PAGE 17

The big switch (off)

Does South Australia's remote solar curtailment scenario await rooftop panel owners nationwide?

PAGE 25

Renters and sustainability

How Covid provides an opportunity—and an obligation—to get rentals up to scratch

WIN

PAGE 75

A home energy super saver prize from Pure Electric worth up to $10,000!

Australian residents only

ISSUE 153

renew.

Technology for a sustainable future

Modular synthesis: all about prefab

OCT - DEC 2020

9 771327 193010 04

ISSN 1327-1628

AU/NZ $9.90

RENEW.ORG.AU

return in light

Image: Neil Barrett

In 2016, eco-housing development The Paddock asked for Renew's help in designing its energy management approach. It was the first opportunity we'd had to test our Sunulator model—and the philosophy that informed its design—in a real-world setting.

The proof was always going to be in the pudding. Now, four years later, the first results are in... and as Damien Moyse explains, we're delighted to find that the pudding tastes very good indeed!

Readers of *Renew* may be familiar with an eco-housing development that we have showcased a few times over recent years: The Paddock, a 1.4 ha site in the central Victorian goldfields town of Castlemaine.

Back in 2016, when the project was in its early stages, the developers asked the energy team at Renew (or, as we were then, the ATA) to advise on the best energy management approaches for the 27-home development. We were delighted to take the opportunity to test our ideas in a real-world situation, and agreed to take up the challenge.

The first seven homes were completed late last year, which means they have been occupied for nearly 12 months. The developers recently supplied Renew with electricity bills and smart meter data from November 2019 onwards (approximately eight months including summer, autumn and the start of winter). In other words, we were presented with data that would allow us to see how successful our energy management strategies had been.

So here's the good news: those strategies have proven very successful indeed! In fact, the houses have performed better than we predicted: they are consuming between 25% and 40% less electricity than predicted, and use around 80% less input energy than typical, new Victorian homes built in 2020.

This is obviously an extremely gratifying result, and we're delighted to share it with the world. It also gives other prospective homebuilders a deep insight into how to construct an energy efficient home—so in this article, we'll do a deep dive into the data, and explain what it reveals.

Taking up the challenge

From the outset of the project, The Paddock's developers (Heather and Neil Barrett) and the project architect (Geoff Crosby) have been committed to working within the framework of the Living Building Challenge (LBC) through planning, design and development. The LBC is a rigorous global standard with a holistic approach to sustainability, and "calls for the creation of building projects at all scales that operate as cleanly, beautifully and efficiently as nature's architecture." To be certified under the Challenge, projects "must meet a series of ambitious performance requirements over a minimum of 12 months of continuous occupancy."

This was the first opportunity that we had been given to test our emerging philosophy on all-electric homes on a real-world project. The key components of that philosophy were:

- High thermal performance of the building shell (in the 7.5 to 8.5 Star range);
- All-electric appliances (no gas or wood);
- Ensuring high efficiency for major appliances such as hot water and heating/cooling systems; and
- On-site generation of renewable electricity.

Renew's all-electric philosophy also had to be combined with the specific energy requirements of the LBC. These dictated that 105% of the project's energy needs had to be supplied by on-site renewable energy on a net annual basis, without the use of on-site combustion (i.e. no gas or wood).

In addition to this, projects also had to provide on-site energy storage for resiliency, demonstrating that enough backup battery power was installed to cover:

- Emergency lighting (at least 10% of lighting load); and
- Refrigeration use for up to one week.

In order to demonstrate that the project could meet these requirements, Renew needed to:

- Construct a plausible load profile for each dwelling—considering all appliance energy use and differing dwelling sizes—on an annual basis, while taking into account daily and seasonal variability (e.g. peak winter heating and hot water);
- Simulate solar generation for different system sizes against those household load profiles, in order to understand the minimum solar system sizes required to achieve the 105% benchmark; and
- Construct separate lighting and refrigeration loads in order to understand the required level of storage for each dwelling.

