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Buildings as batteries

How buildings can support the clean energy transition

If buildings shifted one third of their peak electricity consumption to the middle of the day, this would save $1.7 billion annually and add additional peak capacity equivalent to 52% of Australia's existing coal generation fleet. It would reduce Australia's greenhouse gas emissions from electricity by 1.9% (2,780,000 tonnes) per year and accelerate decarbonisation by encouraging more renewable energy investment. In order to pursue such potential benefits governments should measure and incentivise demand flexibility in buildings.

Discussion paper

Richard Denniss – The Australia Institute
Craig Roussac – Buildings Alive

April 2024

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Level 1, Endeavour House, 1 Franklin St
Canberra, ACT 2601
Tel: (02) 61300530
Email: mail@australiainstitute.org.au
Website: www.australiainstitute.org.au
ISSN: 1836-9014

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Summary

Markets can help to efficiently allocate scarce resources, but the National Electricity Market (NEM) is a market in name only. In reality, participants in the "market" are governed by extensive administrative and legislative rules, and the outcomes are far from efficient. Consider for example:

1) In the middle of the day a significant amount of renewable electricity generation capacity is "curtailed", that is switched off, and is wasted.
2) Governments around Australia are currently trying to incentivise the construction of more renewable energy generation capacity.
3) In order to avoid blackouts at peak times, transmission capacity needs to be able to handle peak capacity. Significant public funding is going towards ensuring transmission infrastructure can handle peak capacity, even though these peaks occur for only a small part of the day on a few days of the year.
4) Aside from transmission upgrades, governments around Australia are supporting the construction of generation infrastructure for peak periods, such as a new gas fired power station at Kurri Kurri,[1] and offering public money to the owners of ageing coal fired power stations to remain open longer.

But despite the fact that there is free renewable energy going to waste in the middle of the day, and state and federal governments are spending billions of dollars to build a generation and transmission system that can cope with the expected growth in afternoon peaks, there are currently few incentives in place to reduce these peaks. There are no price or non-price incentives in place to shift demand for electricity from peak periods (when generation and transmission capacity is constrained and the emission intensity of electricity supply is highest) to times of the day where free, zero-emission electricity capacity is currently going to waste.

Such perverse outcomes are not driven by "the market" but by the out-of-date rules that define the operation of the NEM and rating schemes such as the National Australian Built Environment Rating System (NABERS), which evaluates the "sustainability" of a building's electricity consumption, but without considering how its demand profile impacts the system.

[1] Morton (2021) *Morrison government's $600m gas power plant at Kurri Kurri not needed and won't cover costs, analysts say*, https://www.theguardian.com/australia-news/2021/jun/10/morrison-governments-600m-gas-power-plant-at-kurri-kurri-not-needed-and-wont-cover-costs-analysts-say

While there are many problems facing the supply of electricity in Australia, this paper argues that many of the most efficient, and quickest to implement, solutions lie in shifting the inefficient patterns of demand that have been allowed to develop over past decades.

To be clear, demand management is not new, nor is it new to Australia – Queensland has a demand management program involving more than 150,000 households – but to date it has been inadequately addressed in Australia's energy debates despite its potential to simultaneously lower the cost of electricity, avoid significant investment in new transmission capacity and instantly lower Australia's emissions from the electricity sector at zero upfront cost. While batteries allow load to be spread across the day, they require significant upfront investment. Shifting the demand profile of commercial and institutional buildings, even just by a few hours, can deliver similar benefits to batteries but with no upfront capital investment. This possibility exists because a key issue for Australia's energy system is managing peak loads, particularly on hot summer days when demand for air conditioning remains high in the mid and late afternoon, after output from solar panels has dropped.

Load shifting, that is moving the time of day at which electricity is used, is possible in commercial and institutional buildings because they can act as "thermal batteries" that store energy in the form of warmth in winter or coolness in summer. They can use electricity when it is relatively cheap and reduce their demand when prices are higher. In summer this can mean providing more fresh air and cooling at lunchtime and then letting the building temperature increase slightly through the afternoon. Put simply, as this paper shows, small changes in the control of commercial air conditioners can make a very big difference to the demand for electricity across an entire city.

Furthermore, buildings are the gateway to so-called "behind the meter" Distributed Energy Resources (DER), including stationary batteries, thermal storage technologies, electric vehicles, and other controllable loads.

This paper uses data provided by Buildings Alive to demonstrate the potential of load shifting in commercial buildings to reduce costs, emissions and contribute to solving some of the infrastructure challenges facing Australia's electricity systems.

For example, on 31 January 2019, Sydney's weather was forecast to be very hot and building managers at a large premium-grade office tower were advised that their electricity demand was likely to be extremely high. In response to this forewarning, building managers lowered the internal temperature setpoint by 1 degree for the period 8:30am to 2pm and then let it revert to its normal setting from 2pm onwards.

Data presented in this paper shows that the building in question used more electricity earlier in the day and reduced demand by 200kW relative to forecasts from 2pm to 6pm. The building effectively operated as a battery with capacity of at least 800kWh. We estimate this led to savings of $111 and 221 kg CO_2e in emissions in just one day in just that one building. A battery of that size would cost around $500,000.

Extrapolating across Australia, if 33% of the energy buildings use in the late afternoon in summer were shifted to the middle of the day, that would deliver new peak capacity in the energy market of almost 12 gigawatts (GW). To put that into perspective, such a shift would be equivalent to boosting the output of all coal, gas and hydro power stations by around 25%. The cost saving to consumers in supplying electricity at times of day when it is cheaper and cleaner would reach $1.7 billion per year and annual greenhouse gas emissions from electricity would reduce by 2,780,000 tonnes.

A concerted government program to develop the demand side in the NEM might be able to organise load shifting in 30% of institutional grade office buildings in 2025,60% in 2026 and 90% in 2027 if work starts in late 2024.

Such a program would need to be coupled with an updated national building efficiency rating system that recognises the ability of a building to shift its load to more efficient times of the day and takes the actual emissions intensity of electricity it consumes into account.

A program such as that described above could deliver around 2.6 GW of flexible capacity by the end of 2026. To put this into context, Australia's first Renewable Energy Zone, in Central West Orana in NSW, should deliver around 3 GW of new capacity. It began development in 2017, and is expected to come online in 2025 with transmission links alone costing $675 million.

Such a shift in the time of day of energy use would not require billions of dollars of investment in new transmission, generation or storage. There is no costly technology required to move a significant amount of energy use away from the late afternoon peak in demand and towards the middle of the day, a time when there is a peak in solar supply.

Policy recommendations:

- Direct NABERS to develop and implement an updated building efficiency rating system that recognises load shifting capabilities and accurately reflects the emissions intensity of the electricity that a building consumes
- Governments commit to implement demand flexibility in their own buildings
- Direct energy departments to work with energy innovators and the property sector to accelerate development of load shifting and broader demand response
- Encourage ARENA to solicit for related project proposals under its new mandate
- Encourage CEFC concessional finance to expand the market
- Ensure load shifting can compete in the wholesale demand response market.

For energy ministers trying to fix the crisis in the wholesale market, load shifting is a quick way to increase capacity and improve competition. With relatively modest federal government funding and coordination, commercial building load shifting could start being delivered at scale within months. The analysis in this paper demonstrates that without coordinated action from grid-interactive efficient buildings:

- The clean energy transition will cost more.
- The electricity system will be less stable.
- Renewable energy investment returns will be lower.
- Environmental outcomes will be worse.

Introduction

Australia has faced multiple energy crises in recent years, from unexpected coal generator closures, to coal and gas price spikes, and even market suspensions.[2,3,4] One common theme is that all of these problems relate to electricity supply: generating it and getting it to customers.

While the most obvious problems may be on the supply side, this paper argues that many of the solutions lie in shifting inefficient patterns of demand for electricity. Just as economics concerns itself with the interaction of both supply and demand, policy makers need to look at more than merely how we can generate more electricity. It is just as important to consider how could we use less (and in some cases, more) electricity, particularly at times when the generation, transmission and distribution systems are under strain.

