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Community electricity and storage central management for multi-dwelling developments: an analysis of operating options

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ABSTRACT

A combination of PV, storage and energy management in multi-dwelling developments can be very effective in utilising load diversity and reducing grid dependence. Sharing PV and electricity storage resources within a community renewable energy network (CREN) via an energy management system (EMS) shifts the peak individual loads to times that the grid considers off-peak periods – i.e. night time – so managed off-peak charging and a retail plan with the lowest off-peak pricing affords the community savings in the order of 95.5% compared to the traditional individual grid connection. The balancing performed by the EMS eliminates the paradox of concomitant demand and supply from/to grid that occurs when some of the individual systems in the community have available charge while others do not. The optimisation of off-peak charging avoids 54% of redundant charge which is a financial gain in jurisdictions where feed-in tariffs are much lower than supply charges. Even though this study focuses on an Australian case study it provides a tool that allows the performance of the same analysis for other specific sites and load profiles.

Keywords:

Community energy management;
Community solar PV;
Community battery storage;
Energy management system;

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1. Introduction

The rapid decline in the cost of solar photovoltaic (PV) panels in the last 5 years [1] has created great interest in local power generation and consumption, particularly for households with access to rooftops.

Australia is considered to have the highest installed rooftop PV per capita in the world [2] with more than 16% of homes nationally having a PV system, and up to 30% of homes in some states such as Queensland and South Australia [3].

Numerous studies have been published on the analysis and optimisation of residential PV, particularly on the economics and the effects of consumption tariffs, minimising export and reverse power flow [4] and the influence of load profiles [5—10].

More recently, the availability of battery storage systems provides additional flexibility for such households to better utilise their local generation, through using battery capacity to store excess PV output for use at night, or during peak tariff periods. The combination of local generation and battery storage improves self-consumption [11, 12], and provides the possibility for grid-independence or grid disconnection. However, the economic basis for such action is questionable in many cases, being dependent on PV size/output [13], tariff structures [14] (including feed-in tariffs [15]), load profiles [16], jurisdiction [17], and battery storage costs [13].

It has also been shown that home energy storage may not automatically reduce emissions or energy consumption unless it directly enables renewable energy [18]. Adding to this, is the consideration that broader views, e.g.

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Scenarios nomenclature:

Communal storage	community battery in common space shared through the EMS
Default	aggregated value of all individual consumption before any RE systems
EMS	state of charge and grid dependence of the CREN sharing through EMS
EMS Export	excess generation exported to grid after sharing through EMS
Indiv.Charge	aggregated value of the charge available in the batteries of individual systems
Indiv. Export	aggregated value of the individual excess generation going to the grid
Indiv.Grid.Depend.	aggregated value of the individual loads not served by the CREN
Indiv.Syst.	isolated individual PV + storage systems
EMS-OPCC	continuous (every night) off-peak charging of CREN storage managed by EMS
EMS-OPCM	managed (selective) off-peak charging of CREN storage managed by EMS
EMS-T	generation and storage resources shared by the CREN through the EMS

Abbreviations

BOM	Bureau of Meteorology (Australia)
CREN	community renewable energy network
DR	demand response
DSM	demand side management
EMS	energy management system
IRR	internal rate of return
NPV	net present value
OPC	off-peak charging
OPCC	off-peak charging continuous
OPCM	off-peak charging managed
PV	Photovoltaic
RE	renewable energy

district level [19, 20], might also influence in a positive way the performance of the community systems.

As for PV, the cost of battery energy storage is expected to significantly decrease with installed capacity with a trajectory towards US$340 ±US$60 per kWh once 1 TWh of capacity is installed [21].

While many studies have focussed on individual households [4, 6, 9, 11, 12, 14, 17, 22–27] and some studies on utility owned or controlled community storage [22, 28–30], the analysis of the interplay between local generation and storage in multi-dwelling developments is less common. AlSkaif et al. [31] used a reputation based centralised energy management system to study the fair allocation of storage resource to participants. Luthander et al. [32] found that the economics of shared storage are slightly better than for individual storage. Parra et al. [33] undertook an interdisciplinary review of energy storage for communities showing that community storage – including thermal energy storage – can provide more efficient resource usage, and that citizen participation helps to increase awareness of energy consumption and environmental impacts. Van der Stelt et al. [24] took on a techno-economic analysis of household and community energy storage and showed an annual cost reduction of 22–30% could be achieved. Riesen et al. [23] developed a control algorithm that does not require forecast of PV output for optimisation of residential PV with storage systems, and also showed that aggregation of household storages into a single unit improves curtailment losses compared to the individual case.

In our previous studies, we introduced the concept of a Community Renewable Energy Network (CREN) in which households and businesses in a local community share energy resources [34, 35]. We looked at six basic scenarios, from the default grid connection – i.e. no local generation or storage – with individual PV and grid connection, through the case where a community energy management system operates all individual and communal PV and storage systems with all dwellings accessing the grid through a single connection point. This study did not consider systems costs, but was focussed on understanding the effects of local generation, consumption and storage in different individual and collective configurations, such as environmental impact and energy autonomy [35]. In this work, we use real-world data in a number of scenarios to understand the benefits and costs of individual versus communal optimisation of electricity consumption, storage and generation in the Australia context. The use of real-world data has been shown to be highly desirable to avoid over-estimation of self-consumption and economic benefit [16].

The rest of this paper is organised in four parts. Section 1 describes the scenarios, assumptions and formulations used in this modelling extension of our previous work [35]. Section 2 explains the data used, while Section 3 presents a discussion of the results, and Section 4 provides some concluding remarks. It is to be noted that this paper focusses primarily on the reduction in the community's grid dependence that results from the vertical and horizontal sharing of generation and storage resources. Options for financing, ownership and governance of CREN are considered in the next paper in the series.

Model

For a comprehensive explanation of the base model on which this work extension is grounded, please refer to our previous work in this journal [35]. The intention of this stage of the model is to understand the effects of both vertical and horizontal sharing of local generation and storage community assets. It considers the consumption, PV electricity generation, off-peak charging, storage capacity and state of charge of each individual dwelling, as well as the storage capacity and state of charge of a communal battery available to each dwelling in the community through a centralised EMS.

