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To cite this article: Bradley Riley, Lee V. White, Simon Quilty, Thomas Longden, Norman Frank-Jupurrurla, Serena Morton Nabanunga & Sally Wilson (2023) Connected: rooftop solar, prepay and reducing energy insecurity in remote Australia, *Australian Geographer*, 54:3, 325-346, DOI: [10.1080/00049182.2023.2214959](https://doi.org/10.1080/00049182.2023.2214959)

To link to this article: <https://doi.org/10.1080/00049182.2023.2214959>



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Published online: 09 Jun 2023.



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RESEARCH ARTICLE



Connected: rooftop solar, prepay and reducing energy insecurity in remote Australia

Bradley Riley ^{a,b*}, Lee V. White ^{b,c*}, Simon Quilty ^{d*}, Thomas Longden ^{b,e*}
Norman Frank-Jupurrurla ^{f*}, Serena Morton Nabanunga^{f*} and Sally Wilson ^{c,e*}

^aCentre for Aboriginal Economic Policy Research, ANU, Canberra, Australia; ^bZero Carbon Energy for the Asia Pacific Grand Challenge, ANU, Canberra, Australia; ^cSchool of Regulation and Global Governance, ANU, Canberra, Australia; ^dResearch School of Population Health, ANU, Canberra, Australia; ^eCrawford School of Public Policy, ANU, Canberra, Australia; ^fJulalikari Aboriginal Corporation, Tennant Creek, NT, Australia

ABSTRACT

'It's a good life, that solar'.

Australia is a world leader in per-capita deployment of rooftop solar photovoltaics (PV) with more than three million households realising benefits including reduced energy bills and improved energy security. However, these benefits are unevenly distributed. Research shows First Nations residents of public housing in remote Australia using prepay metering experience frequent 'self-disconnection' from energy services, a known indicator of energy insecurity. Upfront capital costs and an absence of local regulations codifying the ability to connect solar PV have long locked out these households from realising benefits of energy transition in regions host to world class renewable energy generation potential. This article describes early experiences of those residents among the first to install and grid-connect rooftop solar to prepay in Australia's remote Northern Territory. In addition to reduced electricity expenditures, rooftop solar PV mitigates experiences of energy insecurity through reducing the incidence of involuntary 'self-disconnection' due to inability to pay. Support for rooftop solar for prepay households can alleviate frequent exposure to disconnection, bringing multiple co-benefits. Policy responses should focus on reducing barriers to realising the benefits of rooftop PV for priority communities, including First Nations families living in public housing using prepay.

ARTICLE HISTORY

Received 23 December 2022

Accepted 14 May 2023

KEYWORDS

Prepay; solar PV; energy insecurity; disconnection; self-disconnection; First Nations

CONTACT Bradley Riley  Bradley.Riley@anu.edu.au  Centre for Aboriginal Economic Policy Research, Australian National University, Canberra, Australia 2612

*Bradley Riley, Lee White and Thomas Longden are research fellows at the Australian National University's *Grand Challenge: Zero-Carbon Energy for the Asia-Pacific*. Simon Quilty works for Purple House, an Indigenous not for profit health service that specialises in the provision of dialysis in remote communities. Warungu community elder Norman Frank Jupurrurla and Serena Morton Nabanunga acknowledge benefitting from the pro-bono electrical work facilitating the current case study. Installation of solar PV was wholly funded by registered charity Original Power. Sally Wilson is a PhD candidate at the Crawford School of Public Policy.

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Introduction

Access to reliable and affordable clean energy is a fundamental prerequisite to achieving valued health, wellbeing, and social outcomes, as recognised by Sustainable Development Goal (SDG) 7 and the principles of energy justice (UN 2023; Pellicer-Sifres, Simcock, and Boni 2021; Sovacool and Dworkin 2015). Yet energy poverty remains a known risk globally, with many groups lacking electricity access or being unable to adequately meet basic household energy needs, even in countries considered developed (Dobbins et al. 2019; Bednar and Reames 2020; UN 2023). Energy insecurity (broadly synonymous with energy poverty) is a term that reflects this lived experience, wherein the absence or disruption of access to energy impacts negatively upon households' everyday lives (Hernández, Yoon, and Simcock 2022; Hernández 2013). Measures to address energy insecurity represent an important area of research (Powell 2015; Sovacool and Dworkin 2015; Sovacool et al. 2016), and are recognised as critically relevant to First Peoples' self-determination, health and wellbeing in settler colonial contexts where energy access and infrastructures have long been organised differentially based on geography and race (Sovacool et al. 2021; Henderson and Sanders 2017; Powell 2018; Gilmore 2022; Avila-Calero 2017).

In Australia, First Peoples are among those disproportionately affected by household energy insecurity and the compounding impacts of climate change, with impacts for household energy needs (Longden et al. 2021). In remote and regional First Nations communities, where prepaying for access to household energy services is common, research has shown that energy insecurity is amplified by extreme temperatures through increased reliance upon necessary heating and cooling services, compounding risk for those already experiencing energy insecurity in non-interconnected geographies (Longden et al. 2020, 2022). Moreover, while avoiding disconnection from energy services can be challenging under prepay, so too can be realising the benefits associated with the transition to renewable energy (Napaltjari-Davis et al. 2022; Riley 2021; Dwyer and Vernes 2016). Locally abundant solar resources have the potential to mitigate experiences of frequent self-disconnection due to an inability to pay, while contributing to environmental co-benefits through emissions reductions, but this potential is as-yet poorly explored. In this article we examine a case study, identifying challenges and opportunities for public housing residents using prepay seeking to install solar and providing a preliminary discrete example of navigating these. Our interest is in advancing understanding of the potential for rooftop PV to mitigate energy insecurity, through an examination of changes in energy costs and subsequent changes in rates of involuntary self-disconnection from electricity.

Background

This case study of rooftop solar for prepay describes experiences of authors Serena Morton Nabanunga (SMN) and Norman Frank Jupurrurla (NFJ), tenants of House 4, Village Camp, Tennant Creek (Jurnkkurakurr) in Australia's remote Northern Territory (NT). Their voices are heard via direct quotes used throughout this paper.

