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Contracts-for-Difference: An assessment of social equity considerations in the renewable energy transition

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ABSTRACT

This research advances knowledge regarding social equity as it relates to electricity network charges, renewable investments, and household income. While much research has examined social equity issues related to electricity access, research has yet to fully explore how different network tariff designs used to recover the cost of renewable energy investments, such as those related to 'Contracts-for-Difference' (CfDs), impact low-income individuals. We accordingly examine CfDs in more detail, assessing if regressive effects emerge from levying CfD cost recovery via network charges. By analysing energy use and network design charges in Australia, we find that CfDs are a regressive form of taxation used by state governments to fund renewable energy commitments. We illustrate the impact that CfDs have on different energy users and provide recommendations to reform renewable energy policies to provide greater social equity.

1. Introduction

Evaluating existing policy and regulatory frameworks associated with the transition to renewables is essential to identify gaps and limitations related to achieving social equity with respect to electricity network charges and renewable energy investments (Dodd and Nelson, 2019; Heffron, 2021). Scholars across the globe have called for further research into the impact of existing policies and recommended improvements or alternative approaches that prioritize social justice outcomes (Farrell and Lyons, 2015; McCauley and Heffron, 2018). Research has examined social equity issues as they relate to electricity access (see McCauley et al., 2013; Simcock et al., 2021), but less is known regarding how different charging mechanisms impact vulnerable individuals within the community (Axon and Morrissey, 2020). Specifically, further knowledge is required regarding the roles of government agencies in shaping electricity pricing and tariff structures as these tariffs are increasingly used to recover the costs of implementing environmental policies (Belaïd, 2022; Pye et al., 2015; Wilkinson et al., 2020).

We seek to contribute new knowledge in this regard by examining government-issued-Contracts-for-Difference (CfD). A government-issued-CfD is a contract between an energy generator and a government that assures the generator a fixed floor payment price. The costs of making payments to generators through these CfDs are often recovered from consumers through network tariffs. Unlike distributed generation (i.e., smaller-scale renewable energy systems, such as rooftop solar PV), the social implication of such a policy remains underexplored (Boeri et al., 2020; Pye et al., 2015). This is an issue as CfDs are increasingly used by Australian and other governments to underwrite new large-scale renewable energy investments with the purpose of addressing climate change (Bermingham, 2022b).

Accordingly, we consider if and how CfD costs related to renewable energy investments and policy are recovered from different groups of consumers. Our work builds on the work of early studies in this area (e.g., see Bunn and Yusupov, 2015; Eid et al., 2014; Energy Networks Australia, 2022; Jalas and Numminen, 2022). We present case study data to examine if and how government CfDs privatise the profits of large multinational energy businesses and banks and then distribute costs associated with project losses through electricity distribution tariffs. Furthermore, we look at the design of distribution tariffs and their interaction with environmental and social policy objectives.

There are three main areas of focus in our research inquiry, with a particular emphasis on the interaction of environmental and social

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policy. First, we examine key policy instruments used to stimulate investments in renewable energy projects. Second, we assess the role of network tariff design, using the Australian state of New South Wales (NSW) as a case study to illustrate CfD-related cost impacts. Finally, we analyse and discuss the potential impacts of CfDs on different customers, specifically considering the role of energy policy as it relates to environmental and social goals.

Our article is structured as follows. Section 2 provides a brief description of the background literature in relation to renewable investment stimuli and the use of network charges for cost recovery. Our research context is provided in Section 3 with the detailed research methodology and description of data provided in Section 4. Results are documented in Section 5 with discussion and policy recommendations provided in Section 6 and a brief conclusion following.

2. Background literature: network charges and renewable investment stimuli

Governments increasingly use electricity tariffs (and in particular regulated network charges or tariffs) to stimulate investment in renewable energy projects (Belaïd, 2022; Nelson et al., 2011). As networks are regulated monopolies, network tariffs are governed by regulators (e.g., the Australian Energy Regulator, 2020) and legislation (e.g., the NSW *Electricity Safety Act 1945*). These tariffs are cost recovery charges (e.g., associated with infrastructure build and maintenance) as well as other approved fees, such as those related to new renewable energy investments (Onifade, 2016).

Various schemes have emerged in this national context that utilise network and retail charges to foster renewable energy developments (Freebairn, 2020; Nelson et al., 2022). These include renewable obligation certificate (ROC) trading schemes, Premium Feed-in Tariffs (PFiT), and CfDs (Simshauser, 2019).