1.1. Scenarios

The model reflects five scenarios to study the effects of horizontal and vertical sharing of generation and storage assets:

- Default – all dwellings connected individually to the grid with no generation or storage
- Individual Systems – all dwellings having PV generation + storage systems, each dwelling connected individually to the grid
- Community managed by central EMS – all dwellings sharing PV generation and storage assets horizontally through a central EMS
- Community and communal battery managed by EMS – all dwellings sharing PV generation and storage assets horizontally as well as sharing vertically a communal battery managed by the central EMS
- Community and off-peak charging managed by central EMS:
  - continuous off-peak charging – the central EMS manages distribution of available off-peak charge to the community assets for every day of the year
  - managed off-peak charging – the central EMS restricts off-peak charge to winter months and BOM forecast extreme weather events like heatwaves and cold snaps

The Default and Individual Systems scenarios provide the base for performance comparison for the community scenarios – shown in Fig. 1 – modelled in detail in this stage of the study.

1.2. Assumptions

As depicted in Figure 2, the availability of communal resources is not limited to charge and discharge transactional events occurring through the communal battery, the sharing – managed both horizontally and vertically by the EMS – also accounts for energy

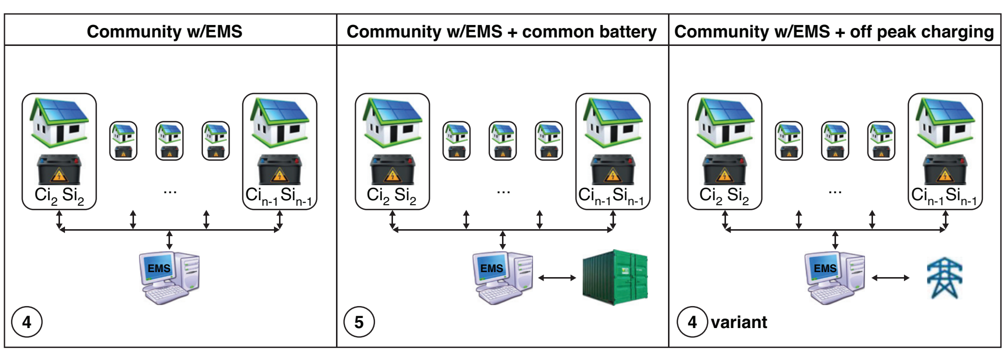

Figure 1: Scenarios modelled in detail: Community managed by central EMS, Community and communal battery managed by EMS, and Community and off-peak charging managed by central EMS. These scenarios correspond to scenarios 4, 5 in the previous paper. The last one is a variant of previous scenario 4

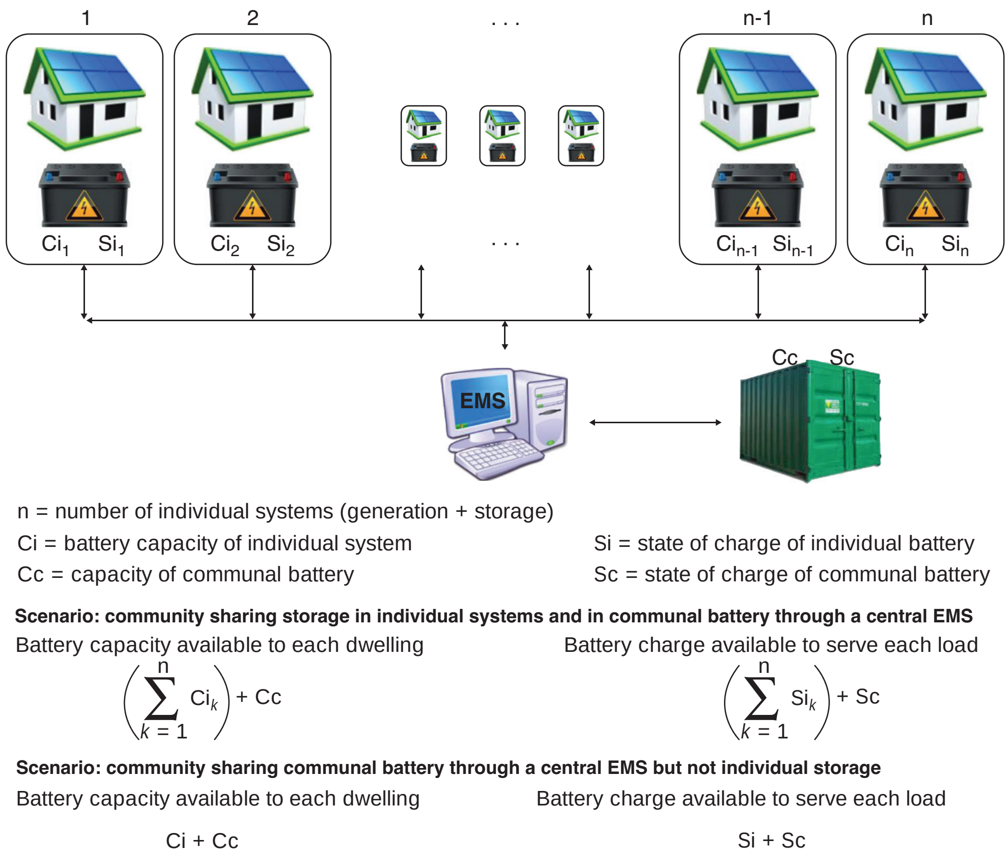

Figure 2: Sharing arrangements of storage capacity and charge

Table 1: Generation and storage capacities of individual dwellings and of the community

Individual resources		Shared community resources			
Power (kW)	**Sto/gen ratio**	**No. of dwellings**	**Power (kWh)**	**Battery (kWh)**	**Communal battery (kW)**
5.4	2.2	51	275	612	
5.9	2.6	10	59	150	500
6.4	2.8	12	77	216	
6.9	2.6	8	55	144	
Totals:		81	466	1122	500

transactions between the individual generation and storage elements of the community.

The model assumes each dwelling to have an individual PV + storage system with generation capacities ranging from 5.4 kW to 6.9 kW – depending on specific dwelling typology – and a storage to generation ratio of between 2.2 to 2.8 – depending on each system's generation capacity – which results in an overall community generation and storage capacity of 466 kW and 1122 kWh respectively, as set out in Table 1.