Time and weather are key factors in determining both electricity supply and demand. In Australia electricity demand peaks on hot days, but even then only at particular times. In the morning, demand rises as households wake up and industry begins operations. Electricity is then plentiful during the middle of the day as Australia's abundant solar panels generate at full capacity and household demand for electricity drops off. However, in the late afternoon and early evening, especially on hot days, electricity demand increases significantly, as residential, industrial and commercial users continue to draw large volumes while the generation from solar panels drops away.

These fluctuations in electricity demand and supply create significant problems for grid stability – they drive up infrastructure requirements as there always needs to be enough generation and "poles and wires" to cope with peak periods of demand, even if this capacity is barely used for the rest of the day or year. Supply and demand fluctuations also make prices volatile – National Electricity Market (NEM) prices can go as high as $15,500 per megawatt hour (MWh) on a hot afternoon, but prices can also be negative when demand is low and renewable energy is supplying its peak capacity. At such times, generators can *pay* up to $1,000/MWh to send electricity out.

These problems can be mitigated by managing demand. The simple fact is that sometimes it is cheaper and easier to reduce demand than to increase supply, even though the

[2] Ha & Reeve (2021) *Coal plants are closing faster than expected. Governments can keep the exit orderly,* https://theconversation.com/coal-plants-are-closing-faster-than-expected-governments-can-keep-the-exit-orderly-172150

[3] Vorrath (2023) *Regulator confirms another coal and gas fuelled power price hike. But why?,* https://reneweconomy.com.au/regulator-confirms-another-coal-and-gas-fuelled-power-price-hike-but-why/

[4] DCCEEW (2022) *AEMO suspends NEM Wholesale Market,* https://www.energy.gov.au/news-media/news/aemo-suspends-nem-wholesale-market

administrative rules that underpin the NEM provide no incentive for such a shift in electricity usage patterns.

Electricity demand management is not a new concept – some form of it has been around since the late 19th Century, when British generator manufacturer REB Crompton led calls for the creation of "off-peak" loads to keep furnaces burning and supply costs down.[5] Likewise, France has used demand management for decades as it is easier to change demand than it is to turn the country's nuclear generators up or down.[6] Similarly, in Australia, many Australians are familiar with "off peak" hot water heating and some states have other programs in place, such as Queensland's PeakSmart, to help shift residential electricity demand over the course of a day. That said, significant opportunities to improve and expand such residential programs exist.

This paper focuses on commercial and institutional buildings and demonstrates they could easily change their energy use in a way that is both profitable and beneficial to occupants and the wider electricity system. The commercial building industry has a well-established culture of energy efficiency innovation. Accordingly, large commercial and institutional buildings are a natural place to start making changes in Australia's energy usage patterns. This would help avoid the necessity of investing in significant new generation, storage and transmission capacity that is expected to be required to meet the current forecasts for peaks in demand.

This paper argues that buildings should be thought of as a means to harness and coordinate so-called "behind the meter" Distributed Energy Resources (DERs), including stationary batteries, thermal storage technologies, electric vehicles, and other easily controllable forms of electricity demand. For example, buildings can act as "thermal batteries" that store energy as warmth in winter or coolness in summer. This means they can use more electricity when it is relatively cheap and reduce their demand when prices are higher. In summer, this means using solar power to cool buildings slightly below the default temperature at lunchtime, then letting the building temperature increase by a degree or two through the afternoon.

Our analysis uses data provided by Buildings Alive, founded by co-author Craig Roussac, from large commercial buildings in Australia to demonstrate that these changes not only save money for building owners, but for all electricity consumers. This is because load shifting not only reduces demand peaks, but in so doing reduces the need for investment in generation, storage and transmission infrastructure. We focus on commercial and institutional buildings as their larger size, lower numbers and the active building

[5] Bowers (1996) Chapter 6: Electricity. In McNeil, I. (Ed*.), An Encyclopaedia of the History of Technology*. United Kingdom: Routledge

[6] Cass (2017) *Saving mega bucks with negawatts*, https://australiainstitute.org.au/report/report-saving-mega-bucks-with-negawatts/

management systems they already possess make them the easiest place to begin load shifting reforms.

Many commercial building types are already covered by the National Australian Built Environment Rating System (NABERS). We argue that NABERS needs to be updated to adequately reflect the emissions benefit of load shifting via flexible time of use capabilities.

1. Load shifting in commercial buildings

Shifting the time of day that electricity is used (load shifting) is cheaper than expanding the peak generation and distribution capacity of the grid. For most commercial buildings, load shifting requires no capital expenditure or any increase in operating costs and there are significant benefits in the form of lower energy prices for individual buildings and reduced need for transmission capacity across the economy.[7]

All large buildings have cooling and heating systems installed already. This capital expenditure is made in order to keep the building comfortable regardless of the outside temperature. The economic benefits of load shifting relate to the fact that significant changes in electricity use can be easily achieved by merely changing how the cooling and heating systems are used. Such changes do not require new infrastructure investments but simply better use of existing infrastructure. Put simply, if buildings are managed deliberately they can, at zero cost, provide the same services as an enormous battery without the need for any transmission wires to connect that battery to its customers.

LOAD SHIFTING ILLUSTRATED

Load shifting does not significantly change the amount of energy consumed in a building but simply the time of the day when it is consumed. In fact, the total amount of electricity consumed may increase slightly when a building employs smart load shifting, but that electricity will be drawn at a time of day when it is far cheaper and less emissions intensive, saving money and carbon pollution in the process. This important point is what is missed when emphasising energy efficiency alone, without considering the time of use, as current building ratings systems like NABERS do.

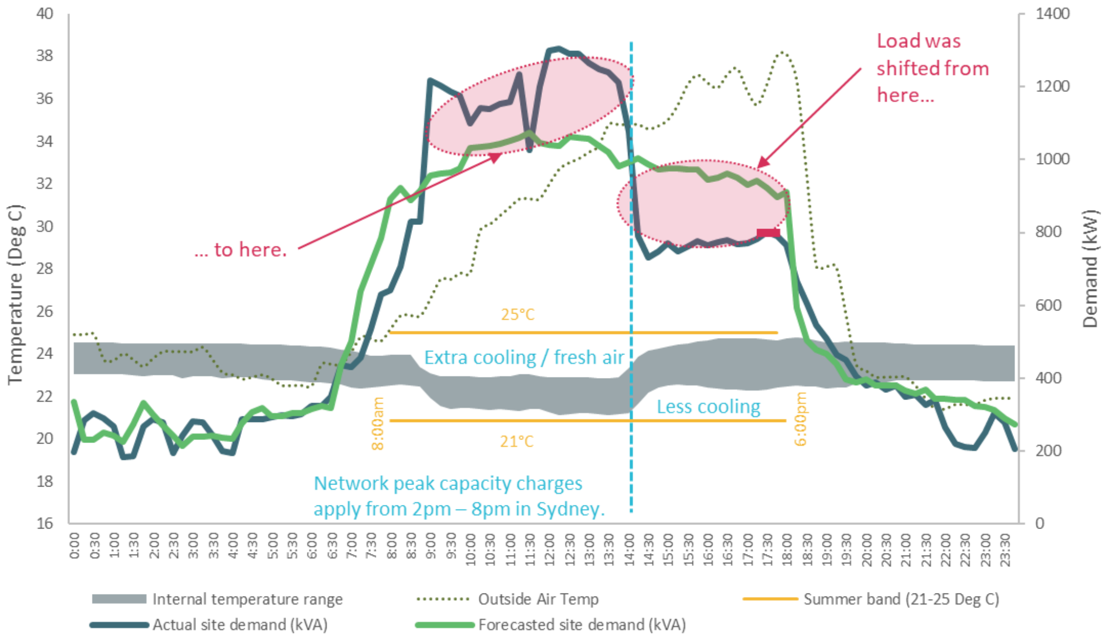
It is helpful to illustrate the concept of load shifting in a large commercial building. The 31st of January 2019 was forecast to be a very hot day and building managers at a large premium-grade office tower in Sydney CBD were advised that their electricity demand was likely to be extremely high. In response to this forewarning, building managers lowered the internal temperature target by 1 degree for the period 8:30am to 2pm and then restored the original temperature target from 2pm onwards. The goals were to reduce "capacity

[7] Building owners can also choose to invest capital in technologies that can further enhance their load-shifting capabilities, such as stationary batteries and thermal storage tanks.

charges"[8] that apply during 2 to 8pm in Sydney CBD and to keep occupants comfortable (there was no consideration of emissions or wholesale electricity cost savings).