Load analysis

Using an early version of the Sunulator—our solar simulation model—Renew built an annual electrical load profile broken down into 30-minute intervals. This profile divided the dwellings into four types, based on their size, and modelled energy usage for each.

As is well known, most residential loads are composed mainly of the power used by space heating/cooling and hot water appliances (in the order of 50% to 75% in total for most homes). In the case of The Paddock, given the site's central Victorian location, heating and hot water were the two most important considerations. As such, we chose to analyse the most efficient heat pump air conditioners and heat pump hot water systems.

At the time of Renew's work, the project architect already had preliminary designs for the dwellings, with an intention to achieve building energy ratings of around 8.5 Stars. As such, Renew used the megajoule per square metre (MJ/m²) benchmark from the

	Dwelling A	Dwelling B	Dwelling C	Dwelling D
Dwelling size	70	90	105	120
Space heating	436	561	655	748
Space cooling	77	99	116	132
Hot water	1663	1663	1786	1786
Lighting	164	201	237	274
Cooktop	200	200	200	200
Oven	200	200	200	200
Fridge	350	350	350	350
Washing machine	350	350	350	350
Dishwasher	300	300	300	300
Dryer	100	100	191	191
TV(s)/monitors	300	375	425	500
Other devices	400	400	400	400
Total annual load	4541	4799	5209	5431
Average daily load	12.44	13.15	14.27	14.88
105% of annual load (for LBC)	4768	5039	5470	5703

Table 1: Projected annual energy use by dwelling type, The Paddock (kWh)

The Paddock's eco-developer Neil Barrett gives us his perspective on the project, and on Renew's role in its conception and planning.

Neil Barrett with his wife—and fellow eco-developer—Heather.

Image: Courtesy of Neil Barrett

I've been involved in energy and environmental issues for 30 or 40 years, so I've known people at Renew forever. [This article's author] Damien [Moyse] was living in Castlemaine at the time when we started [The Paddock], so it was all very convenient [to get Renew involved].

We've been very satisfied with the houses' performance. The energy use is about 70% what Damien predicted: 10 kWh per household per day, compared with Damien's prediction of 14 kWh. We've got two- and four-bedroom houses, so the average is probably a bit less than three bedrooms. They are not big houses but Damien estimated that they could use, I think, around 13/14/15 kWh a day and it's down to nine. Almost a third of that comes from the solar so we are not importing much at all from the grid—but we are exporting a lot!

Damien's work gave us a clear idea of where we were heading with energy use at the time, and the whole project would have worked fine if energy use [had matched] those predictions. But as it turns out, the residents have done actually a lot better than Renew predicted they might!

We live right next door and we have a lot of contact with the residents because the place is still being constructed—we've only done seven houses out of 26 so far—and all the tenants have been pleased with the low energy use. They haven't had to turn the heating on nearly as much during winter as they thought they would have to. Just one example: in one of the four-bedroom houses, we have a young couple with a baby, [and they] only felt they needed to turn the air conditioning on for 30 minutes in the whole of summer. They were here from late November through all of summer, and they used 30 minutes of aircon!

We've been greatly impressed with the people who have come here. The relationships are wonderful. It might be tempting for a developer to say that as a marketing exercise, but it's true! People love living here. We've got a quote from one of the tenants on our website, talking about how lovely it is waking up in the morning with nature being so close.

That was one of the factors we had to take into account when we decided to do the Living Building Challenge—that nature has to be easily accessible. Tenants can see trees from their houses. They can go outside and lovely natural features are all around them. Overall, people are very happy living here.