Location

Tennant Creek is one of the NT's four major towns, located between the capital city Darwin (Garamilla) to the north and Alice Springs (Mparntwe) to the south, marking

the intersection of the Stuart and Barkly Highways. Tennant Creek serves the largest concentration of residents in the Barkly region, a vast, culturally and resource rich province, encompassing more than 323,514 square kilometres – roughly the size of the United Kingdom or New Zealand (Barkly Regional Council 2023). With an official population of 2,949 people, the town of Tennant Creek represents approximately 2.9% of the total population of the Northern Territory; over half (55%) of all residents are Indigenous (ABS 2021). A distinct feature of major towns across the NT are discrete Indigenous living areas known as Town Camps and Tennant Creek has 7 recognised Town Camps including Village Camp, where authors SMN and NFJ live. Within Town Camps, all residents live in public housing whereas across the township 10% of homes are owned outright and 60% are rented (APH 2019; ABS 2021). Climatically, the town is in the tropical, semi-arid, low rainfall zone, experiencing temperature extremes during hot, dry summer months followed by mild winters (BOM 2023). The region has long featured in the development plans of Australian governments and their industrial partners and the latest iteration of this is the Beetaloo Strategic Basin Plan, part of the gas-fired recovery strategy launched in response to the COVID-19 economic downturn (DISER 2021; Barkly Regional Council 2023). More recently First Nations homelands in the region have attracted interest from large-scale, privatised clean energy developers (O'Neill et al. 2021; Hannam 2022). The region sees almost 300 sunny days per year and is host to some of the clearest skies and highest solar potential in the world (see Figure 1).

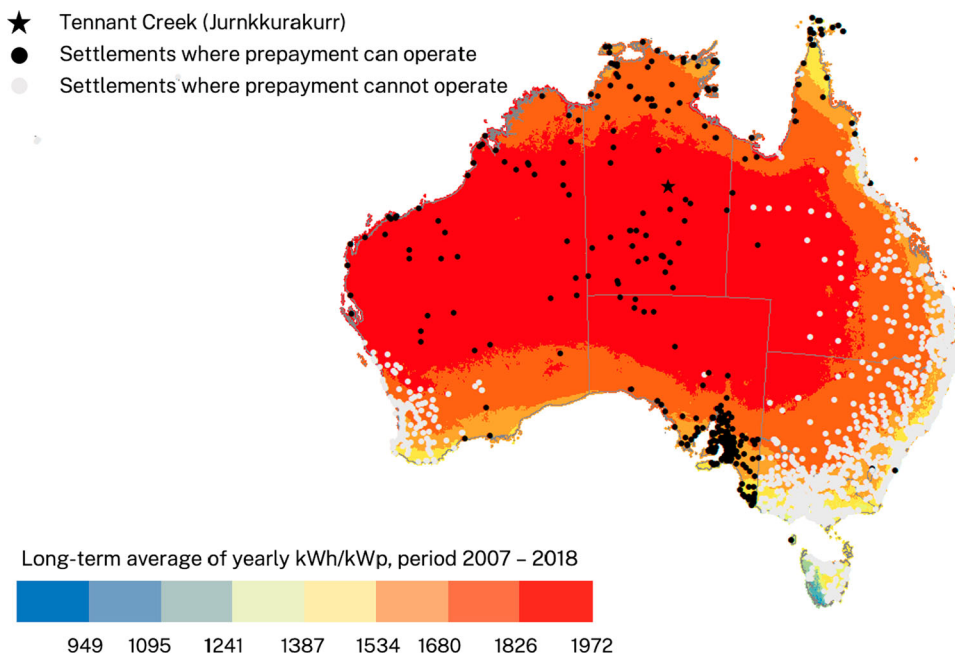


Figure 1. Figure 1 Solar PV potential (kWh/kWp) and those settlements where prepayment can operate (original dataset).

Note: Map of Australian Photovoltaic Potential via Global Solar Atlas, <https://solargis.com/maps-and-gis-data/download/australia>. licensed by The World Bank under the Creative Commons Attribution license (CC BY 4.0). Only settlements with estimated resident population of >200 are represented in dataset.

Prepaid electricity

Prepaid household electricity is prevalent in many First Nations communities in remote Australia, however its use is prohibited in Australia's most populous states. Estimates suggest that approximately 15,000 First Nations households use prepay in non-interconnected regions including in north-west Western Australia, off-grid parts of Queensland, South Australia and the remote Northern Territory – where the innovation of prepay provided an ‘individualized, market-based, low trust’ (Tooze 2023) mechanism to facilitate the introduction of user pays for essential services in remote Aboriginal communities starting in 1992 (Riley 2021; Ings 2020). Prepayment ‘flips the risk’ so that customers prepurchase the electricity they are going to use as ‘hard-pressed customers extend an advance (to the utility) not the other way around’ (Tooze 2023). Moreover, customers who prepay for electricity have fewer rights and protections than customers who post pay, reflecting both the relative rarity of prepay in Australia and the different regulatory frameworks that have evolved iteratively and are arranged spatially across the nation's federation of six states and two self-governing territories (QCOSS 2014). Remedial policymaking typically resides with the state and territory governments, while available protections find greatest effect within the consensus oriented cooperative arrangements of the National Energy Market (NEM) – which spans Australia's eastern seaboard and where a relatively harmonised customer protection framework operates through the National Energy Customer Framework (NECF). Beyond the NEM, regulatory frameworks differ between and within jurisdictions and result in a complex mosaic of consumer protections.

In the NT, electricity supply is regulated differently between major networks and remote, isolated networks. Tennant Creek is located in a regulated region where electricity is generated by a 19.8MW gas-fired power station and supplied via one of the territory's four main regulated networks by the NT's sole licensed network operator, Power and Water Corporation (PWC) (PowerWater 2022; Territory Generation 2022) (see Figure 2). Jacana Energy (Jacana) is the primary retailer for residential customers in Tennant Creek and across the regulated networks, where both post and prepay metering options are available under a standard retail contract (Jacana Energy 2023; Northern Territory Utilities Commission 2021; NT Utilities Commission 2020a; 2019).

Customer numbers by metre type are not publicly available at the township level, however, prepay is typically the default payment system for Indigenous public housing in the NT and residents of Village Camp House 4 have long prepaid for access to electricity. Operationally, households mandated or electing to use prepay pay upfront for their electricity before consuming it and once depleted a modest loan of emergency credit (around \$20) becomes available. Upon expiry of all available credit, households are de-energised and residents must ‘top-up’ by purchasing credit from community stores.

NFJ: We go about a mile past the north end of town to ‘top-up’ (pay for power). That’s how it happens. Get a taxi, go pay for power, come home. It’s too much. I’m only on a pension, I only get paid so much each week.