In the modelling, the EMS incurs no losses itself and manages:

- the sum of:
  - all individual excess generation after individual dwelling load is served and individual battery is charged
  - all individual states of battery charge after individual dwelling load is served
- community centralised battery
- off-peak charging from grid of community batteries – individual and communal
- import and export of energy from/to the grid

1.2.1. Service of individual dwelling loads

As shown in Figure 3, the model assumes that the load of each individual dwelling can be served at five different points by different elements in the overall

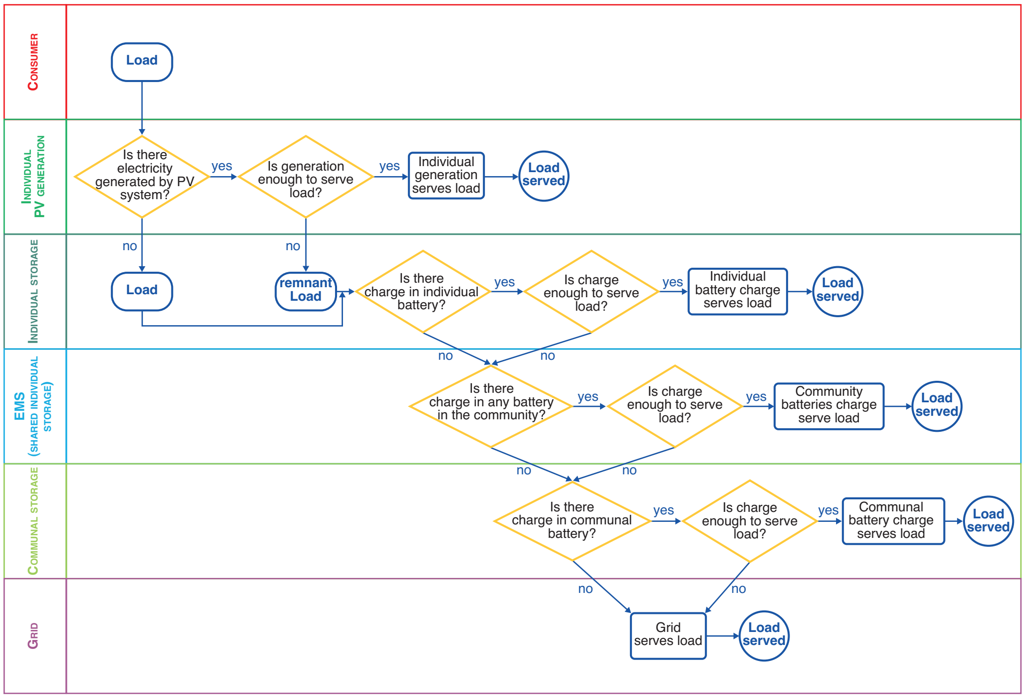

Figure 3: Flowchart summarising how the model uses the different elements of the electrical energy system to service the load of any individual dwelling

community system. The load in any given dwelling is served according to the following process rules:

1. if the individual PV system is generating electricity
   - the load is served by that generation
2. if the individual PV system is generating electricity, but not sufficient to serve the load
   - the unserved load resorts to the battery charge of the individual energy system
3. if there is charge in the battery of the individual energy system
   - the load is served from the charge in that battery
4. if there is no charge in the battery of the individual system, or the charge is not sufficient to serve the load
   - the unserved load resorts to the EMS to access the excess generation from other dwellings
5. if there is sufficient excess generation from the systems of other dwellings
   - the EMS serves the load from that excess generation
6. if there is not excess generation from the systems of other dwellings, or the excess generation is not sufficient to serve the load
   - the EMS resorts to the charge in the batteries in the systems of other dwellings
7. if there is sufficient charge in the batteries in the systems of other dwellings
   - the EMS serves the load with the charge from the batteries in the systems of other dwellings
8. if there is no charge in the batteries in the systems in other dwellings, or the charge is not sufficient to serve the load
   - the EMS resorts to the charge in the community centralised battery
9. if there is sufficient charge in the community centralised battery
   - the load is served from the charge in the community centralised battery
10. if there is not charge in the community centralised battery, or the charge is not sufficient to serve the load
    - the unserved load is served by the grid

1.2.2. Off-peak charging of batteries

Because retailers offer up to 66% discount for electricity consumption during the overnight periods of low demand, the model also assumes – as shown in Figure 4 – that the EMS manages overnight off-peak charging and that the

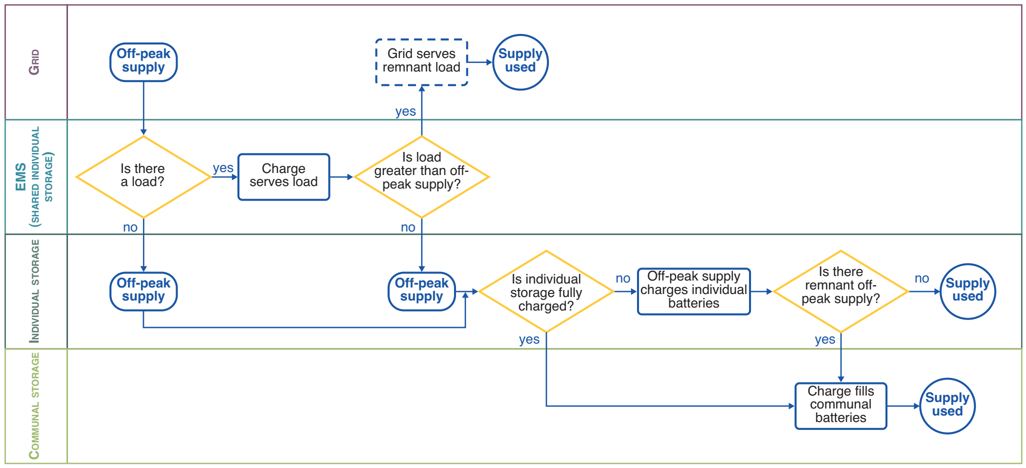

Figure 4: Flowchart summarising how the model allocates the overnight off-peak supply to either serve a load or charge the different storage assets in the electrical energy system of the CREN

controlled off-peak charge from the grid can be used at three different points by different elements in the overall community system. This off-peak charge is used by the community according to the following process rules:

1. if there is a load registered by the EMS from any individual dwelling,
   - the off-peak serves the load
2. if there is no load or the off-peak supply is greater than the load
   - the full off-peak supply or part thereof – after serving load – charges the individual batteries
   - the off-peak supply is distributed equally amongst all batteries for as long as there are individual batteries that are not completely charged
3. if all the individual batteries are all fully charged
   - the off-peak supply charges the communal battery

The model also assumes:

- the EMS can be programmed to access and distribute off-peak charging:
  – when extreme weather events – heatwaves and cold snaps – are forecast
  – when the community batteries do not reach full charge at any point in time during a period of two consecutive days
  – during the winter period
- off-peak charging can be limited to a specific maximum amount by the EMS

1.2.3. Export of excess generation to grid

As shown in Figure 5, the model assumes that the energy supplied by the PV system of each individual dwelling can be used at four different points by different elements in the overall community system before being exported to the grid. The energy supplied by the PV system of any given dwelling is used according to the following process rules:

1. when any individual PV system is generating electricity
   - that energy is used to serve the load of that particular dwelling
2. if the individual PV system is generating more electricity than is required to serve the load of that dwelling
   - the excess energy is used to charge the individual storage of that dwelling
3. if the individual storage of the energy system of that particular dwelling is fully charged or the available supply exceeds the charge required
   - the excess energy is used by the EMS to serve the loads of the other individual systems in the community
   - the excess energy is distributed equally to serve the loads for as long as there are individual loads requiring servicing
4. if the excess energy available to the EMS from the community of individual systems exceeds the requirement of the community loads
   - the excess energy is used by the EMS to charge the individual batteries of the community
   - the excess energy is distributed equally amongst all batteries for as long as there are individual batteries that are not completely charged

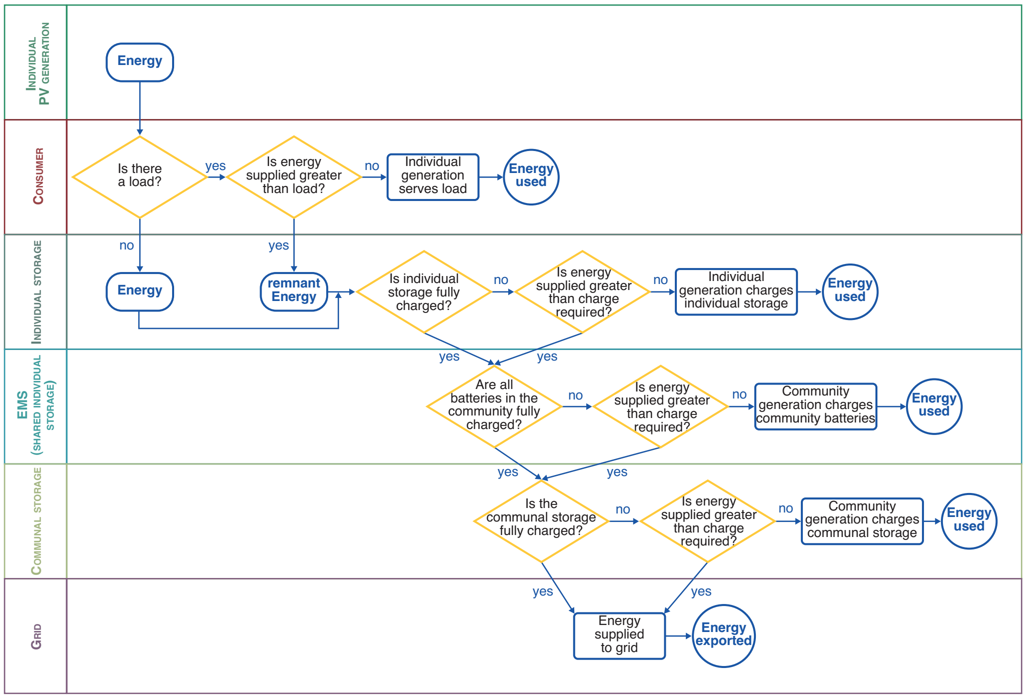

Figure 5: Flowchart summarising how the model allocates the energy supplied by individual PV systems to the different elements of the electrical energy system

5. if the individual batteries are fully charged or the available energy surplus exceeds the charge required
   - the EMS uses the excess energy to charge the communal storage
6. if the communal storage is fully charged or the available energy surplus exceeds the charge required
   - the EMS exports the excess energy to the grid

2. Data

As explained in detail in our previous work [35], solar irradiation data for the SAM simulations was obtained from the International Weather for Energy Calculations (IWEC) for Melbourne airport, Victoria, Australia - 37.67°N and 144.83°E. The input data for modelling the grid dependence of the various scenarios was sourced from a local retailer and includes real-world time series of electricity consumption – aggregated to a temporal resolution of 1-hour intervals – for 300 homes in the local area of the proposed development in Melbourne.

The electricity charges for the cost of service comparisons is sourced from EnergyAustralia residential electricity plans – Night Saver [36] and Flexi Saver [37] – available to the residents of the area of the proposed development.

The extreme weather event forecasts and warnings are publicly available from the Australian Bureau of Meteorology (BOM) both online [38] and from news media across the country.

3. Results and discussion

With the growing research – both formal and informal – looking into the possibilities of integrating PV generation and storage into community settings, it has become clear that significant benefits are possible with these setups over conventional approaches [39–43].

As was demonstrated in our previous modelling of individual PV + storage systems, important reductions in grid dependence – 86% for the community modelled – are obtained by the introduction of such discrete systems within new developments. The subsequent modelling of horizontal sharing of resources between those individual systems – managed by a central EMS - shows a further 35% reduction in grid dependence which allows the community to be self-sufficient most of the year.