Figure 1 below shows how building managers were able to shift their demand, minimise capacity charges and increase grid stability by simply changing the internal temperature target by 1 degree for less than a day. The horizontal axis is the time of day. The two vertical axes show temperature (external and internal) and the electrical load – the rate at which energy is being consumed, which is measured in watts:

Figure 1: A large commercial office building behaving as a "battery", 31 January 2019



Source: Buildings Alive

Figure 1 shows that the building in question was able to increase its demand (dark blue line) above what was forecast (green line) between 9am and 2pm by dropping its internal target temperature by 1 degree. Because they had "precooled" the building in the morning, after 2pm they were able to reduce their demand for electricity to 200kW below the forecast levels.

Figure 1 is based on data collected by Buildings Alive. Buildings Alive provides a range of services to commercial building managers to help them manage their energy use. To provide these services, Buildings Alive creates a model of energy use for each building they help to manage, a model that, among other things, can accurately predict the amount of electricity a building will use on any given day based on the weather conditions and activity in the building. The "forecast site demand" in Figure 1 is based on that model.

[8] In Sydney CBD, capacity charges are calculated from an electricity meter's highest 30-minute period of consumption between 2pm to 8pm and are reset on a rolling 12-month basis.

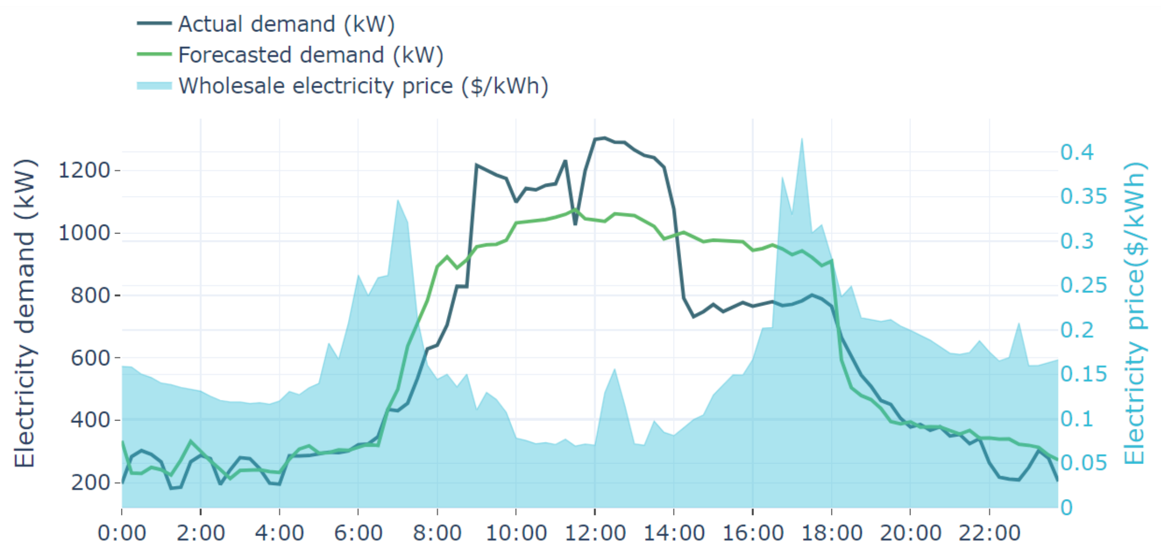
While internal temperatures (grey band) were initially lower than usual and allowed to increase after 2pm, these internal temperatures always remained within the building management's summer band temperatures. In short, Figure 1 shows how electricity consumption was shifted from the afternoon to the morning with no impact on the building's occupants but making a significant contribution to reducing peak electricity load for the building late in the afternoon.

The building managers did not consider the carbon impacts of their intervention; their only objectives were to maintain healthy and comfortable indoor environmental conditions for their occupants and avoid an increase in their network capacity charge which is based on the peak level of electricity used by a building in the previous 12 months. Put simply, by avoiding one hour's peak demand, the building paid less for its electricity for the following 12 months.

The building shifted 200kW of load for four hours, effectively operating as a battery with capacity of at least 800kWh. An actual battery of this capacity would cost at least $500,000 and also require transmission lines to connect it to customers.

Figure 2 shows how this same building would have helped avoid an afternoon peak in electricity demand, avoid renewable energy generators being forced to "curtail" their electricity production, and avoid the need for as much investment in transmission capacity in an electricity market with considerable volatility – South Australia. It compares the building's actual and forecast demand with data on wholesale prices in South Australia over a typical summer day.

Figure 2: Demand management on typical 2022 summer day, South Australia, prices

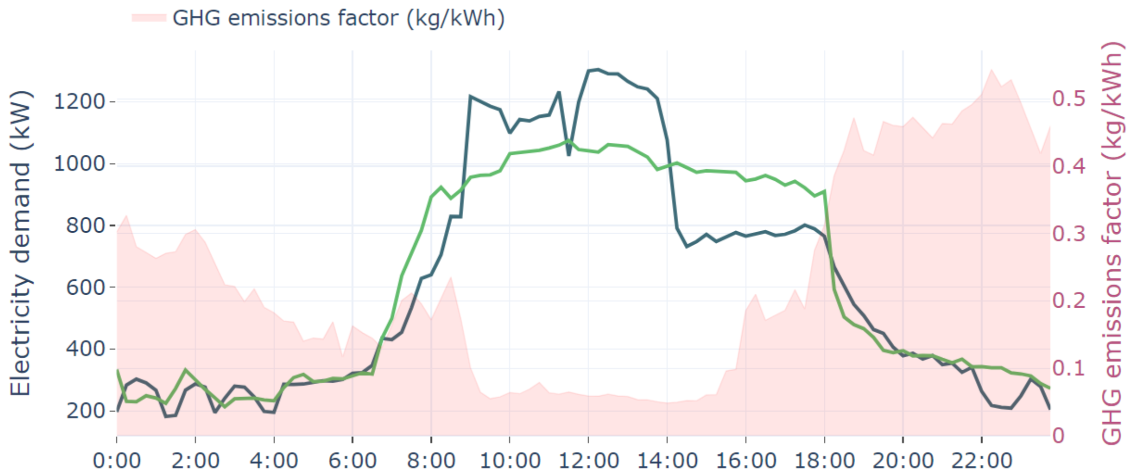


Source: Buildings Alive

The shaded blue area in Figure 2 shows the electricity price has a morning peak from about 6am to 7.30am then a higher peak from about 4.30pm to 6pm. As in Figure 1, the building managing its demand manages to increase energy use above its forecast usage from 9am to 2pm while electricity is cheapest, mainly below $0.1/kWh. The building then reduces its demand during the 4:30 to 6pm peak when prices were over $0.3/kWh. We estimate this saving at $122 for this one building, but the real saving to the economy comes from the ability to curtail investment in new transmission and distribution infrastructure (which are only needed to meet peaks in demand) rather than curtailing renewable energy generation earlier in the day.

The shift of demand to the period where renewable energy is at maximum capacity, and away from the fossil fuel-fired peak, also provides an emissions benefit. Figure 3 below shows the building's performance against the carbon intensity of the South Australian grid.