Is there anything we'd change next time? Yeah, we're building stage two now, and definitely incorporating lessons learned from stage one. For example, we probably underestimated the amount of storage that people would want, even though there's a fair amount. We've decided to make the ceilings available [for storage], and they are pretty high—there is a good space between ceiling and roof, and a lot of that is available with a ladder going up and so people can use that. We are also putting the rather unattractive tanks for the hot water service into the front garden, on the south side of the houses, behind a nice screen. We're going to increase the size of the carports, which are about 10 m away from the houses, so there's no problem at all fitting batteries into them—that's probably the best place for batteries, rather than being attached to the house in some way.

> *People say to us, "Can this really be done? Such high-quality houses with an average 8.1 rating—can you do it within a reasonable budget?" And now we can say, "Yes. It can."*

I think ultimately, what we've learned is that it can be done. I mean, people say to us, "Can this really be done? Such high-quality houses with an average 8.1 rating—can you do it within a reasonable budget?" And we now can say, "Yes, it can." We will be increasingly trying to get local developers to come to have a look and sit down and have a chat to us about it.

Our building costs have been a bit higher than we'd hoped, and we had to put our prices up accordingly, but we still managed to do what we set out to do. The main thing for us as developers is that we get a lot of kudos from the people living here. It's great to provide houses for people who love living in them.

As told to Mardi DuPlessis

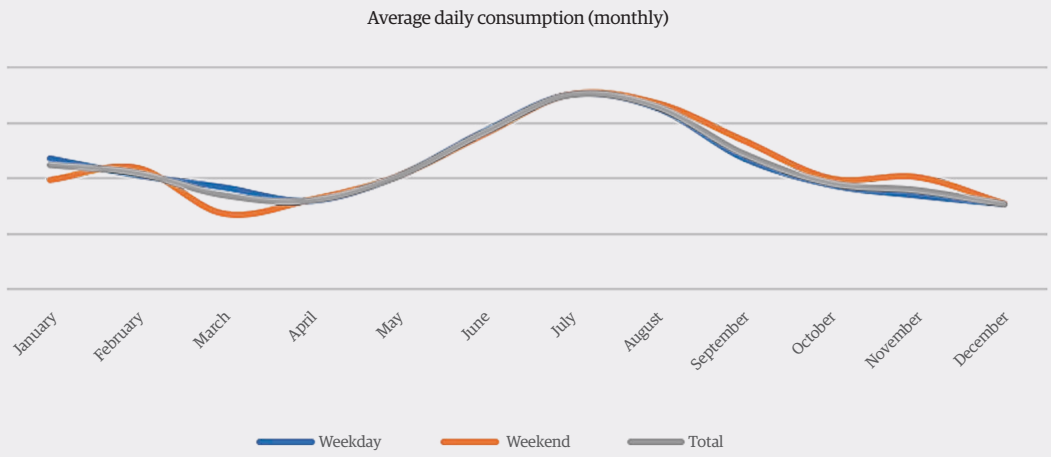

Chart 1: Average daily load (kWh) by month, small home, The Paddock.

Nationwide House Energy Rating Scheme (NatHERS) for the closest climate zone (Ballarat). Ultimately the final building designs would average 8.2 Stars.

Lighting (LED) and remaining household appliances were also selected and modelled individually, drawing upon performance data from the national Equipment Energy Efficiency (E^3) program.

Table 1 (on the previous page) summarises the projected annual loads for each category of dwelling. It shows that:

- Total annual loads ranged between about 4500 kWh and 5500 kWh per year;
- Average daily loads ranged between 12.4 and 14.9 kWh per day (this is the pure electricity consumption, before any on-site solar generation is used to supply some of this load); and
- To meet the 105% LBC requirement, between about 4800 kWh and 5700 kWh per year was needed per dwelling.

The load profile was designed to be winter peaking, given the larger heating loads in the Castlemaine region, and also assumed that the heat pump hot water system was timed to operate during the day, to take advantage of on-site solar generation.

Average daily electricity consumption by month is presented in Chart 1. As can be seen, the three winter months had the highest average daily loads:

The average daily load profile by month was also calculated and is presented in Chart 2. The impact of the winter heat pump operation timed between (approximately) 10am and 2pm can be seen clearly.