Credit is first used to repay any accrued debt before household energy services are recommenced (Greally 2022; Dwyer and Vernes 2016). In the NT prepay customers pay the

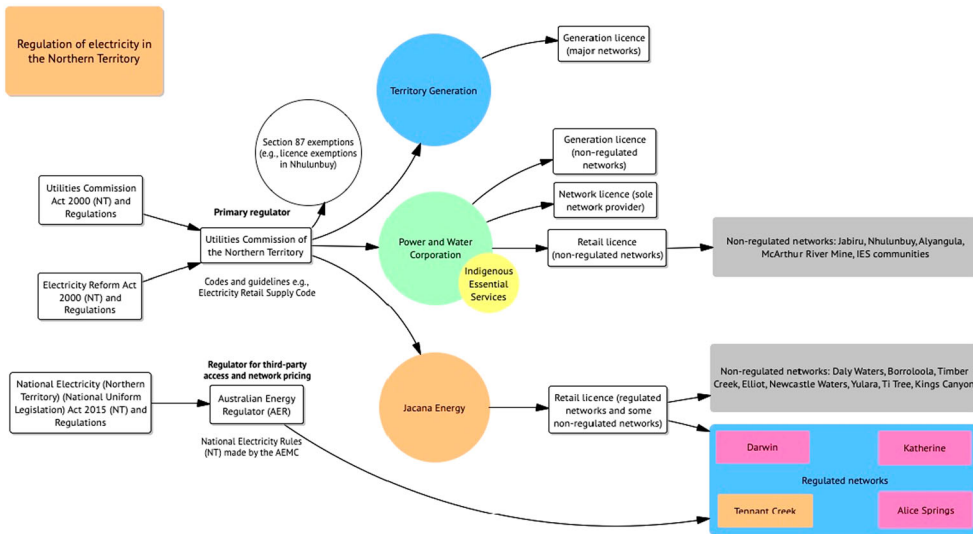


Figure 2. The Northern Territory Electricity Regime. Power and Water Corporation is the sole licensed network provider for regulated networks and non-regulated networks in the NT. In regulated networks, Jacana Energy is the primary retailer for residential customers. The local electricity regulator is the Utilities Commission of the Northern Territory.

domestic prepaid tariff of 30.0941 cents per kilowatt hour, a premium of 2.7211 cents per kilowatt hour above the standard tariff of 27.373 cents per kilowatt hour on the basis that the tariff includes a fixed daily supply component (see Figure 3). The reported benefits of prepay chiefly relate to the avoidance of energy debt and improved flexibility in the distribution of energy costs, while the ongoing risk faced by prepay households is that of immediate ‘self-disconnection’ for non-payment (‘Prepayment Electricity Metres’ 1937; Riley 2021; K. O’Sullivan, Howden-Chapman, and Fougere 2015).

Self-disconnection as indicator of energy insecurity

For the many First Nations residents of remote communities and towns where prepay is ubiquitous, household energy security has long been far from guaranteed. Prior to the

Power tariffs

Domestic

Standard meter

27.373 cents per kilowatt hour plus fixed charge of 53.96 cents per day.
Amount (GST inclusive)

Prepayment meter

30.0941 cents per kilowatt hour includes a fixed daily charge.
Amount (GST inclusive)

Figure 3. Power tariffs in the NT.

Note: <https://www.powerwater.com.au/customers/remote/power-pricing-and-tariffs> accessed 12th December 2022.

COVID-19 pandemic, research by Longden et al found that for 3300 households living in 28 communities in the Northern Territory where prepay is mandated, involuntary self-disconnection events were experienced by almost all (91%) households during the 2018/19 financial year, while almost three quarters (74%) of households were disconnected more than ten times (Longden et al. 2022). The percentage of days in the study sample ($n \sim 1,045,725$) with any type (same-day or multi-day) of disconnection across all regions (equatorial, coastal tropical, savannah, hot persistently dry grassland) was 10% (Longden et al. 2021). Moreover the case study that is the focus of this article took place during a period when rates of energy insecurity among prepay customers in the NT were observed by the local electricity regulator, the Utilities Commission of the Northern Territory ('Commission'), as having deteriorated (Utilities Commission of the Northern Territory 2022). The Commission's Electricity Retail Review 2020/2021 offers a glimpse of the extent of issues precipitating the case study, reporting on self-disconnection numbers for prepay households residing in the major centres of Tennant Creek, Darwin, Katherine and Alice Springs. The report shows that during 2019/2020, 2,049 households recorded 69,888 self-disconnection events. This represents 34 disconnections per metre for an average duration of 380 min (Klerck 2020; NT Utilities Commission 2020b). In 2020/2021 this increased to 84,439 self-disconnection events experienced by an expanded cohort of 2,173 households, or approximately 39 disconnections per prepay metre for an average duration of 504 min. This prompted the Northern Territory Utilities Commission to note:

in isolation and with limited comparison to historical data, the total number of disconnections and their duration appears very high and (the utilities commission) concede(s) that the deterioration in energy security across 2020/21 for pre-pay households is concerning (NT Utilities Commission 2021, 7).

Energy insecurity indicated by self-disconnection is linked to a host of negative health and wellbeing impacts, and likely amplifies negative outcomes for those already experiencing disadvantage (K. C. O'Sullivan et al. 2013; Bhattacharya et al. 2003; Dudley 2022). Prior studies show that chronic disease and heat stress can combine to exacerbate morbidity and mortality (Longden et al. 2020). The importance of reliable access to electricity in relation to human health and development irrespective of capacity to pay, is regularly highlighted in the literature, as are the potentially punitive effects attending disconnection (Baker, Carley, and Konisky 2021; Climate Council 2014). This is particularly so for the very young, the elderly or those who are unwell or have underlying health issues (Bednar and Reames 2020; K. O'Sullivan, Howden-Chapman, and Fougere 2015).

NFJ: *When it is coming up to summer, for these kids – electricity is number 1, food number 2, fuel number 3.*

The interactions between extreme heat, energy-use and health and wellbeing are explained by author SMN, who regularly takes measures to save on energy costs in order to keep her family cool when temperatures rise past 40 °C at her home in Tennant Creek.

SMN: *It's not uncommon for the family to sleep in one room to reduce air-con use over-night. Or we'll relocate mattresses outside on hot nights. Extreme heat is making life*

hotter and harder for our people. The power cuts combined with extreme heat and hot housing are all impacting on community health and wellbeing.

Within regulated energy markets in Australia, the impacts of disconnection are recognised within legislative guidance recommending that disconnection due to an inability to pay is a risk best avoided, and only ever a measure of last resort (Australian Energy Regulator 2021). Consequently, within jurisdictions regulated by the NECF less than 1% (<61,000) of more than 6.7 million households in the NEM are recorded as experiencing a single disconnection event within an annual reporting window (Australian Energy Regulator 2019). By way of contrast, the energy insecurity of prepay customers living in non-interconnected regions is rarely tracked or disclosed in a transparent or organised way. Self-disconnections are therefore often less visible and less readily advertised in public facing utility reporting (Dwyer and Vernes 2016). As observed by Ruiters (2007) ‘the direct effect of prepayment has been to remove the public visibility and awareness of disconnections ... and to ‘privatise’ that decision within the lives of the poorest households. Prepayment systems allow companies to escape the public opprobrium which disconnection brings’ (Ruiters 2008; 2007).

Rooftop PV and prepay?