Figure 3: Demand management on typical 2022 summer day, South Australia, emissions



Source: Buildings Alive

The pink shaded area in Figure 3 shows that emissions intensity of electricity drops during the middle of the day when solar production is highest, from about 9.30am to about 4pm, and then rises to a peak from about 7pm until about midnight, when gas generation rises. We estimate the emissions savings from the active management of this one building at 150 kg CO2e for just one day.

NSW's electricity generation fleet is even more emissions intensive than South Australia's. The predominance of black coal generators means fossil fuels accounted for 66% of NSW generation in 2023, compared with 24% in South Australia.[9] Operating in NSW, we estimate this building saved $111 and 221 kg CO2e in emissions for just one day's active management of the buildings energy use.

If owners and tenants are empowered to shift the time of day at which they heat and cool their buildings, and are adequately rewarded for doing so, this simple and very low cost

[9] This accounts for local generation only, not the fossil fuel contribution of imports. (n.d.) *OpenNEM: New South Wales*, https://opennem.org.au (Accessed 22 April 2024)

measure will produce significant economic and environmental benefits. It would reduce demand at times when fossil fuel production is high and thus emissions are high, and shift it to times when solar production is high and emissions are low. Unfortunately, the current design of the NEM and the NABERS energy rating system impede such choices, rather than encourage them.

2. Australia-wide potential to save money and emissions

If power shifting and demand management in Australia's buildings were more widely adopted it would have significant impacts on cost savings, infrastructure needs and carbon emissions. The following results are supported by calculations in Appendix A.

If Australia's buildings shifted 33% of the energy they use in the late afternoon in summer to the middle of the day, that would deliver new peak capacity in the energy market of almost 12 GW, the equivalent to boosting the output of Australia's coal, gas and hydro power stations by around 25%.[10] Consumers could also save $1.7 billion per year on their electricity bills if they were able to access the wholesale price savings.

A load shift of this magnitude would revolutionise how Australia invests in the peak capacity of its electricity system. It would effectively provide new peak capacity for other energy users, equivalent to half of Australia's existing coal fleet (52% of nameplate capacity) or more than all of Australia's gas and diesel generators (108%). It would also limit and defer the need for generation, transmission and infrastructure investments.

Indeed, we believe the estimate of a 33% potential shift in peak load is conservative. During times of peak demand on a summer afternoon, air conditioning in an office building can account for around 70–80% of electricity use. In a typical household, the variability in demand for electricity for air conditioning is similar.

A concerted government program to develop the demand side in the NEM might be able to organise load shifting in 30% of institutional grade office buildings in 2025 and 60% in 2026 and 90% in 2027 if work starts in late 2024.[11] The core of this market development would be a commitment for all large government buildings to load shift by the end of 2025. (see section 3: Policy).

A program such as this could deliver around 2.6 GW of flexible capacity by the end of 2026. To put this into context, Australia's first Renewable Energy Zone, in Central West Orana in NSW, will deliver around 3 GW of new capacity. The project was first proposed by the government in 2017. Currently it is planned that the transmission may be completed by

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[10] See calculations in Appendix A. Full spreadsheet available on request.

[11] Estimate based on market penetration of the NABERS program, which in 2020/21 stood at 74%. In 2010-11 about 15% of office buildings were rated and it seems reasonable that a modest federal program could double this rate. (n.d.) *NABERS Annual Report 2020-2021 Life of Program Statistics*, https://nabers.info/annual-report/2020-2021/life-of-program-statistics/

2025. The Central West Orana REZ Transmission Link may cost around $675 million.[12] The new generation and storage assets will cost about another $5 billion and could be expected to come online from 2026 onwards.[13]

A shift in the time of day of electricity use would not require tens of billions of dollars of investment in new transmission, generation or storage. There is no costly technology required to move a significant amount of energy use away from the late afternoon peak in demand and towards the middle of the day, when there is a peak in solar supply.

Across Australia's major cities, and around the world, large commercial buildings including the Sydney Opera House are already demonstrating the feasibility and profitability of load shifting.[14] Further, because renewable energy generation accounts for a significantly higher portion of energy supply during the middle of the day, shifting load from the afternoon peak (when most coal fired power stations are running) to the middle of the day (when solar panels are at their most productive) reduces greenhouse gas emissions and encourages further investment in renewables. If Australia's buildings – residential and non-residential – shifted around 33% of the energy they use in the late afternoon and mornings to the middle of the day, that would reduce carbon dioxide emissions by 2,780,000 tonnes per year, or 1.9% of Australia's total annual emissions from electricity generation.

[12] AEMO (2020) *2020 Integrated System Plan*, p.62

[13] (2022) *Central-West Orana Renewable Energy Zone*, https://www.energyco.nsw.gov.au/renewable-energy-zones/centralwest-orana-renewable-energy-zone

[14] Green Building Council Australia (2023) *Grid-interactive efficient buildings paper,* https://new.gbca.org.au/case-studies/building/grid-interactive-efficient-buildings-paper/

3. Policies to support load shifting and demand response

This section outlines a set of measures for energy ministers to consider if governments wish to encourage industry to build broader nationwide demand side capacity.

1. ***Direct NABERS to develop and implement an updated building efficiency rating system that recognises load shifting capabilities and accurately reflects the emissions intensity of the electricity that a building consumes.***

   NABERS is Australia's leading building performance rating scheme. When NABERS was launched almost 25 years ago,[15] Variable Renewable Energy (VRE) did not exist in Australia. Now that we are in the era of VRE and electrification, NABERS's assessment methodology should change so that it calculates and communicates a building's greenhouse gas emissions from energy use. Just like in the late-1990's, current building owners that want to innovate and lead a market transformation have nothing authoritative and independent that they can turn to tell their story to stakeholders. NABERS should help them. (See appendix F for more discussion on the history of NABERS.)

2. ***Governments commit to implement demand flexibility in their own buildings***
   The federal and state governments own, lease and manage a significant holding of commercial and institutional buildings and public housing. They can lead the broader building sector by demonstrating demand flexibility and promoting the benefits to policy makers, stakeholders and the public.

3. ***Direct energy departments to work with energy innovators and the property sector to accelerate development of load shifting and broader demand response***

   Energy departments could organise the development of load shifting and broader demand side and electrification efforts. There are market development, workforce, public education and supply chain issues which would be addressed immediately and do not require any legislation or new institutions. There should be specific education programs for building managers, property investors, and owners. There should also be continuous industry development, to assist demand response aggregators, retailers and technology innovators (particularly building management software and control systems).

[15] By the NSW Government on 2 September 1999 as the Building Greenhouse Rating (BGR) scheme. It subsequently was renamed the Australian Building Greenhouse Rating (ABGR) before being NABERS.

4. ***Encourage ARENA to solicit for related project proposals under its new mandate***
   In July 2022, Chris Bowen, Minister for Climate Change and Energy, announced a new mandate for the Australian Renewable Energy Agency that removes fossil fuels and specifically targets demand side resources.[16] ARENA should be encouraged to engage with the commercial and institutional property sectors to identify load-flex opportunities in buildings.

5. ***Encourage CEFC concessional finance to expand the market***
   By 30 June 2021, the Clean Energy Finance Corporation had invested $9.5 billion including $3.7 billion in energy efficiency, including building upgrade projects. The CEFC could share outcomes from its investments with government and support the coordination of a load shifting initiative targeting grid-interactive efficient buildings.

6. ***Ensure load shifting can compete in the wholesale demand response market***
   Load shifting does not require any change to the wholesale market. In June 2020, in response to a rule change co-sponsored by the Australia Institute, the Australian Energy Market Commission changed the NEM rules to allow demand responses such as load shifting to bid into the wholesale market.[17] However, it may be that the procedures created by the Australian Energy Market Operator (AEMO) to govern participation in the demand response market are a barrier to load shifting and the emergence of grid-interactive efficient buildings.