	3 kW	4 kW	6 kW
Annual generation (kWh)	4354	5804	8705
Self-consumption of solar energy (kWh)	45%	37%	27%
Export to grid (kWh)	55%	63%	73%
Annual bill saving (year one, $)	514	628	834
System cost ($)	5500	7500	10,500
Simple payback (years)	11	12	17

Table 2: Solar PV generation simulations, The Paddock

	For 20 dwellings	For 30 dwellings
Refrigeration storage capacity (weekly, kWh)	140	210
Indoor lighting storage capacity (weekly, kWh)	8.4	12.6
Outdoor/CA lighting storage capacity (weekly, kWh)	7.0	7.0
Total storage capacity required (kWh)	175	260
Storage capacity required per dwelling (kWh)	9.0	9.0

Table 3: Indicative LBC storage capacity requirement, The Paddock

Solar generation analysis

Our Sunulator was also used to simulate the solar generation for each dwelling, to ensure compliance with the LBC requirement.

The key factor in Sunulator's accuracy is the integration of location-specific solar insolation data within the model. The closest location for which Renew had BoM data was Bendigo (less than 40 km away from the site).

Renew modeled three PV system sizes (3 kW, 4 kW and 6 kW) as part of the solar-only simulations. The results are set out in Table 2. As per the load analysis in Table 1, the 105% requirement for the various dwelling types (A, B, C and D) were 4768, 5039, 5470 and 5703 kWh, respectively.

As such, the key takeaways from the modeling were that:

- The 3 kW system is too small to meet the LBC requirement for all dwellings;
- The 4 kW system easily meets the requirements for Dwellings A, B and C, and also narrowly meets the requirement for Dwelling D.

Given the variability of actual loads that would eventuate once the site was developed, Renew recommended a minimum 4 kW of solar PV per dwelling. The developers followed this recommendation.

Storage

The LBC requirement for storage included a requirement that the project demonstrate sufficient backup battery power to cover:

- Emergency lighting (at least 10% of lighting load); and
- Refrigeration use for up to one week.

To inform the design of the storage system, Renew modelled a level of refrigeration and indoor lighting loads for one week, along with an additional 10 kWh per day for outdoor and common area lighting across the site.