NFJ: *In Tennant Creek at the moment, only rich people have got solar.*

According to the International Energy Agency, Australia has the highest rate of installed solar PV capacity per capita in the world (IEA 2022). The percentage of dwellings with solar PV installations varies by state/territory and by postcode (APVI 2023). A significant factor in the success of rooftop solar in Australia is that it provides an asset class readily accessible to homeowners – they own the roof and the walls upon which to install the required hardware, and they accrue the benefits directly. Moreover, private ownership of housing in Australia is a source of wealth and access to upfront capital is a crucial prerequisite to solar installation. Owner-occupiers are seven times more likely to have access to rooftop solar than renters, while one in three Australians are renters (including those in public housing) (Best 2022; Best, Burke, and Nishitatenno 2019; Hammerle and Burke 2022). Only 4% of rental households have solar PV (Hammerle and Burke 2022). Split incentives occur when the capital cost of installation is borne by the homeowner while the benefits (in lower electricity bills) accrue to tenants, dissuading investment. Calculating the relative benefits of installation therefore requires renters remain tenants over longer terms. In this context, the value proposition of installing solar relates to the capacity for and commitment to, benefit sharing (Sturmberg and Cumming 2018). These factors are particularly salient for First Nations communities in Australia’s remote Northern Territory, where costs are higher and the savings from deferred investment greater, where the Northern Territory Government acts as the landlord and monopoly energy provider, and where land is often communally held and there is no private housing market (F. Markham and Klerck 2022).

In this case study the network provider PWC had no existing precedent to easily facilitate connection of solar with prepay metering, and the initial (solar) connection application was rejected on the basis of regulatory and technical barriers related to a lack of institutional knowledge about the compatibility of solar and prepay, as well as the

absence of a prepaid metering option on the relevant paperwork (Mellor 2022). This uncertainty about project sequencing and the lack of an applicable feed-in tariff (FiT) meant delays in connecting the system and in receiving payment for exports, precipitating a complex set of negotiations between residents and their advocates, the electricity distributor and (separately) the retailer, preceding installation. PWC and Jacana subsequently committed to ensuring the project progressed on the basis of cooperating on a trial led by Original Power, for the purpose of integrating rooftop solar PV and prepay.

Connection agreements are a prerequisite for customers to sell the excess energy they generate to the utility. Without a connection agreement rooftop solar cannot be connected to the grid (or local standalone network as the case may be) for load balancing through import and export. The presence or absence of standard connection agreements is recognised as a key factor enabling or inhibiting the amount and types of renewable energy adopted, effectively governing who and where benefits in energy transition (Theo et al. 2017). Key features of best-practice interconnection standards include clear parameters; no unnecessary limits on system size; applications streamlined according to complexity, enabling small system applications to be fast-tracked; reasonable timeframes; and well explained interconnection and engineering charges (Mercure et al. 2021; Wilkinson, John, and Morrison 2021; Energy Networks Association 2022; Hess and Lee 2020). In the NT, the government-owned network provider PWC is responsible for the installation of electricity metering, including prepay metering. Separately, the Department of Territory Families, Housing and Communities (DTFHC) is responsible for approving all works including permission to install rooftop solar on Territory owned, Council managed housing. In this case study DTFHC required an engineer's report verifying structural integrity of the roof and walls as built, to facilitate installation of rooftop PV. DTFHC required the tenants (NFJ and SMN) sign a tenancy variation committing to fund the removal of all solar panels and balance of system components, should the family discontinue tenancy.¹ Liability for these expenses associated with verifying structural integrity, as well as necessary system maintenance and potential future removal were all assured by (registered charity) Original Power, for the purpose of the trial.

NFJ: *The community has noticed, they talk about our house, they say 'how come you've got solar?'. I explain we had to put up a lot of arguments ... to government, to the housing mob, to Power and Water, to get solar on my roof. The journey here has been a long one, we're really pleased to see that the Northern Territory government is coming to the table. It's taken a lot of persistence and leadership by Original Power and others.*

Method

Our research methodology is based on the principles underpinning ethical Australian Indigenous research as expressed in the Australian Institute for Aboriginal and Torres Strait Islander (AIATSIS) Code of Ethics for Aboriginal and Torres Strait Islander Research including; Aboriginal and Torres Strait Islander self-determination, leadership, impact and value, sustainability and accountability ('AIATSIS Code of Ethics for Aboriginal and Torres Strait Islander Research' 2020; Coghlan and Brydon-Miller 2014). Authors of the current article include Norman Frank and Selena Morton who are both Tennant Creek based Warumungu Traditional Owners, the rest of our team are non-Indigenous researchers based at the Australian National University while SQ also

works for the Indigenous not-for-profit health service Purple House in Central Australia. For the current research article our team worked alongside Aboriginal-led charity Original Power. Here we adopt a mixed methods approach (Creswell and Plano-Clark 2018) where First Nations people participate in setting the research agenda and relevant aspects of the research, in order to provide early-stage analyses of the benefits of installing rooftop solar for prepay. The following sections summarise the relevant project details, including costs and processes for installation and the methodology for performing quantitative and thematic analyses.

Project details

During the COVID-19 pandemic, the Aboriginal-led registered charity Original Power raised funding totalling \$10,134, with the aim of spearheading the demonstration project focused on improving access to renewable energy for prepay customers living in NT public housing (Mellor 2022). Motivated by the wish of (authors) NFJ and SMN to reduce household energy expenses and avoid frequent disconnections, Original Power helped the family install $22 \times 300\text{W}$ panels (6.6 kW) on the roof of their government owned, council-managed single-story, three-bedroom house (see Figure 4 (a) and (b)). Collaborative planning efforts between authors, relevant authorities and contractors enabled Original Power to install 6.6 kW of PV and a 10 kW (battery ready) inverter in early July 2021. A cooperative trial was agreed with the utility, which consisted of two parts. The system initially operated as a \$0 export arrangement between 26/11/2021 and 18/3/2022, in time to offer the family some protection from the regions frequent summer heatwaves. This period of \$0 export agreement is not typical of solar installations for Northern Territory post-pay customers however arose from the lack of existing processes for prepayment customers wishing to connect solar. In the case of post-pay customers, FiT entitlements begin once the retailer is satisfied eligibility requirements



(a)



(b)

Figure 4. (a) Author Norman Frank Jupururrla at home in Jurnkkurakurr (Tennant Creek) NT (b) Original Power installing 6.6 kW of rooftop solar PV, Village Camp House 4.

Note: Photos Original Power.

have been met and it approves the customer's request for a FiT. The second stage of the trial commenced on 18/03/2022, when the retailer finalised paperwork facilitating export agreement for the standard FiT of 8.3 c/kWh, as applicable to prepay. Original Power then initiated energy planning discussions with the household that included a comprehensive energy and appliance audit.