   Ministers could direct AEMO to report on whether the existing wholesale demand response baselines are adequate to enabling load shifting and, if not, to specifically design a new baseline to capture the demand profile of commercial buildings.

[16] Bowen (2022) *The Albanese Government is putting the R back in ARENA*, https://minister.dcceew.gov.au/bowen/media-releases/albanese-government-putting-r-back-arena
[17] Long (2020) *Electricity users to get paid to cut usage under radical change*, https://www.abc.net.au/news/2020-06-11/customers-paid-for-reducing-electricity-demand-radical-change/12343790

Conclusion

The Australian Government has set a goal to have 82% of energy in the National Electricity Market (NEM) sourced from renewables by 2030. Inevitably, this will mean that the entire grid will operate for extended periods with generation from wind and solar exceeding demand, i.e., at 100% renewables. To provide the power systems capable of supporting this new and very different operating environment, the Australian Energy Market Operator (AEMO) is developing an engineering framework that assumes the penetration of renewables will reach 100% for brief (approx. half-hour) periods as early as 2025.[18] AEMO's Engineering Roadmap addresses this challenge under the assumption that there will be little or no active demand-side contribution made by buildings, or the built environment more broadly, for the foreseeable future.

Without coordinated action from grid-interactive efficient buildings:

The clean energy transition will cost more.

AEMO, in its Integrated System Plan (ISP) published in June 2022, has projected a nine-fold increase in grid-scale wind and solar capacity and a near five-fold increase in distributed solar by 2050. To accommodate this transformation of the Australian electricity system, AEMO has called for "urgent efforts" to invest $12.7 billion in currently actionable transmission infrastructure projects. This investment constitutes about 4% of the $315 billion total spend "needed to develop, operate and maintain the generation, storage and future network investments of the NEM to 2050" (AEMO 2022, p15).[19]

While AEMO's modelling takes into consideration the energy efficiency policies of state and federal governments, currently there are no policies to harness the potential for grid-interactive efficient buildings. AEMO has therefore had to assume an unnecessarily high cost to provide additional generation, storage and network infrastructure.

The electricity system will be less stable.

As noted by AEMO, even if actionable projects "progress as urgently as possible", in some cases "the optimal timing would be earlier than what is achievable" (p.12). Large-scale infrastructure investments can be delayed for myriad reasons, including shortages in the availability of labour, skills, finance and materials and also the need to take community and environmental considerations into account. For example, by 2024 Australia is expected have

[18] AEMO (2022) *Engineering Roadmap to 100% Renewables*. https://aemo.com.au/-/media/files/initiatives/engineering-framework/2022/engineering-roadmap-to-100-per-cent-renewables.pdf
[19] AEMO (2022) *2022 Integrated System Plan for the National Electricity Market*. https://aemo.com.au/-/media/files/major-publications/isp/2022/2022-documents/2022-integrated-system-plan-isp.pdf?la=en

a shortfall of 41,000 engineering professionals required to deliver *currently committed* public infrastructure projects[20] and Weld Australia is forecasting a shortfall of 70,000 welders by 2030.[21]

Stop-gap measures may be required to maintain grid stability and address delays in the delivery of planned infrastructure investments. These include involuntary curtailment (shutting off) of variable renewable energy generation during favourable wind and solar conditions and brown-outs, black-outs, and involuntary load shedding at times of peak demand.

Renewable energy investment returns will be lower.

Because non-dispatchable renewable energy generators like wind and solar rely on the weather, they must use financial instruments or storage technologies to manage their market exposure and access the most favourable pricing. Alternatively, they can just disconnect from the grid at times when weather conditions are good and wholesale power prices are low.

All of these approaches are costly and discourage investment because they diminish investment returns. By contrast, if so-called "firming" can instead be provided from grid-interactive efficient buildings shifting their demand according to the availability of clean energy, the wholesale market price becomes more stable. Excess generation at times of high wind and solar availability will be taken up by buildings at a fair price to the generators, thus enhancing their investment returns and driving more investment.

Environmental outcomes will be worse.

Significant environmental impacts arise from the generation, transmission, distribution, and storage of electricity. While a rapid transition away from fossil fuels to 100% renewable energy is essential for tackling the climate crisis, renewables are not without environmental issues of their own. Environmental harm caused by extracting raw materials, building on landscapes and end of life disposal should be avoided to the maximum extent possible. This requires a concerted effort to build out the technologies, systems and processes to harness the built environment's capacity to even out network demand and minimise any over-investment in more expensive and environmentally harmful solutions. Doing so will also accelerate progress towards a fully decarbonised electricity grid.

[20] Infrastructure Australia (2021) *Infrastructure workforce and skills supply: A report from Infrastructure Australia's Market Capacity Program*. https://www.infrastructureaustralia.gov.au/sites/default/files/2021-10/Infrastructure%20Workforce%20and%20Skills%20Supply%20report%20211013.pdf

[21] Margolis and Waterson (2022) *Australia needs 70,000 more welders by 2030 to help power renewable energy shift, Weld Australia says*. https://www.abc.net.au/news/2022-11-24/70-000-welders-needed-in-australia-by-2030/101689142

Appendix A: Estimate calculations

Table 1: Electricity system assumptions and estimates

Australia's Electricity System	**Unit**	**Summer / Winter**		**Annual**		**Sources**
		Peak	**Range**	**Estimate**	**Range**	
Consumption (commercial / inst.)	kWh/m2			225	100-350	NABERS reverse calculator, assumes a ~3-star average all-electric building
Consumption (residential)	kWh/m2			46	20-70	Various online, author experience, assumes av dwelling 25kWh/day, 200m2
Demand (commercial / inst.)	W/m2	40	25-60			Buildings Alive data
Demand (residential)	W/m2	20	10-40			Various online, author experience, assumes ave dwelling 4kW peak 1/2 hourly demand, 200m2
Office buildings	M m2			70		Author estimate based on PCA investment grade
Retail buildings	M m2			50		Author estimate based on PCA investment grade
Institutional buildings	M m2			30		Author estimate
Other buildings	M m2			50		Author estimate
Residential	M m2			1400		Author estimate, assumes 25M population, 3.5 people per 200m2 household (57m2 per person)
Currently, the NEM relies on dispatchable firm capacity from:						
Coal-fired generation	MW	23,000				AEMO 2022 Integrated System Plan
Gas-fired & liquid-fuelled generation	MW	11,000				AEMO 2022 Integrated System Plan
Hydro generation	MW	7,000				AEMO 2022 Integrated System Plan
Pumped hydro & battery storage	MW	1,500				AEMO 2022 Integrated System Plan
TOTAL	MW	42,500				AEMO 2022 Integrated System Plan
NEM CO2 intensity evening/ morning	kg/kWh			0.8		Buildings Alive, generated from NEM fuel-mix data
NEM carbon intensity middle of day	kg/kWh			0.5		Buildings Alive, generated from NEM fuel-mix data

Wholesale price evening / morning	$/MWh			200		Buildings Alive, generated from NEM price data
Wholesale price middle of the day	$/MWh			20		Buildings Alive, generated from NEM price data
Australia's national GHG emissions	kt CO2-e			488,000		DCCEEW
Australia's national GHG emissions from electricity	kt CO2-e			148,500		DCCEEW