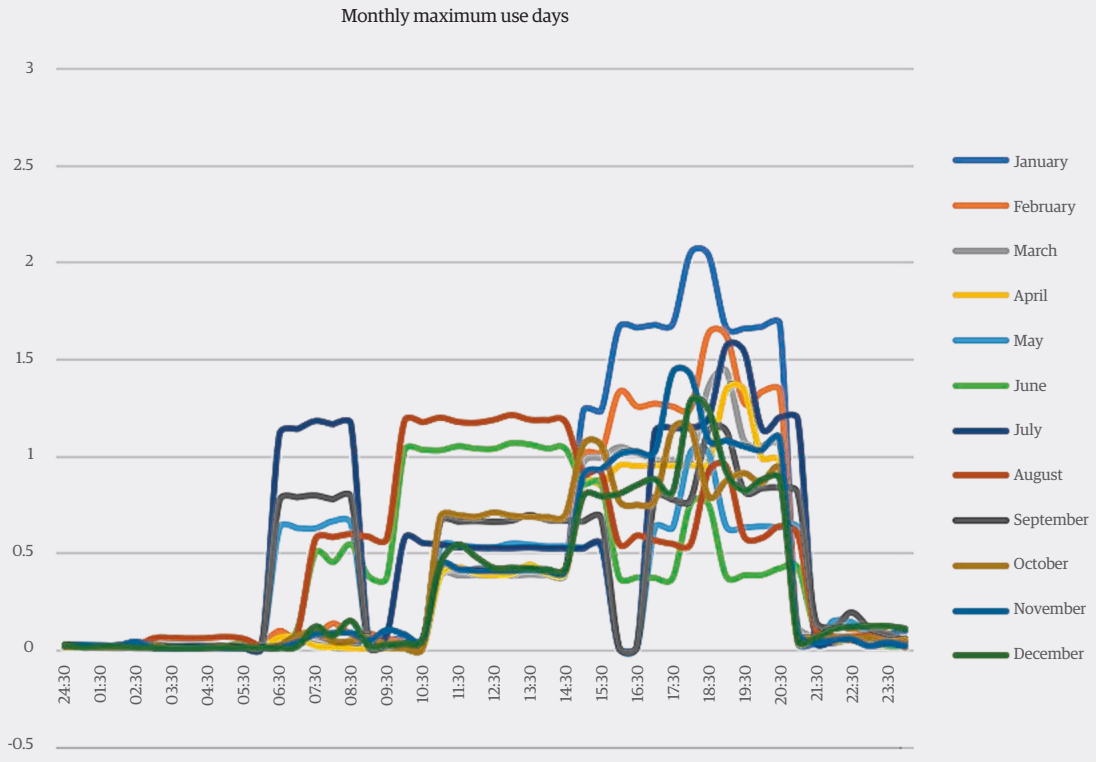

Chart 2: Average daily load profile (kW) by month, small home, The Paddock.

The results gave the weekly storage capacity requirements across the site, and per dwelling, set out in Table 3.

The required 9 kWh of individual storage per dwelling is significant (and in 2016, was very costly) in the context of what will be ultimately a grid-connected site.

The site was developed as an embedded network (or micro-grid), with one point of connection to the local distribution network—a consequence of the fact that the site was community-titled. However, the electrical engineering costs to develop the micro-grid to accommodate more cost effective centralised energy storage (as opposed to separate, per-dwelling batteries) were too high. (Some were three times the price). Mandating batteries for all residents was decided to be imposing too high a cost.

As such, Renew recommended monitoring developments in the market regarding storage and micro-grids. In the future, Renew believes there is likely to be a strong economic case for maximising the value of shared solar and storage across all tenants within small to medium sized eco-developments.

Actual dwelling performance

The first seven homes have been occupied since late 2019. *Renew* was supplied with electricity bills and smart meter data from November 2019 onwards (approximately eight months including summer, autumn and the start of winter).

So how have the houses performed? The data is set out in Table 4, and as we can say, they've performed very well indeed:

- The seven homes have a total average daily consumption of 7.6 kWh per day, for the eight-month period;
- Adjusted to include two higher winter months (July and August), Renew estimates their total average daily consumption would be approximately 9.0 kWh per day, for a full 12-month period;
- This compares to Renew's 2016 prediction of between 12 and 15 kWh per day—meaning The Paddock homes are consuming between 25% and 40% less electricity than predicted!

	Value
Imports from grid	5.7
Exports to grid	14.1
Electricity consumption (actual)	7.6
Electricity consumption (actual, adjusted for 12 months)	9.0
Electricity consumption (Renew prediction, 2016)	12.0 - 15.0

Table 4: Average energy per dwelling, The Paddock, kWh/day (Nov 2019 to Jun 2020)

The performance of The Paddock's dwellings can be compared to typical, new homes built in Victoria. Typically, these:

- Are no better than 6 Star energy rating (and sometimes worse);
- Are "dual fuel" (i.e. have mains gas and mains electricity connected);
- Use gas for heating, hot water and cooking; and
- Consume approximately 12 kWh per day of electricity and another 100 MJ per day of mains gas.

By comparison, The Paddock dwellings use around 80% less input energy than typical, new Victorian homes built in 2020. This is an amazing result and one that both vindicated Renew's original advice and actually exceeded expectations!

AUTHOR:
Damien Moyse
Damien is Renew's Policy & Research Manager and responsible for Renew's advocacy, policy development and advice services and consulting projects.