NFJ: Solar comes like a Nungkarri (healer/doctor) it's a clever thing. Wumpurrani (country-men) call it Nungkarri. It's something really technical, really smart, it works from the sun.

Analyses

Quantitative analyses were subsequently performed to understand changes in rates of household self-disconnection and energy costs pre and post installation of rooftop solar. Analyses is based on household energy data from the demonstration project during the period November 2019 to July 2022. Data are not freely available and were sourced via requests made by NFJ in September 2021 from data custodians PWC. The process of data acquisition was performed by utility staff upon receipt of signed consent forms, templates of which are available online.² Fifteen-minute electricity interval data was used to calculate daily electricity use, including that met by the grid before and after solar installation. Energy costs prior to and post installation were measured. Data on the incidence of involuntary self-disconnections were provided as time and date electricity services were discontinued and subsequently restored. Electricity (supply-side) outages are reported via the utility's website and social media and all instances were recorded and extracted from the dataset for the purpose of identifying involuntary self-disconnections due to inability to pay. Calculations of the frequency and duration of self-disconnection events were performed during the specified date range. Data analyses were conducted using Stata MP 16.1 and graphics were created with R v.4.1.1. Complementing quantitative analyses are insights drawn from thematic analysis of the lived experiences and interview reflections of authors NFJ and SMN recorded before, during and after installation of rooftop solar on their home; these insights are incorporated throughout the paper and reflect an autoethnographic approach (Coghlan and Brydon-Miller 2014).

Results

Reduced costs

For households experiencing energy insecurity, expenditure on energy costs competes with other necessary family expenditures such as food and fuel costs. Findings of analyses (see Figure 5a) indicate that solar PV reduced grid draw in the months November 2021 to June 2022 by a range of 231–631 kWh, representing avoided monthly costs of \$84 to \$195. This was additionally associated with 176–507 kWh of solar export per month, representing a monthly electricity cost offset of \$16 to \$46. There has been an observable reduction in household energy drawn from the grid after install of solar PV (Figure 5a). Average grid electricity use per month between November 2021 and June 2022 was 27 kWh, compared to 38 kWh for November 2020 to June 2021. This difference in use

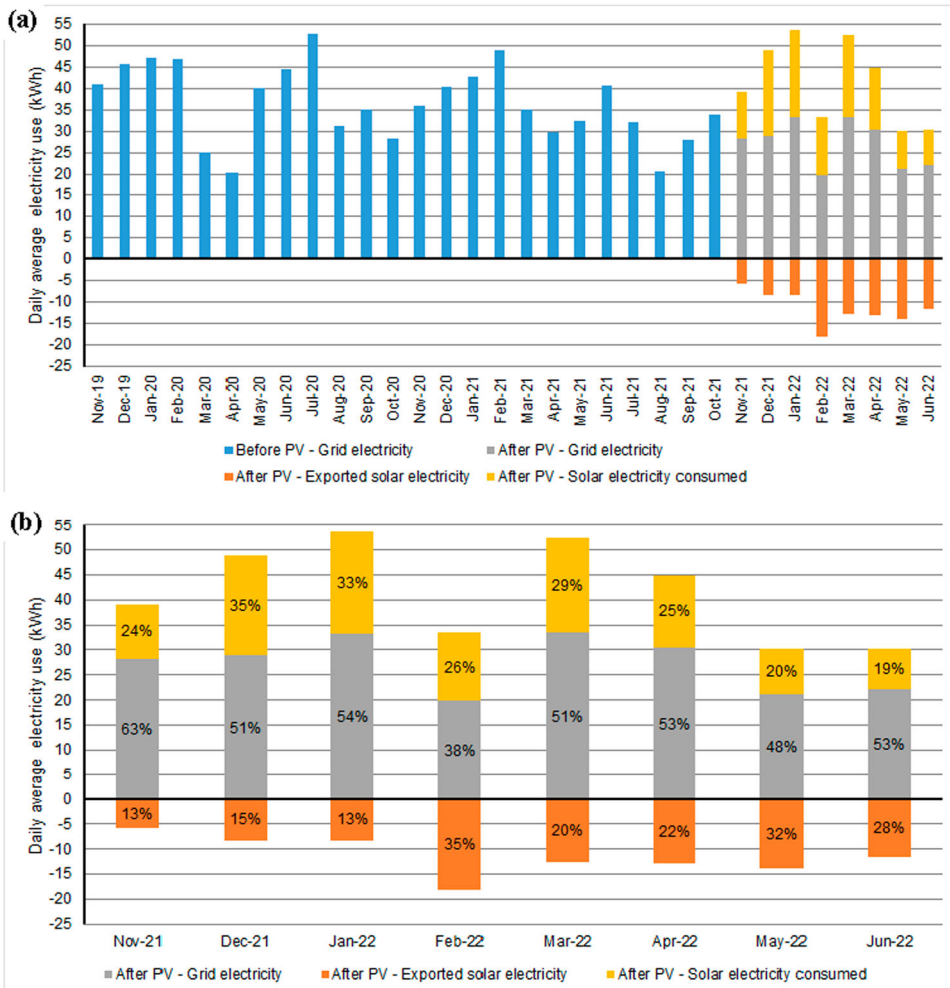


Figure 5. (a) Electricity use pre and post solar installation (b) Electricity use and exports to the grid after installation (by month) (c) Expenditure on electricity pre and post solar installation (d) Electricity use and exports to the grid after installation (by month), including calculated potential FIT revenue for the period 26/11/2021 – 18/3/2022 when the system operated on a \$0 export arrangement.

is proximate to the average daily amount of solar electricity consumed by the household, at 14 kWh. It is notable that no significant changes in overall household electricity usage (both grid and self-consumed solar) were observed during the trial despite intended actions to improve energy efficiency.

