 4kW system (dots) up to mid-2016.

Panel cleaning robot, Ecoppia project, Israel

Storage

Right now, the price and cost of ownership for residential-sized batteries means that owning one is mostly a green choice, not a financial one. However, over the past few years the reduction in battery price per unit of stored energy has exceeded even the most optimistic predictions. One of the newest products on the market, the lithium-ion Tesla Powerwall 2, has twice the storage capacity of its previous model for much the same price.

While it is virtually certain that battery prices will come down dramatically in the next few years, the regulatory environment surrounding batteries the most popular battery type is less definite. The Australian standard for battery installations, AS/NZS 5139, is being revised. The current draft includes strict requirements around fire safeguards for some battery types including the most popular, lithium-ion. The requirements would potentially include the need to construct battery enclosures with high fire resistance ratings or active fire control measures. These requirements would significantly increase the cost of installing a home battery. Battery manufacturers are protesting the changes, saying that they amount to a virtual ban on lithium-ion home batteries. If the changes are enacted, financially viable batteries may be delayed until alternative non–flammable technologies such as aqueous-ion batteries can be manufactured more cheaply at scale.

Commercial models

The number of emerging commercial, operating and financing models for energy generation, storage and management is perhaps greater than any other part of the energy industry. We will briefly describe a few models that are particularly relevant to the microgrid concept for Ginninderry.

Virtual net metering (VNM) is an emerging concept in the Australian electricity market. VNM allows a site with excess generation to assign the exported electricity to one or more other sites through reconciling consumption and generation data at each site. The VNM concept allows electricity to be traded across sites that may be geographically separated geographically. These sites may be owned by the same party or involve a third-party generation entities such as a solar farm, or aggregated customer base.

Electricity retailers are well placed to provide VNM services by using their monitoring and administrative capability to reconcile generation and consumption profiles, providing sell-buy pricing between the generator and the consumer, and using existing billing systems to attribute costs and benefits. At least one retailer already offers a VNM service in its local area.

At Ginninderry, VNM could provide many of the commercial benefits of a microgrid and a degree of future-proofing against grid electricity price increases. However, a VNM system would need to be coupled with other measures to have a more than limited benefits for the physical resilience of the system.

The *decentralised energy exchange* (deX) is an open, virtual marketplace that will allow small generation and storage devices to participate in the wider energy market. A pilot project is under development by GreenSync, Reposit Power, Mojo, ActewAGL and United Energy, with funding from ARENA.

The deX is a digital marketplace where owners of rooftop solar PV, batteries and other energy systems can instantly monetise the upstream value of these assets to network utilities. They can buy and sell power on the marketplace, or be paid to reduce their demand on the grid by using battery storage and demand management technologies during peak events.

At Ginninderry, the deX can offer many of the same functions as virtual net metering, with the added ability to trade energy with any other participant rather than a limited number of other customers.

The *virtual power plant* (VPP) is a (typically) cloud-based control centre that coordinates the activities of many distributed energy generation systems, storage systems and controllable demands. In principle, these systems can be of many types, but current VPPs link small household batteries (which are themselves usually linked to rooftop PV systems) into a virtual battery that has sufficient aggregated capacity to benefit from participating in the national electricity market. AGL Energy is currently operating a 1,000-home pilot project in Adelaide, partly funded by ARENA.

A VPP at Ginninderry could aggregate 1,000 homes into a virtual battery with a capacity anywhere from 5MW to 10MW. The equivalent centralised battery system would occupy 10–15 40-foot shipping containers.

Electric vehicles

The design for the first 300 homes included an allowance for electric vehicle (EV) charging. To plan for the first 1,000 homes, however, more emphasis on electric vehicles will be needed.

In 2015, EVs accounted for an insignificant proportion of the vehicle market, at around 0.2% of total sales. A study by AEMO, however, predicts that EVs will account for around 27% of all vehicle sales by 2035–36. In the next ten years, sales growth is likely to be constrained by a limited range of vehicle types and styles on the market, and a lack of public charging infrastructure (especially for fast charging). On the other hand, the ACT is one of the most forward-looking jurisdictions in Australia, and has a strong agenda to reduce Territory-wide greenhouse gas emissions. The growth of EV sales in the ACT may well outstrip growth in other states and territories.

The greatest impact of EVs will be on the electricity infrastructure needed to support peak charging times such as early evening, especially for fast charging. The unpredictability of EV market share between now and 2020 makes EVs difficult to plan for in the short term. Ultimately, however, the homes built at Ginninderry in the next few years will still be there in 2050, and the project's mandate to plan for technology evolution means that EV charging will be a focus of our future efforts. Of particular interest is the possibility of using EVs as mobile batteries, able to both supplement the storage capacity of the precinct and to provide energy to support the grid at critical times.

Regulatory landscape

In the ACT, the progress towards a 100% renewable grid is likely to put greater pressure on existing infrastructure, and create greater incentives for utilities, Government, developers and others to come to grips with a high proportion of renewables, large-scale batteries, EVs, demand management, and new commercial models.

It is a common complaint in parts of the energy industry that national regulations (administered by the AER, AEMO and AEMC) have failed to adapt to the many new possibilities for energy management, trading, generation and storage. However, the Council of Australian Governments (COAG) has recognised that the existing regulatory landscape is unsuited to support innovation and growth in emerging energy sectors, particularly microgrids, and has recently canvassed stakeholder input on a proposal for a national fit-for-purpose microgrid regulatory framework. The Ginninderry working party developed a submission to this process, focussed on grid-connected microgrids such as the one envisioned for Ginninderry.

3.4. The way forward

The experience of the first 300 homes helped the team to understand the process of creating a precinct-scale energy solution that has never been done before. In future planning, the team will focus on the crucial importance of:

- consulting early, often and deeply with electrical and gas network providers
- drawing together the many multidisciplinary aspects of a microgrid with wide but targeted consultation with industry, government, regulators and consultants
- recognising and allowing for the uncertainty associated with nearly every element of modelling
- recognising and allowing for change by designing flexible systems
- drawing out win-win solutions by tightly coupling financial, technical and practical considerations.

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