Table 2: Calculations of impacts of power shifts in buildings in NEM and SWIS

Consumption (commercial / inst.)	GWh/yr			45,000	20%	**Therefore, around 50% of Australia's annual electricity consumption comes from buildings**
Consumption (residential)	GWh/yr			64,400	29%	
Consumption (non-building uses)	GWh/yr			110,600	50%	
Consumption - ALL	GWh/yr			220,000	100%	Source: derived from https://opennem.org.au (FY22 approx. 200GWh on the NEM and 20GWh on the SWIS)
Demand (commercial / inst.)	MW	8,000	17%			
Demand (residential)	MW	28,000	60%	**Therefore, 77% of Australia's available capacity at peak times is used by residential and non-residential buildings**		
Other demand (at peak times)	MW	10,750	23%			
Dispatchable capacity - AU ALL	MW	46,750	100%			
<u>Assuming peak load shift in buildings of</u>	**33%**					
Peak demand reduction (commercial/in)	MW	2,640	(equiv. peak capacity increase)			
Peak demand reduction (residential)	MW	9,240	(equiv. peak capacity increase)			
Dispatchable capacity from buildings	MW	11,880	**25%**	**would be added to Australia's dispatchable capacity, equivalent to…**		
				52%	**of Australia's existing coal generation capacity**	
				108%	**of existing gas & liquid-fuelled generation capacity**	
				170%	**of existing hydro generation capacity**	
<u>…and assuming peak to daytime load shift is for …</u>	**3**			**792%**	**of existing pumped hydro & battery storage capacity**	
		hours per day, 5 days per week				
Reduction in emissions (commercial/in)	kt/yr	618				

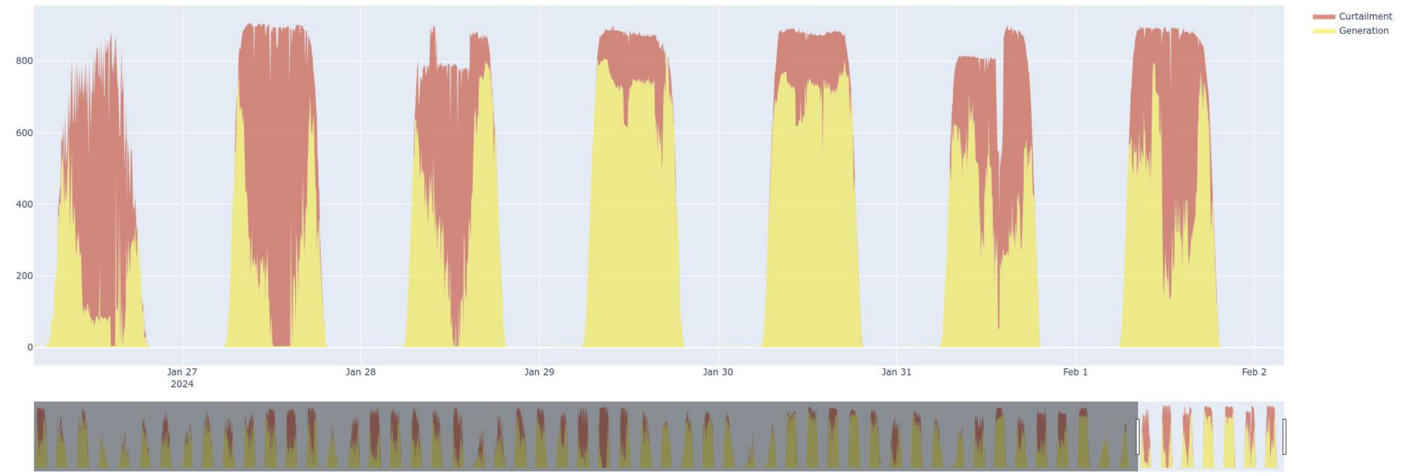
Reduction in emissions (residential)	kt/yr	2,162			
Reduction in emissions from buildings	kt/yr	2,780	**0.57%**	**reduction in Australia's total annual greenhouse gas emissions**	
			1.87%	**reduction in Australia's total annual greenhouse gas emissions from electricity**	
Reduction in electricity supply cost (commercial / inst.)	$ mil	371			
Reduction in electricity supply cost (resi)	$ mil	1,297			
Reduction in electricity supply cost	$ mil	**$1,668**	**Annual reduction in the cost to Australia's commercial, institutional and residential buildings**		

Appendix B: Challenges for Australia's electricity system

Curtailment

Renewable energy in Australia has reached a level where it can be so abundant that it is a challenge to manage. This can result in situations such as negative wholesale power prices and network managers needing to "curtail" solar and wind generation.[22] A typical curtailment pattern for Victoria is illustrated in Figure 1, below, with generation supplied to the NEM in yellow and curtailment in brown.

Figure 1: Curtailment of solar energy generation in Victoria



Source: UNSW Collaboration on Energy & Environmental Markets, unpublished

Capacity constraints

At other times, when industry and household demand peak simultaneously, early in the morning and around sunset for example, the market price of power can increase to extraordinary levels. This spike in demand also places significant pressure on increasingly unreliable, ageing coal and gas fired power stations, as well as the transmission capacity of the grid more generally.[23]

[22] Purtill (2022) 'What is renewable energy curtailment and how does it affect rooftop solar?', *ABC News*, https://www.abc.net.au/news/science/2022-02-16/solar-how-is-it-affected-by-renewable-energy-curtailment/100830738

[23] Rolfe and Tyson (2023) 'NSW power grid under pressure as heatwave continues', *Daily Telegraph*, https://www.dailytelegraph.com.au/news/nsw/nsw-power-grid-under-pressure-as-mercury-soared-on-monday/news-story/e42226f066e4b158c6efb02f3ca9bbc7

Transmission investment

The Australian Energy Market Operator (AEMO), in its Integrated System Plan (ISP) published in June 2022, projected a nine-fold increase in grid-scale wind and solar capacity and a near five-fold increase in distributed solar by 2050. To accommodate this transformation of the Australian electricity system, AEMO called for “urgent efforts” to invest $12.7 billion in currently actionable transmission infrastructure projects. This investment constitutes about 4% of the $315 billion total spend that AEMO projects is “needed to develop, operate and maintain the generation, storage and future network investments of the NEM to 2050” (AEMO 2022, p15).[24]

However, AEMO has also recently stated that project development delays and broader supply chain challenges “have the potential to result in periods of high risk throughout the 10-year horizon”.[25] As noted by AEMO, even if actionable projects “progress as urgently as possible”, in some cases “the optimal timing would be earlier than what is achievable” (p.12).

Large-scale infrastructure investments can be delayed for myriad reasons, including shortages in the availability of labour, skills, finance and materials and also the need to take community and environmental considerations into account. For example, by 2024 Australia was expected have a shortfall of 41,000 engineering professionals required to deliver *currently committed* public infrastructure projects[26] and Weld Australia is forecasting a shortfall of 70,000 welders by 2030.[27]

Cost blowouts to transmission, generation and storage projects, such as the recently announced $10 billion extra for Snowy 2.0 (increasing from $2 billion to $12 billion)[28] highlight the challenge of delivering major infrastructure projects at the rate the clean energy transition requires.

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[24] AEMO (2022). *2022 Integrated System Plan for the National Electricity Market*. https://aemo.com.au/-/media/files/major-publications/isp/2022/2022-documents/2022-integrated-system-plan-isp.pdf?la=en

[25] AEMO (2023). *2023 Electricity Statement of Opportunities*. https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2023/2023-electricity-statement-of-opportunities.pdf

[26] Infrastructure Australia. (2021). *Infrastructure workforce and skills supply: A report from Infrastructure Australia's Market Capacity Program*. https://www.infrastructureaustralia.gov.au/sites/default/files/2021-10/Infrastructure%20Workforce%20and%20Skills%20Supply%20report%20211013.pdf

[27] Margolis, Z. and L. Waterson. (2022, November 24). *Australia needs 70,000 more welders by 2030 to help power renewable energy shift, Weld Australia says*. ABC News. https://www.abc.net.au/news/2022-11-24/70-000-welders-needed-in-australia-by-2030/101689142

[28] Lowrey, T. (2023, 31 August). *Snowy Hydro expansion hits reset button as costs blow out to $12 billion*. ABC News. https://www.abc.net.au/news/2023-08-31/snowy-hydro-reset-project-to-cost-12-billion/102797650

Decreasing renewable energy investment returns

Because non-dispatchable and variable renewable energy generators like wind and solar rely on the weather, they must use financial instruments or storage technologies to manage their market exposure and access the most favourable pricing. Alternatively, they can just "curtail" their supply by disconnecting from the grid at times when weather conditions are good and wholesale power prices are low.