Whilst energy generation potential varies due to seasonal differences, Tennant Creek is characterised by sunny days and clear skies. Rooftop solar PV provides a large proportion of electricity in all months reviewed (Figure 5b). The monthly breakdown of electricity used and exported is detailed in Figure 5b. Over the hot summer months (May and June 2022) there were many periods where solar generation was greater than household energy consumption with the excess generation sold back to the grid. About 19%–35% of

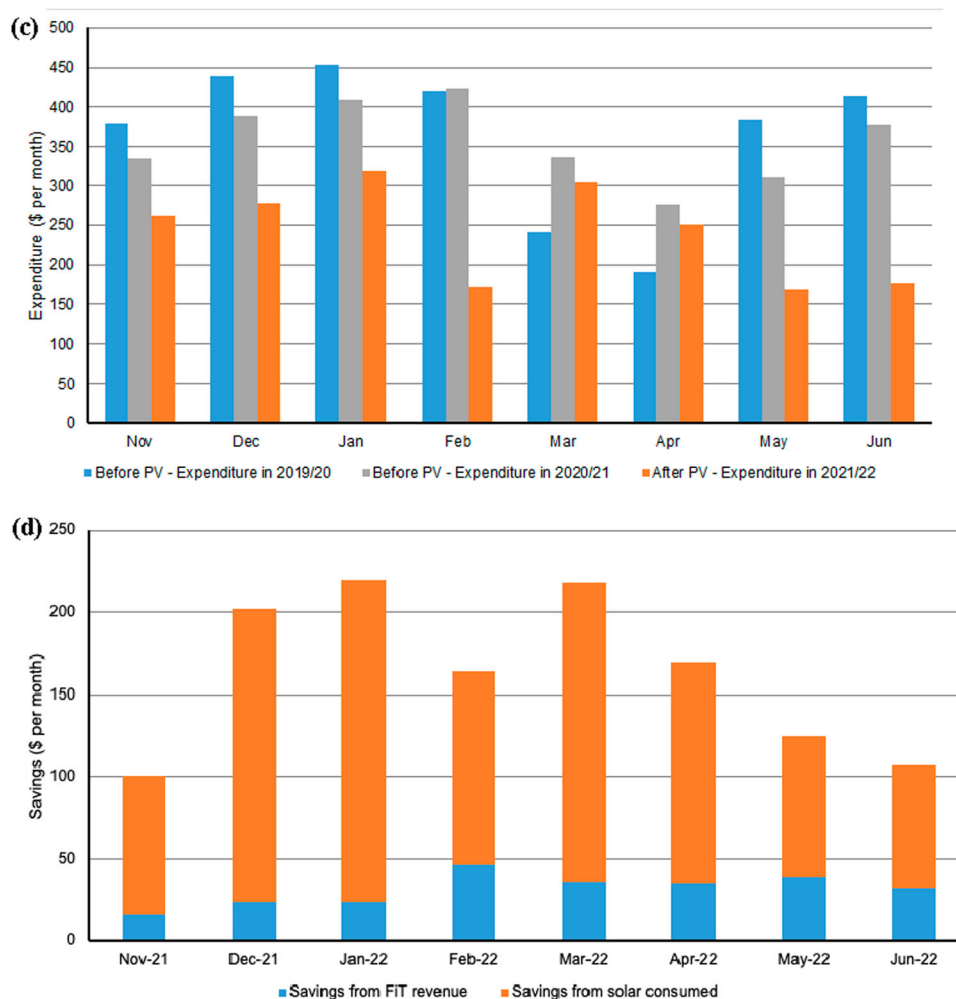


Figure 5. Continued.

total household electricity use each month represents self-consumed solar, while a minimum of 13% each month is solar exports to the grid.

Monthly household expenditure on electricity pre and post solar installation is shown at Figure 5c. Most potential monetary benefits are observed as realised by costs avoided through self-consumption. During 2021/22 expenditure on purchase of grid electricity was 39% lower than for 2019/20. This represents avoided grid electricity expenses of \$1067 to \$1130 for the period between November and June, or approximate indicative avoided costs of \$133 per month (see Figure 5d).

SMN: *We used to keep putting dollars in that meter ... especially when it was hot. We had to put more and more money in the power box. Now [we have panels on the roof], we don't have to put any money in.*

Preliminary analysis indicates that the solar PV system with an expected lifetime of up to 25 years on panels (inverter has a lesser lifespan) costing approximately \$10,000 has

a payback period of a little over 7 years assuming the removal of panels is not required by housing authorities within that timeframe. Seasonal variation will no doubt affect these calculations, and we caution that current estimates are conservative – they could feasibly be lower due to the preliminary nature of our analyses. The standard FiT is applied directly as prepay metre credit, and in addition to avoided grid costs, the FiT represents an additional change in required energy expenditures. Combining avoided costs from self-consumed electricity with offset costs from estimated FiT, the Nov 2021 to June 2022 period would have seen 33% lower expenditure on electricity compared to the Nov 2020 to June 2021 (pre solar), and 34% lower than for 2019/20 (pre solar).

NFJ: *Before we had solar it was hard. Now we have panels on the roof, it is better. We get support from that sun. It's a lot better than how it was. It's more sustainable.*

Keeping connected

Prior to solar installation, self-disconnection events due to inability to pay varied by month, between 0 and 6 per month, with disconnections increasing during hotter summer months – a maximum number of 6 involuntary self-disconnections were experienced in November 2020 (see [Figure 6a](#)). In the 12 months prior to solar installation, the total duration of disconnections experienced each month were within a range from 0 to 1,650 min (27.5 h) per month, with the highest duration being in November 2020 (see [Figure 6b](#)). In the 12 months pre-solar installation (November 2020 to October 2021), there were 12 self-disconnections totalling 47 h (see [Figure 6c](#)). These figures are consistent with the frequency of self-disconnections experienced the year prior (November 2019 to October 2020, as at [Figure 6c](#)).

SMN: *When we disconnect, it's really hard. We worry about the fridge, cold water. The food goes off.*

Post-solar installation, there were no involuntary self-disconnections (November 2021 to June 2022) both during the period when solar exports were uncompensated and after the standard NT FiT of 8.3 cents per kWh was applied. Realising access to the known benefits of solar PV has improved household energy security for residents of Village Camp House 4 as measured by the frequency and duration of involuntary self-disconnection events experienced due to an inability to pay.³

Fully subsidised, decentralised renewable energy has significantly reduced grid energy use and reduced related financial stress for authors NFJ and SMN and their family. Improved incomes available to support food and fuel security, uninterrupted access to refrigeration due to disconnections avoided (and the likely benefits for food security and storage of medicines), as well as lower levels of anxiety and household disruption associated with frequent 'self-disconnection' and food loss/spoilage; these are but some of the benefits described by authors SMN and NFJ throughout this article. These benefits look set to accrue into the future. We acknowledge that the limitations of a small sample size, in this case a single household case study, mean that the findings of our data are not representative of prepay households broadly, however our interest lies in providing a preliminary snapshot of what