Sharing horizontally – using an EMS to access all supply to serve any load – provides a significant improvement to the overall system performance during most of the year – with the exception of winter months and extreme heatwaves. However, as can be seen in Figure 6 – which reflects the typical southern hemisphere seasonal demand curve – it is to be noted that even though the overall grid dependence is reduced, the hourly demand – in kWh – for supply from the grid is at times larger in the sharing through EMS scenario than it is in the non-sharing individual systems scenario. This is due to the fact that the benefit of the diversity factor that reduces the overall community demand when considering the different electricity usage, storage and export of the individual systems is lost under the EMS scenario when all batteries are depleted and there is no local generation to replenish charge. The result is the hourly demand maximum peak of the year for the community going from 105.35 kWh for individual systems to 144.4 kWh for the EMS centrally managed community scenario. Although both scenarios improve on the traditional (no local generation and storage system) default maximum hourly peak demand of 191.47 kWh – 45% and 25% respectively – the central EMS scenario does have a 37% higher hourly peak than the individual systems setup.

It is also worth noting that, because these systems are so heavily reliant on weather conditions, the base scenario and the RE systems scenarios have their maximum hourly peaks occurring at different times: the base scenario maximum hourly consumption of 191.47 kWh occurs during the extended January heatwave – 14th to 17th January – at 7:00 pm on the 15th of January, while the RE systems maximum peaks occur during an extremely hot day in February – the 8th at 8:00 pm for the

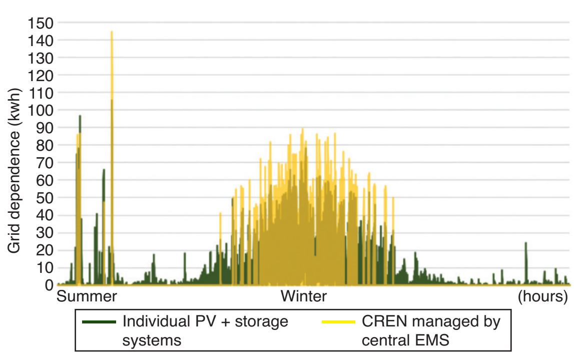

Figure 6: Hourly dependence of the community on the grid for two scenarios: individual dwellings each with its own, unshared PV + storage system, and the community sharing the generation and storage resources through a central EMS that balances all loads and available supply

individual systems and 10:00 pm for the EMS managed community. Even though consumption is over 26% less during the February particularly hot day than it is during the January heatwave – on average, considering the 48-hour period around the peak – the low generation of the RE systems due to poor weather conditions is not enough to charge the batteries. When the weather conditions are favourable for PV generation, the base scenario maximum hourly demand occurring during the peak charging period is shifted to the off-peak charging period – 11:00 pm for individual systems scenario and 2:00 am for EMS scenario – and reduced by 59% (to 78.07 kWh) and 66% (to 65.69 kWh) respectively for each scenario.

To illustrate the effects for the community of the diversity factor and the aggregation of resources, Table 2 comprises 48 hours during the heatwave in the middle of summer that brought about the maximum hourly peak demand – 191.47 kWh – for the base scenario at 5 pm on the 15th of January. The Individual Grid Dependence (Indiv.Grid.Depend.) column shows that despite there being charge (Indiv.Charge) and even excess generation (Indiv.Export) in some of the individual systems, others have their batteries depleted and do not generate enough for their own demand so need to resort to supply from the grid. Thus, albeit with reduced unserved demand, the community is grid dependent during most hours because of the insufficiency of some individual systems to provide for the load of the dwellings on top of which they sit. The isolation of the systems results in the paradoxical situation of the community requiring supply from the grid for some of its systems while at the same time having some other of the systems exporting excess generation to the same grid. The balancing performed by the EMS reduces the number of hours of grid dependence from 47 to just 14 – i.e. 70% reduction in hours, 50% in terms of kWh – eliminating the paradox of concomitant demand and supply from/to grid while reducing export by 38% measured in kWh. However, once the EMS has distributed all the resources – generation and storage – available to the community, the demand from the grid for this interval is equivalent to the 'raw' demand, i.e. the demand of the community without any systems partially reducing the aggregate load. During particularly high demand periods, while in the individual systems scenario there generally are some dwellings that are not sourcing electricity from the grid – those that still have charge in their individual batteries – in the EMS scenario, that idle charge has been used so there is no attenuation of base overall consumption.

Table 2: Comparison of grid dependence, battery charge, and generation export between isolated individual systems and EMS managed community: aggregate of individual systems grid dependence (Indiv.Grid.Depend.), aggregate of individual systems battery charge (Indiv.Charge), aggregate of individual systems export to grid (Indiv.Export), grid dependence and state of charge of storage systems belonging to the community managed by central EMS (EMS), and communal export to grid managed by central EMS. Negative red numbers denote grid dependence, green numbers denote export and black numbers represent state of charge.

	Hour	Indiv. Grid Depend.	Indiv. Charge	Indiv. Export	EMS	EMS Export
	14:00	0	985.42	182.56	1122.00	244.37
	15:00	–0.17	1013.81	174.23	1122.00	205.56
	16:00	–0.69	1014.77	135.18	1122.00	138.26
	17:00	–3.04	990.06	78.81	1122.00	54.74
	18:00	–12.25	900.37	31.58	1053.66	0
Jan-14	19:00	–26.08	772.84	5.04	902.98	0
	20:00	–46.20	622.32	0	701.65	D
	21:00	–59.04	498.09	0	512.48	0
	22:00	–74.66	404.01	0	336.27	0
	23:00	–74.18	324.34	0	175.00	0
	24:00	–68.87	271.06	0	45.96	0
	01:00	–65.94	236.15	0	–55.90	0
	02:00	–60.88	208.70	0	–85.83	0
	03:00	–61.19	188.12	0	–79.90	0
	04:00	–61.37	171.83	0	–76.19	0
	05:00	–49.82	158.91	0	–61.56	0
	06:00	–49.86	147.14	0	–60.56	0
	07:00	–36.56	144.79	0	–38.41	0
	08:00	–25.36	163.55	0	–5.06	0
	09:00	–20.01	209.29	1.19	31.32	0
	10:00	–11.27	317.85	11.24	138.89	0
	11:00	–4.60	466.60	23.17	303.83	0
Jan-15	12:00	–2.93	635.76	38.34	503.27	0
	13:00	–2.16	776.88	83.91	715.58	0
	14:00	–1.78	879.67	124.60	925.24	0
	15:00	–1.94	939.28	156.01	1122.00	23.35
	16:00	–2.71	963.77	124.17	1122.00	149.17
	17:00	–4.47	937.48	78.97	1122.00	52.05
	18:00	–13.91	857.97	33.56	1064.29	0
	19:00	–31.29	733.20	5.01	910.61	0
	20:00	–52.16	588.60	0	708.63	0
	21:00	–51.66	465.08	0	528.29	0
	22:00	–76.60	385.90	0	364.85	0
	23:00	–78.07	321.43	0	214.50	0
	24:00	–63.24	278.13	0	101.64	0
	01:00	–60.20	248.28	0	5.56	0
	02:00	–49.83	225.27	0	–65.69	0
	03:00	–47.83	205.79	0	–65.54	0
	04:00	–48.26	190.64	0	–62.04	0
	05:00	–45.77	177.53	0	–57.68	0
	06:00	–44.95	166.94	0	–54.58	0
Jan-16	07:00	–28.55	165.10	0	–29.87	0
	08:00	–16.92	194.04	0	14.26	0
	09:00	–19.31	239.45	0.99	43.00	0
	10:00	–14.98	319.65	5.67	114.79	0
	11:00	–8.62	436.73	15.92	238.05	0
	12:00	–4.76	580.21	25.27	399.48	0
	13:00	–3.89	711.30	56.62	575.80	0