All of these approaches are costly and discourage investment because they diminish investment returns. By contrast, if "firming" can instead be provided by shifting demand according to the availability of clean energy, the wholesale market price becomes more stable. Excess generation at times of high wind and solar availability will be taken up by buildings at a fair price to the generators, thus enhancing their investment returns and driving more investment.

Overinvestment in supply

The dominant approach to meeting spikes in demand has been to increase supply from large, industrial power plants, often at great expense. This has led to a situation where coal and gas fired power stations need to remain online despite only being necessary for brief periods of peak demand. At times of peak demand, prices also peak to exorbitant levels, which are passed on to households and commercial energy users.

This energy security dilemma has been the main justification used for the potential extension of the Eraring coal fired power plant beyond its intended closure date of August 2025.[29] Any potential extension is expected to come at a significant cost to NSW taxpayers,[30] but that will pale into insignificance when compared with the impacts on human health, the environment and economic activity, which has a predicted annual cost of $1.7 billion.[31]

[29] Hannam and McLeod (2023) 'NSW to enter talks to extend life of Eraring, Australia's largest coal-fired power station', *The Guardian*, https://www.theguardian.com/australia-news/2023/sep/05/eraring-coal-fired-power-station-nsw-government-in-talks-to-extend-operation

[30] Williamson (2024) '"Unconscionable:" Eraring delay could cost $150m a year, adding to massive Origin windfall, report says', *RenewEconomy*, https://reneweconomy.com.au/unconscionable-eraring-delay-could-cost-150m-a-year-adding-to-massive-origin-windfall-report-says/

[31] Whitson (2023) 'Analysis finds extending Eraring's lifespan could cost $1.7 billion in damages a year', *ABC News*, https://www.abc.net.au/news/2023-09-28/analysis-eraring-lifespan-1-7-billion-damages-annual-coal-730/102901044

Appendix C: What is a grid-interactive efficient building?

A grid-interactive efficient building (GEB) is a fully-electric building capable of providing energy-efficient building services and dynamic grid services through connected, smart control of multiple flexible building loads and distributed energy resources (DER).[32]

As outlined by the American Council for an Energy-Efficient Economy (ACEEE), GEBs can be viewed from two perspectives: that of the individual building system, and that of the building as part of the grid system.[33] From a building systems perspective, GEBs are first and foremost energy efficient and fully electric. They are well insulated, have energy-efficient windows, and use highly efficient mechanical and lighting systems. They also use electricity for all their energy needs. GEBs leverage advanced technology like smart equipment, sensors, and controls to optimise energy use based on occupancy, weather, and a whole range of other factors. In the commercial sector, these controls go a step further, to encompass an energy management and information system (EMIS) and building management and control systems (BMCS).

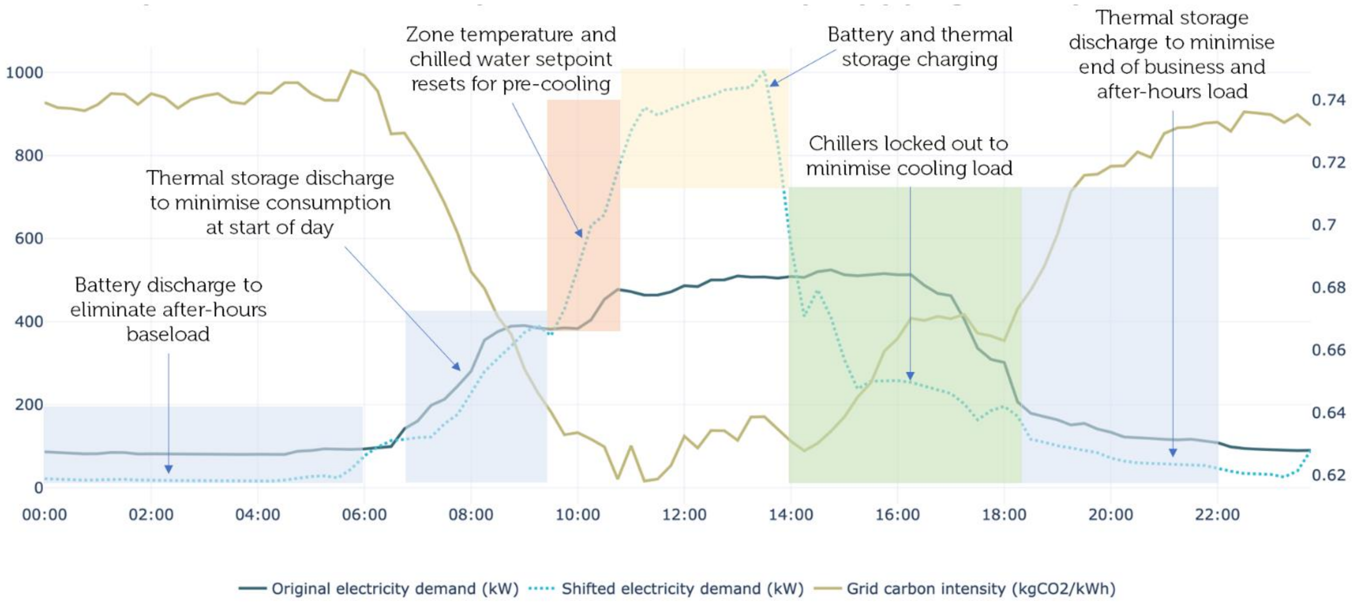
GEBs differ from an efficient smart building in a key way: their ability to connect and interact with the local grid system. The two-way flow of information between the grid and a GEB enables the building to act as a flexible resource for grid managers. For instance, the building can draw on energy storage when the grid is at peak use, thereby shifting its load. It can also reduce load during peak times, such as through lighting control or reducing HVAC energy consumption during peak times. Grid-interactive buildings can respond to time-dependent grid needs, making them a part of the evolving electricity grid. The ability to communicate with the grid in real-time allows for smarter energy consumption and reduced carbon footprint.

The functions and timing of a GEB are illustrated in Figure 2 below.

[32] For an introduction to Grid-interactive Efficient Buildings in the Australia context, see Green Building Council of Australia, 2023, *From net zero to zero: a discussion paper on grid-interactive efficient buildings*, https://new.gbca.org.au/green-star/green-star-strategy/electrification/#geb

[33] https://www.aceee.org/sites/default/files/pdfs/gebs-103019.pdf

Figure 2: Electricity demand with load flexibility for a commercial office building in Sydney during Spring / Autumn



Source: Buildings Alive, unpublished

Grid-interactive buildings support advanced monitoring and control for buildings and community energy systems. They are characterised by several capabilities, such as co-optimising multiple end-uses (lighting, HVAC) and DERs, including generation and storage. They optimise operations over a time window and incorporate predictions about relevant inputs into the optimisation. This capability allows buildings to leverage storage and other sources of scheduling flexibility to shape energy use over multiple time scales to respond to grid needs while minimising negative impacts on occupants.

Approximately 50% of Australia's electricity is consumed in buildings, and at peak times buildings account for about 77% of network demand. One of the most significant benefits of grid-interactive buildings is their flexibility in providing dynamic load control to support the electricity grid. They can shed, shift, and modulate loads, which provide ancillary services such as frequency regulation and voltage control. In general, fast responding controls, communications, and loads can provide a broader set of grid services.

Our analysis demonstrates that much of the built environment's electricity demand, particularly in commercial office and retail buildings, can be shifted. Our findings were consistent across all buildings analysed in all locations: demand from buildings can be *doubled* during times of abundant clean energy and *halved* at times when networks are constrained and renewable energy is scarce. The opportunities this presents for reducing greenhouse emissions, improving grid stability, and minimising the cost of the clean energy transition are profound and growing.