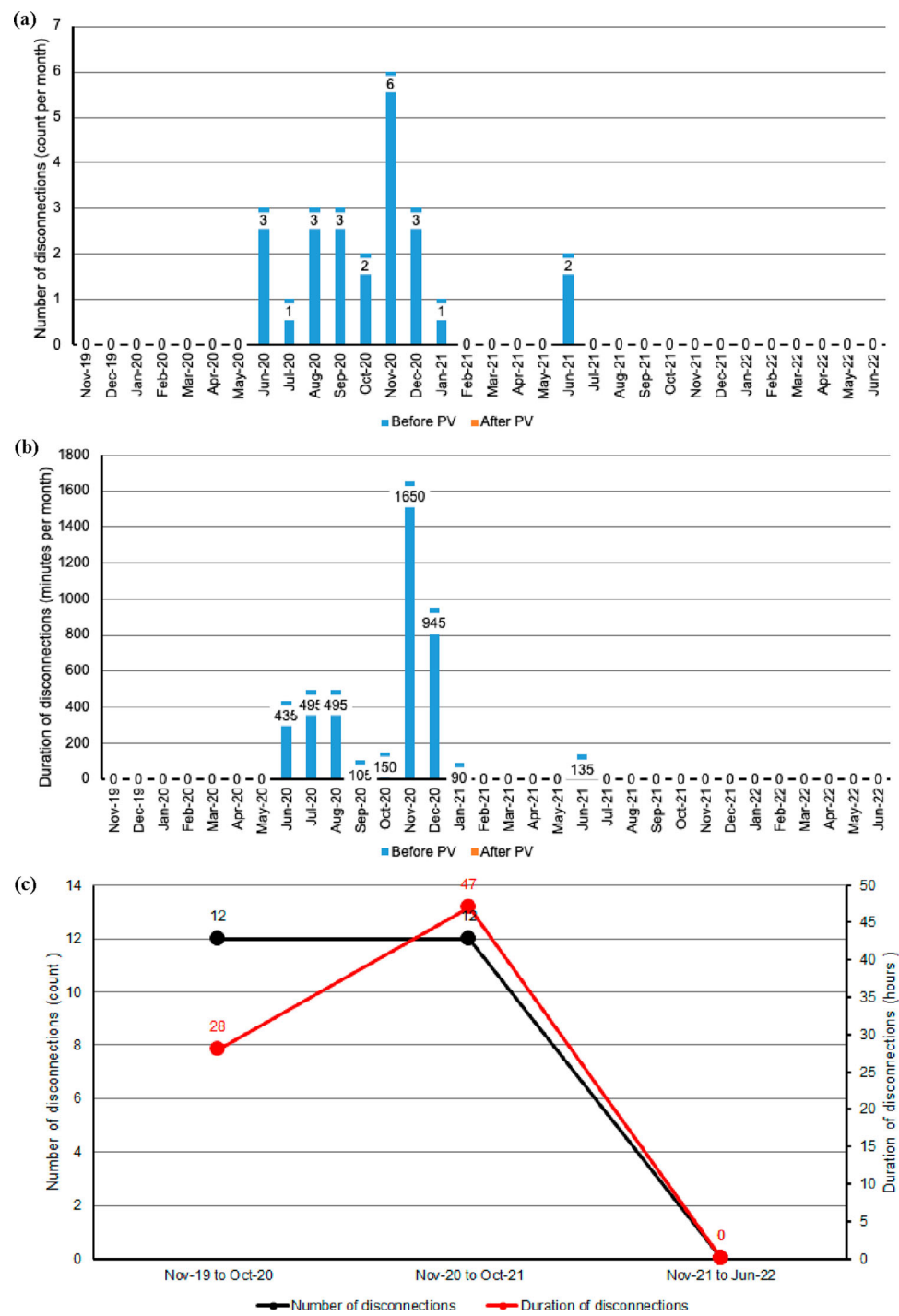


Figure 6. (a) Number of involuntary self-disconnections pre and post solar installation (b) Length of self-disconnections pre and post solar installation (c) Number and duration of self-disconnections pre and post solar installation.

might be gained by prepay households accessing rooftop solar PV. Benefits associated with solar installation for similar households could foreseeably be expected to include some combination of experiences of improved household energy security based on lower expenditures.

NFJ: *Now we have solar, it gives us more money for our pocket. It's a good life, that solar.*

Discussion

In Australia, the energy insecurity of prepay households has long been under-recognised and procedurally neglected. Prior to the incremental implementation of smart metres, rates of involuntary self-disconnection have not been recorded and energy hardship among prepay households using analog metering has tended to be hidden. This lack of data – both of rates of self-disconnection and in any changes in frequency and duration that might be associated with remedial efforts has long been a flaw with prepay from a social policy perspective. The outcomes of this infrastructural underdevelopment are non-trivial: the policy-based abandonment of racialised people results in everyday experiences of energy insecurity that exposes them to risks of adverse social and health impacts including premature death (Longden et al. 2022; Longden 2019; O'Sullivan et al. 2013). Such conflicted policy landscapes derive from what Ruth Wilson Gilmore observes as being the 'neutral fact of unequal power and its fatal exploitation' (Gilmore 2002, 22). As clean energy developments roll out at individual, municipal and regional levels it is crucial that energy transition policies ensure a certain portion of benefits accrue directly to those who are most in need, as those who stand to gain the most. Prepay households are among those most at risk as they are known to experience high rates of energy insecurity measured by involuntary self-disconnection. Yet pervasive barriers to accessing the benefits of rooftop solar risk perpetuating the 'bureaucratic invention of household energy insecurity' (Grealy 2022). Drawing parallels with Dana Powell's literal and symbolic *landscapes of power* operating in settler colonial contexts, we seek with this article to begin to identify the ways 'that situate energy development as underdevelopment' for First Nations (Powell 2015, 63) while contending that rooftop PV presents an important opportunity for addressing shortcomings in material reconciliation in Australia. We note the challenges identified in this case study occurred in the context of a regulated network in the NT, where processes and administrative requirements for installing solar for post pay customers are already well established. There currently exist different and additional barriers for prepay customers living in remote communities in the NT, where electricity services and solar connections are not regulated, as well as for those customers using prepay who reside in other states and territories where local policies and regulations apply. Further, our community based collaborators note the absence of readily available historical data for prepay makes it challenging for residents and supporting organisations to calculate payback rates, introducing the risk that access to subsidies are hampered, impeding advocacy efforts (Mellor 2022). Greater levels of access to energy data are increasingly important for local community organisations to effectively participate in the development of supportive policy reforms. The National Agreement on Closing the Gap in partnership recognises that sharing 'data and information is most useful to Aboriginal and Torres

Strait Islander organizations and communities to obtain a comprehensive picture of what is happening in their communities and to support decision-making' (Council of Australian Governments 2019).