From a financial perspective – given that feed-in tariffs average 6 cents per kWh while usage charges average 30 cents per kWh – the benefit provided by the horizontal sharing managed by the EMS during this 48-hour period amounts to a 48% reduction in the net payment owed by the community to the grid retailer considering usage and feed-in transactions.

The addition of communal storage is not as beneficial as initially thought. Even though there is some improvement as can be seen in Figure 7, in the particular case modelled for this research, increasing overall storage capacity by almost 45% by means of a communal battery results in 7.8% reduction in the number of hours the CREN is grid dependent and 8.7% reduction in the amount of energy required from the grid, while the exported excess electricity is only reduced by 1.5%. The proposed 0.5 MWh communal battery is of effective use – i.e. to reduce grid dependence – for only 71 hours during the whole year, i.e. less than 1% of the time. The real advantage of the communal battery is the reduction of the maximum hourly peak demand from the grid, which drops from 144 kWh for the 'just EMS' scenario to 84 kWh when the communal battery is in use during the February heatwave. The maximum peak during the winter months (90 kWh) remains the same for both scenarios because the PV generation is not sufficient to charge even the batteries in the individual systems, thus rendering the communal storage redundant. The flattening of peak demand results in a reduction in electrical infrastructure needs – i.e. less grid capacity to supply the reduced maximum hourly demand. However, the infrastructure savings and the marginal improvement in self-sufficiency cannot compensate the cost of the additional storage, as shown below.

Substituting the communal battery with managed off-peak charging results – as Figure 8 shows – in the maximum hourly peak increasing to 120 kWh – 11:00pm on the 8th February – which represents an increase of 33% (30 kWh) on the central battery scenario, but an improvement of 17% (24 kWh) when compared to the 'just EMS' scenario. Using the average Australian power factor – 0.98 -, the 30 kWh maximum peak increase represents a requirement of additional capacity from the grid of 31 kVA, or the equivalent of two average residential meters. Incurring the cost of the 500 kWh central battery to flatten the maximum peak that occurs during that single hour of extreme high demand coinciding with a long period of adverse weather does not make economic sense given that the infrastructure benefit difference between the scenarios is the same.

From the purely grid dependence perspective represented in Figure 9, the community sharing generation and storage assets through a central EMS provides the greatest overall reduction in electricity required from the grid. The default traditional individual connection requires 378.2 MWh, the individually connected PV + storage systems draw 52.4 MWh, and the community sharing through EMS uses 34.1 MWh, while the constant and managed off-peak charging scenarios require 91.1 MWh and 34.7 MWh respectively.

When it comes to different charging periods, continuous off-peak charging at a rate of 30 kWh – value

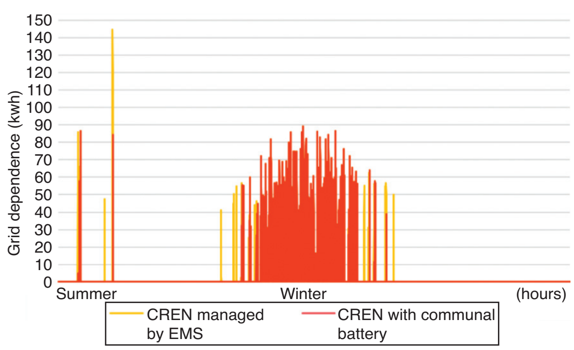

Figure 7: Hourly dependence of the community on the grid for two scenarios: community sharing horizontally the generation and storage resources through a central EMS and the same community setting but with an additional communal battery adding 500 kWh storage capacity

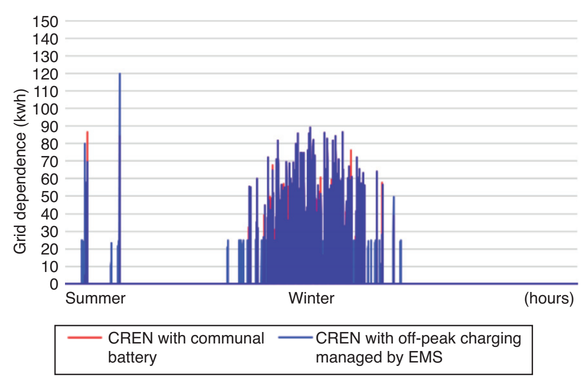

Figure 8: Hourly dependence of the community on the grid for two scenarios: community sharing individual resources as well as a communal battery all managed through a central EMS and the same community but without the communal battery and with off-peak charging managed by the EMS

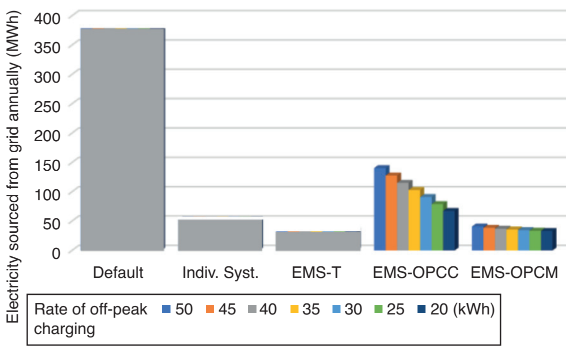

Figure 9: Comparison of grid dependence for 5 scenarios: the default traditional connection to grid, individual generation +storage systems, community individual assets managed by central EMS, community assets + continuous off-peak charging managed by central EMS (EMS-OPCC), and community assets + selectively managed off-peak charging managed by central EMS (EMS-OPCM)