Appendix D: Why Australia's electricity system needs grid-interactive efficient buildings

To achieve the Australian Government's goal of 82% of energy in the National Electricity Market (NEM) being sourced from renewables by 2030, the entire grid will need to operate for extended periods with generation from wind and solar exceeding demand, i.e., at 100% renewables. To provide the power systems capable of supporting this new and very different operating environment, the AEMO is developing an engineering framework that assumes the penetration of renewables will reach 100% for brief (approx. half-hour) periods as early as 2025.[34] AEMO's Engineering Roadmap addresses this challenge under the assumption that there will be little or no active demand-side contribution made by buildings, or the built environment more broadly, for the foreseeable future.

While AEMO's modelling takes into consideration the energy efficiency policies of state and federal governments, currently there are no policies to harness the potential for grid-interactive efficient buildings. AEMO has therefore had to assume an unnecessarily high cost to provide additional generation, storage and network infrastructure. As noted above, recent project blowouts suggest the full cost will be even higher.

New data from the US Department of Energy's Lawrence Berkeley National Laboratory and energy consulting firm Brattle Group shows that efficient, grid-responsive buildings would make a zero-carbon grid $100B USD cheaper per year — if utilities and policymakers can act in time.

> Utilities and policymakers have little time to waste if they hope to capture the full cost-cutting value of more efficient and grid-interactive buildings. If they lack confidence that buildings are really getting more efficient and better at demand flexibility, they'll simply have to build the additional generation and grid capacity needed to meet the peak loads they expect over the years to come. And doing so requires them to spend money that more efficient and flexible buildings could help them save.[35]

[34] AEMO (2022). *Engineering Roadmap to 100% Renewables*. https://aemo.com.au/-/media/files/initiatives/engineering-framework/2022/engineering-roadmap-to-100-per-cent-renewables.pdf

[35] St. John, J. (2023, 22 August). *Why efficient buildings are key to decarbonizing the power grid*. Canary Media. https://www.canarymedia.com/articles/energy-efficiency/why-efficient-buildings-are-key-to-decarbonizing-the-power-grid

Appendix E: Why buildings have not been helping with the clean energy transition

With a few possible exceptions, grid-interactive efficient buildings do not exist in Australia currently and there are three main barriers holding back their emergence:

1) Lack of financial incentives
2) No compliance or reporting obligations
3) No opportunity for reputational benefit.

During the 1990s in the decade leading up to the launch of the National Australian Built Environment Rating System (NABERS), when energy efficiency standards in commercial buildings were plummeting (and being forecast to get worse),[36] only barriers 2 and 3 were standing in the way of a turn-around. Barrier 1 was not a problem for building owners and operators because they could save money by saving energy.[37] Unfortunately, while there is now a clear correlation between the emissions intensity of the electricity grid and the wholesale market price (cleaner is cheaper), both of which vary every five-minutes, price signals generally do not get passed through to end users because the rates they pay are fixed in contracts. Building owners do have the option to engage directly with the wholesale market if they wish, but most perceive this as too risky given the volatility in prices caused by inelastic demand – a classic chicken/egg problem. This problem will go away when building owners perceive the reputational benefits from reducing emissions as being greater than the risk of price uncertainty (noting that load-flex reduces the risk).

Likewise, over the past two decades a variety of compliance and reporting programs have emerged in Australia and internationally that require (or allow) demonstration of progress in reducing greenhouse emissions from building operations. The Carbon Disclosure Project (CDP), the Carbon Risk Real Estate Monitor (CRREM) and Australia's National Greenhouse and Energy Reporting (NGER) scheme are examples. None of these systems consider the time-varying carbon intensity of electricity, although the Australian Government has indicated it will develop a Guarantee of Origin (GO) scheme to align with the European

[36] The Cabinet Office New South Wales (1999, 17 September). *NSW Government Submission to The Productivity Commission Research Study on Improving the Future Performance of Buildings*. https://www.pc.gov.au/inquiries/completed/building-performance/submissions/the_cabinet_office,_nsw/sub025.pdf.

[37] Although there were inconsistencies. Building owners could save money by operating inefficient thermal storage systems with cheap off-peak power pricing designed to support the 24/7 operation of coal power stations – a practice that NABERS was responsible for near-eliminating.

Union’s recently introduced Renewable Energy Directive (REDIII) that requires time and location matching for renewable energy claims. There is, however, no indication that compliance schemes will drive progress on grid-interactive efficient buildings in Australia this decade.

These twin problems represent an opportunity to harness the potential of buildings to work as batteries. By changing the time that energy is used in commercial buildings, energy security can be improved with minimal intervention and investment.

Appendix F: The way we measure (and incentivise) building performance needs to change

NABERS is Australia's leading building performance rating scheme. It has widespread adoption across building sectors including hotels, shopping centres, apartments, offices, data centres, and NABERS ratings are integrated into Australian Government disclosure schemes including the Commercial Building Disclosure scheme and the Net Zero in Government Operations Strategy.[38] NABERS is recognised globally as one of the most credible and effective tools for rating the operational impact of buildings.

When NABERS was launched almost 25 years ago,[39] Variable Renewable Energy (VRE) did not exist in Australia. Coal accounted for 96% of generation on the NEM, gas accounted for about 3% and hydro was less than 1%. Fast forward to 2024, and over the past year VRE, primarily from wind and solar, has provided 31% of electricity supplied across the NEM. VRE only exceeded 1% of the NEM's supply mix for the first time in 2010, at exactly the mid-point in the history of NABERS.

As noted by the NSW Government in its 1999 submission to the Productivity Commission's *Improving the Future Performance of Buildings* study, the scheme's objective was "for commercial buildings to stimulate market demand for improved cost, energy and greenhouse performance".[40]

> The rating is based on greenhouse emissions rather than energy. A greenhouse rating allows flexibility of fuel switching as well as technology improvements to improve a building's rating. The greenhouse rating is outcome focussed and it compliments other initiatives under the National Greenhouse Strategy. An important component of the scheme is communicating the linkages between design, cost, energy consumption and greenhouse gas emissions.

Back in 1999, the generation of each kilowatt-hour of electricity supplied on the NEM required just over a kilogram of CO_2 to be released into the atmosphere. Emissions intensities varied between states, but they did not vary over time. Every kilowatt-hour used or saved had a constant and directly proportional greenhouse emissions impact. Utility bills

[38] https://www.finance.gov.au/government/climate-action-government-operations/aps-net-zero-emissions-2030

[39] By the NSW Government on 2 September 1999 as the Building Greenhouse Rating (BGR) scheme. It subsequently was renamed the Australian Building Greenhouse Rating (ABGR) before being NABERS.

[40] Ibid, The Cabinet Office New South Wales (1999, 17 September).

(which were made of paper and came in the mail) did not quantify the volume of emissions, however they did report energy use. It was therefore a simple task for NABERS to rate a building's greenhouse emissions intensity by applying a fixed conversion factor to a measured amount of energy use. This approach was consistent with the scheme's stated objective of reducing greenhouse emissions by providing a clear market signal about the performance of buildings.

With the emergence of VRE over the past 15 years, the relationship between electricity use and greenhouse emissions has decoupled. In NSW last week (26 March 2024), for example, carbon pollution from each kilowatt-hour of electricity ranged from 846g CO_2-e/kWh at 6:30AM to 500g at midday, i.e., electricity was 41% cleaner at midday than it was at 6:30AM. In South Australia on the same day, a kilowatt-hour saved (or used) between 11:00am to 4:00pm had virtually no impact on greenhouse emissions at all, because the grid was being supplied almost exclusively from wind and solar power. In contrast, just a few hours earlier, at 7:30am, 40% of South Australia's electricity was being imported from Victoria, and most of that was generated by burning brown coal in the Latrobe Valley with an emissions intensity of well over 1,000g CO_2-e/kWh.

Data is readily available, and you can see this variability and compare it with California and the UK on the landing page of Buildings Alive's website: https://buildingsalive.com/.