There remain opportunities and gaps – for utilities, communities, and relevant territory and federal government agencies – to work together on developing policies with consideration for priority communities, including First Nations public housing residents who prepay for access to energy services and experience daily the risks associated with self-disconnection. Whilst we identify the potential for rooftop solar to mitigate the known risk of self-disconnection in this article, we do not wish to suggest rooftop solar as a universal panacea to entrenched disadvantage. Limited access to thin labour markets in remote areas, the well reported inadequacy of current rates of income support to meet essential food and fuel needs, and the unaffordability and thermal inefficiency of dwellings in a context where almost all public housing tenants are Aboriginal, are all key drivers of public health and wellbeing in the NT. Moreover, we acknowledge there are likely to be circumstances where the application of rooftop solar may not be appropriate, viable or desirable. To influence the viability of First Nations participation in household solar PV uptake will require economies of scale and greater access to finance, in the context of local resource constraints where more than half of Indigenous households in the NT fall below the poverty line (see F. Markham and Biddle 2018), (see Dillon 2022; F. Markham and Klerck 2022; F., Markham, Smith, and Morphy 2020; F. Markham and Biddle 2018). Yet the possibilities inherent within energy futures 'that do not perpetuate settler colonial logics of power' (Powell 2015) mean that neither renting nor prepay should wholly preclude prepay customers from directly accessing the benefits of clean energy. The extensive solar resource available in many of the communities where prepay can operate make them among the most suitable locations for solar power generation in the world. This presents significant opportunity for self-consumption and reduced household financial outflows for otherwise hard-pressed households. In addition to residential rooftop PV, options likely include virtual power plants that can provide improvements akin to those demonstrated when appropriately designed.⁴ Barriers to rooftop solar deployment can be overcome or mitigated by governance committed to 'sharing the benefit' directly with households, requiring political support for just, community-centred and evidence-based policymaking (Mercure et al. 2021). In designing policies to increase access to clean energy for public housing residents using prepay, realistic changes will necessarily employ comprehensive community engagement to build understanding of the relative costs and benefits of deployment. To date, limited research in Australia has considered local support and demand for energy transition in First Nations communities. Insights may be drawn from previous noteworthy programs designed to advance clean energy uptake in remote communities, many supported by federal, state and territory governments.⁵ A common feature across these successful initiatives has been a commitment to resourcing meaningful community engagement and participatory decision-making processes.

Conclusion

NJF: The main thing is, I don't need to worry about my power anymore. Clean energy is the medicine our people need. I dream of having solar on every house in town.

For many First Nations residents of public housing using prepay, self-disconnection from energy services presents a known risk that must be navigated daily. For these households, temperature extremes increase both their reliance on those services that energy provides, and the risk of those services being disconnected. Self-disconnection is a known indicator of energy insecurity, albeit unrecorded in most public facing reporting. This absence has long been matched by the lack of a connection agreement and export tariff enabling prepay households to realise the benefits of rooftop PV. In describing the experience of authors SMN and NFJ in connecting rooftop solar to prepay, this case study shows that accessing solar PV significantly reduces household electricity expenditures, freeing-up of income for other essentials. Furthermore, accessing subsidised rooftop solar has had an important additional benefit for this prepay household – by reducing the frequency and duration of involuntary self-disconnection events and helping keep the household connected to energy services. There is much to be gained by extending support for access to solar to public housing residents using prepay and by codifying support for the economic inclusion of First Nations in energy transition. Much will hinge upon multiple sectors of Australian governments acknowledging the extent of current energy injustices, incorporating feedback and committing to policy reform so as to ensure priority communities share in, rather than simply host, the benefits of a transition to clean energy. To do so requires acknowledging where current jurisdictional standards can be improved in relation to service delivery, based on minimum standards for energy access. It is crucial that in transitioning away from costly and polluting imported liquid fuels and toward locally abundant renewable energy resources, a portion of the benefits are realised directly by prepay households, whose energy insecurity has until recently been hidden. Energy transition policy in Australia should not only benefit those already with the most, but rather deliver real change through strengthening opportunities to address socio-economic inequalities between Indigenous and non-Indigenous Australians. There is scope to progress this aim through policy aimed at the fair distribution of risk and gain, bridging the gap between the status quo and promised transformative outcomes for all families and communities in energy transition.

Notes

1. "Alterations to the premises require written approval from the Department. You will be responsible to pay for all related alteration costs. You will also have to pay for removing or fixing the alterations when you move out". Fact sheet available at; https://tfhc.nt.gov.au/__data/assets/pdf_file/0012/979572/alterations-additions-fs15.pdf.
2. https://www.powerwater.com.au/__data/assets/pdf_file/0020/29351/Historical-Electricity-Consumption-Data-Request-Form.pdf, accessed 19th December 2022.
3. On 18/12/2022 the family were absent as they spent time away at Lake Nash, NT on holidays. During this time the inverter at House 4 Village Camp lost grid reference and shutdown the solar system, requiring restart upon their return. Upon discussion and given their absence meant the family were unaware and unable to perform necessary remedial action, the research team made the decision not to include this single incidence of a technical fault associated with the integration of prepay metering with solar from the

dataset. This raised a critical point for discussion and further learnings in relation to the integration of PV with prepay metering. Inverters provide the interface between energy sources such as solar panels and the larger grid and generally shut off power to these energy sources in the case of a supply side outage, in order to protect the larger network to which they are connected. Electricity generated by the solar panels during these events can neither be self-consumed nor used to 'top-up' or re-establish energy services to the home. Rooftop solar integrated with newer 'standalone' inverter technology on the other hand can keep supplying critical load circuits during outages – with the potential to keep prepay households connected to energy services even during times of outage. This represents an important area for future research.

4. One such example has been operating in South Australia since 2020, see <https://www.housing.sa.gov.au/latest-news/virtual-power-plant-provides-solar-to-more-than-4100-housing-sa-customers>, accessed 19th December 2022.
5. Early initiatives provided energy services to small outstations and homelands, including the well-regarded Bushlight project by the Centre for Appropriate Technology. More recently, Solar SETuP enabled the network provider to reduce losses resulting from the disparity between the uniform tariff able to be charged and the inevitably higher costs associated with remote (high-cost) networks (ARENA 2019). Rooftop PV on communal buildings with high electricity use, such as community stores, sports-halls, community centres and staff accommodation have been successfully deployed, however fewer projects have explicitly focussed on reducing the known incidence of household energy insecurity associated with prepayment (Mellor 2022).

Disclosure statement

Authors Norman Frank Jupurrurla and Serena Morton Nabanunga acknowledge benefitting from the pro-bono electrical work that facilitated this current case study, wholly funded by Aboriginal-led registered charity Original Power. No other potential conflict of interest was reported by the author(s).

Funding

The map produced at Figure 1 was supported by Energy Consumers Australia: [Grant Number ARFEB22001].

ORCID

Bradley Riley  <http://orcid.org/0000-0002-0518-1870>

Lee V. White  <http://orcid.org/0000-0002-2052-9142>

Simon Quilty  <http://orcid.org/0000-0003-4804-9834>

Thomas Longden  <http://orcid.org/0000-0001-7593-659X>

Norman Frank-Jupurrurla  <http://orcid.org/0000-0001-9089-6012>

Sally Wilson  <http://orcid.org/0000-0001-8817-3237>

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