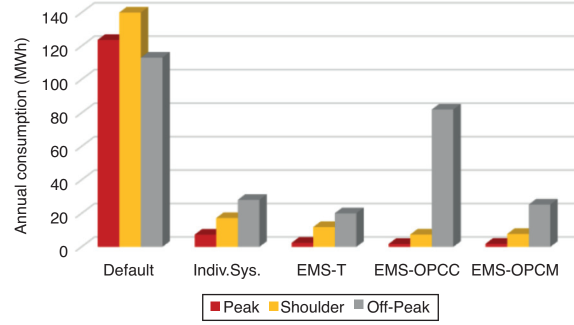

Figure 10: Comparison of peak, shoulder and off-peak electricity consumption for 5 scenarios: the default traditional connection to grid, individual generation +storage systems, community individual assets managed by central EMS, community assets + continuous off-peak charging managed by central EMS, and community assets + selectively managed off-peak charging managed by central EMS

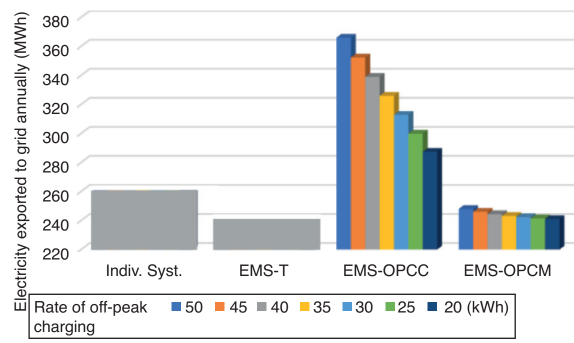

Figure 11: Comparison of electricity export to grid for 4 scenarios: individual generation +storage systems, community individual assets managed by central EMS, community assets + continuous off-peak charging managed by central EMS, and community assets + selectively managed off-peak charging managed by central EMS

used to obtain results in Figure 10 – reduces grid dependence during peak periods by a further 10 hours when compared to community sharing local assets (42 hours) but in exchange for that improvement – 10 hours (0.66 MWh) peak and 114 hours (4.47 MWh) shoulder – it increases the draw from the grid during off-peak periods by 2709 hours (61.98 MWh). On the other hand, managed off-peak charging at the same 30 kWh rate reduces grid dependence – compared to EMS scenario – by 7 hours (0.55 MWh) during peak periods and 104 hours (4.12 MWh) during shoulder periods, but it only increases the draw during off-peak periods by 314 hours (5.22 MWh).

Continuous off-peak charging does not provide any particular benefit – in terms of cost of electricity supplied by grid as shown in Figures 12 and 13 – when compared to selectively managed off-peak charging or even just horizontal management of the community's generation and storage assets by the EMS. For more than 9 months of the year, the continuous off-peak charging just fills during the night the batteries that either have capacity in excess of the load they are supplying or would have been replenished by local generation during the day. This makes more than 54% of the PV generation redundant which does not make pecuniary sense because it implies buying expensive grid electricity in exchange for selling excess cheap PV generation.

The reduction in the cost of electricity sourced from the grid by the use of a CREN setup is very significant: from over AU$125,526 to AU$6,294, representing 95.5% as can be seen in Figures 13 and 14 respectively. In the default scenario, the usage charges are the largest component of the grid-supplied service cost, however, in the individual systems scenario the fixed supply charge becomes the main component of that cost. The fact that in the community setting the number of connections is reduced is what makes the bulk of the savings for the users of the community interconnected systems; the fixed supply charge – which is the largest cost to individual systems – is reduced to a minimum. This is particularly evident in the OPCM scenario where, even though there is a slightly higher usage during off-peak times, the reduced maximum peak

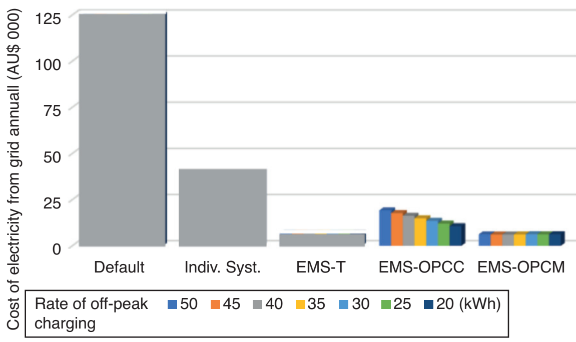

Figure 12: Comparison of expenditure by the community for electricity sourced from the grid for 5 scenarios: the default traditional connection to grid, individual generation +storage systems, community individual assets managed by central EMS, community assets + continuous off-peak charging managed by central EMS, and community assets + selectively managed off-peak charging managed by central EMS

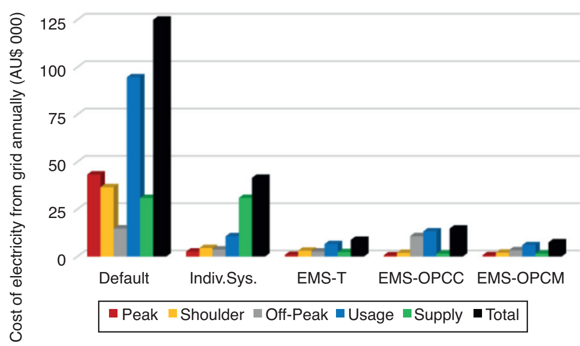

Figure 13: Comparison of usage, supply and total charges for the 5 scenarios: the default traditional connection to grid, individual generation +storage systems, community individual assets managed by central EMS, community assets + continuous off-peak charging managed by central EMS, and community assets + selectively managed off-peak charging managed by central EMS

demand means that the supply charge is reduced, thus making this scenario the most cost effective. – Of course, the larger the community, the greater the savings in fixed supply charges.

Another thing worth noting in these results is that the highest hourly peaks in grid dependence for the community happen during a clearly delimited period of the year – i.e. winter – or during extreme weather events – e.g. heatwaves, particularly cold days, extended overcast periods, etc – which can be forecast quite accurately 24 to 48 hours in advance. This ‘notice’ period could be used by the community to

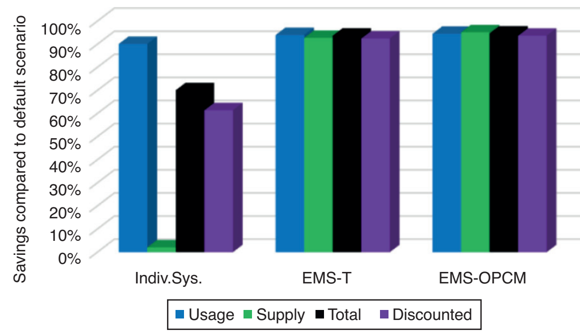

Figure 14: Comparison of savings achieved in usage, supply and total charges by the 3 scenarios – individual generation + storage systems, community individual assets managed by central EMS and community assets + selectively managed off-peak charging managed by central EMS – when compared to the traditional default individual connection to grid

improve the economic performance of the system by the implementation of a strategy that combines demand side management (DSM) and demand response (DR) with tactical off-peak charging of batteries.

Daily hourly maximum domestic electricity consumption seems to follow the Pareto principle in that most of the peaks are produced by just a small fraction of the total units. As Figure 15 shows, the single dwelling peak demand is produced mostly by one dwelling – i.e. unit B4 – and this daily peak demand – further illustrated by Figure 16 – happens mostly during the night. The pattern of consumption exhibited by unit B4 points to load shifting by the user who makes the most of the off-peak price signalling. If the CREN were to implement DSM and DR, users like B4 can be expected to shift that peak demand from the grid off-peak timing/pricing – i.e. late night – to the CREN ‘off-peak’ timing/pricing – during the middle of the day when generation is at its highest – thus reducing both the peak demand on batteries and the exports to grid.

Even though the traditional retailers would obviously miss out on profits as a result of the optimal implementation of CRENs, the grid as a network would benefit from the fact that the CREN provides a single point of connection for the whole community. From a technology perspective, the grid could manage more easily the load and feed-in of a single connection than 81 individual connections – in the case studied in this paper – which would require forecasting and response to 81 different demands and exports.

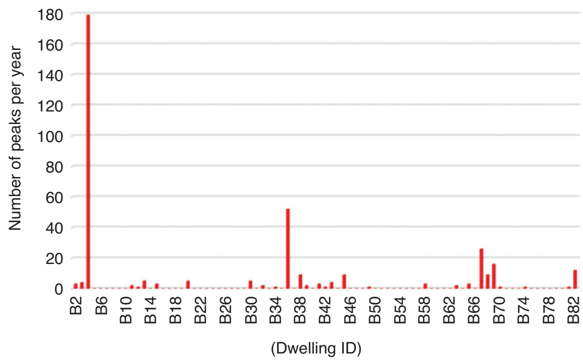

Figure 15: Number of daily peaks that each single dwelling produces each year

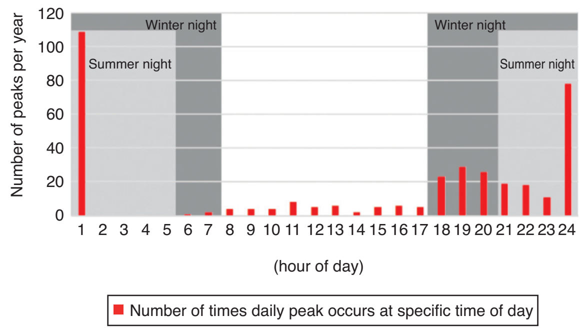

Figure 16: Time of day at which the daily single dwelling peak demand occurs

The previous analysis of benefits provided by a CREN and the different options for off-peak charging are as far as a basic financial analysis of CREN will allow when just considering the technology and its immediate benefits. Given that in the case of a CREN implementation in a new development the costs and benefits of the system are shared between developer and community, happen at different times and serve different purposes, the financial analysis is much more complex than the traditional payback, NPV, IRR or any of the other methods usually applied to calculate the economic viability of the setup.

Although not considered in this study, the widespread adoption of EVs in the CREN should have very little effect on off-peak pricing even if all the vehicles in the community were electric and charging at the same time during the night. Off-peak pricing would not change because there are not enough vehicles to make a difference to the retailer. Off-peak pricing is not dependent on the amount of electricity a residential customer purchases but on the period that the retailer has its lowest demand – not for any particular customer, but for the whole pool of its customer base. This will typically be hundreds of thousands, or millions of customers. Of course, if retailers greatly change their tariff structure for any reason, then a change to the operating strategy of the CREN might be justified. The high flexibility of the CREN design presented here will allow the community to respond optimally to such changes.

The financing, ownership and some governance options for CREN implementation in new developments are studied in detail in the next paper in the series. This paper focussed on energy sharing and the benefits afforded to the community in terms of the reduction in the cost of grid-supplied electricity. The modelling of the detailed financing of infrastructure is the work now in progress and is the subject of the next phase of the study.

4. Conclusions

A combination of PV, energy management and storage in multi-dwelling developments can be very effective in reducing grid dependence. Amongst the main benefits, it transfers to the CREN the advantage of diversity that usually allows the traditional grid operators and retailers to optimise the use of resources in terms of both capacity and supply.

Sharing PV and electricity storage resources via an EMS shifts the CREN peak individual loads to times that the grid considers off-peak periods – i.e. night time – so managed off-peak charging and a retail plan with the lowest off-peak pricing affords the community savings in the order of 95.5% compared to the traditional individual grid connection.

As opposed to the case of other jurisdictions where feed-in tariffs are substantial – e.g. Germany – in Australia self-consumption of PV generation is the best use PV system owners can give to the electricity generated locally, so the optimisation of off-peak charging to avoid 54% of redundant charge results in further financial benefit.

The benefits of EMS sharing and off-peak charging could be further enhanced by the implementation of DSM and DR which help flatten the daily consumption curve, thus optimising the use of the generation and storage resources.

Even though this study focuses on an Australian case study – specifically a new development proposed in Melbourne – it provides a tool that allows the performance of the same analysis for other specific sites and load profiles.

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