ROC trading schemes work by obligating electricity suppliers to obtain a certain proportion of their energy from renewable sources (Mitchell et al., 2006). Suppliers earn ROCs for each unit of renewable electricity generated, which can then be traded or purchased to meet their obligations, with costs passed on to consumers (Shao et al., 2022). ROCs have been found to stimulate strategic renewable investments, including investments in innovative technologies that lower energy prices (Wood and Dow, 2010, 2011). This is because ROCs place the financial risk of returns on private developers and thus incentivise competition (Foxon and Pearson, 2007; Woodman and Mitchell, 2011). However, governments have recently shifted away from ROCs to PFiTs and CfDs (Simshauser, 2019). The policy rationale is that consumer costs can be lowered by de-risking investments and reducing the cost of capital deployed in new generation (see NSW Government, 2020; as an example).[2]

PFiTs involve offering a guaranteed payment rate for renewable electricity generation, typically over a long-term contract (Schallenberg-Rodriguez and Haas, 2012). PFiTs have been shown to provide a stable income stream for renewable energy producers and shield generators and investors from market instability (Poruschi et al., 2018). PFiTs offer a fixed premium tariff that is higher than the prevailing market rate (Zahedi, 2010). This premium is directly passed on to energy consumers through energy bills and is found to lead to higher energy prices (Nelson et al., 2011). This notably impacts low-income individuals and people without solar PV due to their higher energy consumption patterns and bills as a percentage of income (Simshauser, 2016).

Of the three schemes, CfDs, which offer a floor energy price, remain the most understudied (Simshauser, 2019). Studies that do exist examine market efficiency (Onifade, 2016). They find that CfDs provide a planned approach to de-carbonization in which renewable energy generators are assured a minimum energy price (Welisch and Poudineh, 2020). This is said to offer market stability for generators, making it easier for them to secure investors and financiers to fund the infrastructure (May et al., 2018). However, given that generators are shielded from competitive market forces (e.g., through new technology which reduces energy prices), CfDs may lead to higher consumer energy prices (Nelson et al., 2022). Costs associated with the gap between market and CfD-agreed energy prices are passed on to consumers through energy bills. However, the cost implications of CfD cost recovery via network tariffs on different socio-economic individuals and communities is yet to be established. We therefore ask: "How are different individuals and communities impacted by CfD cost recovery?" and explore in what follows an assessment of CfD impacts as they relate to tariff design, which determines how CfD costs are recovered from electricity customers (Simshauser, 2019).

3. Research context: network tariff design and CfDs

In Australia, network tariff design is determined by various factors and is regulated by the Australian Energy Regulator (2020). At present the overall network tariff design aims to cover the costs associated with the transmission and distribution of electricity from power generators to consumers. Under National Electricity Market (NEM) rules set by the Australian Energy Regulator (2020), networks are not explicitly required to consider social equity. The onus therefore rests with sub-regional governments and network operators who interpret and apply rules and principles under the NEM (Simshauser and Tiernan, 2019).

Australia's electricity network is divided into several regions, and each region has its own network operator responsible for the transmission and distribution of electricity (Australian Energy Regulator, 2020). These operators are usually state-owned corporations or private companies and are regulated under state legislation (Bermingham, 2022a). Specific details of the network tariff design can vary across different regions and electricity distributors. The vast majority of customers in Australia remain on simple two-part tariffs with a relatively low fixed charge (in cents per day) and a variable charge for energy consumption irrespective of when the consumption occurs (in cents per kWh). To provide a catalyst for change, we seek to advance insight related to the potential impacts of CfD cost recovery as it relates to tariff design.

Specifically, Australia and the state of NSW was selected as the case study because of its national and sub-regional reliance on coal for electricity and economic development (Evans and Phelan, 2016). Australia is among the 20 largest global emitters of carbon dioxide and is the second-largest exporter of coal in the world (Heffron, 2021). Specific communities in the Hunter Valley of NSW are particularly vulnerable to greenhouse gas mitigation due to the heavy reliance upon coal mining and thermal power generation for economic activity (Centre for Policy Development [CPD], 2022).

NSW is also a relevant case study because of its ambitious 'NSW Energy Roadmap' policy aimed at rapidly transitioning the state away from coal and towards renewable energy. The legislation requires a subsidiary of the electricity market operator to underwrite new wind and solar projects by issuing CfDs that shield wind and solar projects from the risk of market losses (see Simshauser, 2019; Catapult, 2020; Nelson et al., 2022). CfD costs are then recovered via distribution network charges. We seek to understand whether this unintentionally privatises the profits of large energy businesses and financial institutions and regressively distributes potential losses over energy consumers.

4. Methods and data

Given that in Australia CfD costs are recovered through distribution

[2] This explanation ignores the most salient point raised by Simshauser (2019): market risks cannot be avoided in energy markets due to the inherently volatile nature of supply and demand.

network charges, our analysis seeks to understand the social equity impacts associated with this cost recovery approach. Specifically, to answer our central question of how different individuals and communities are impacted by cost recovery of CfDs via network charges, we consider three sub-questions that informed data collection and analysis:

1. Does cost recovery under CfDs disproportionately impact low-income consumers?
2. What is the distribution of CfD cost recovery borne by different socio-economic communities?
3. Can customers reduce the impact of CfDs costs by having solar?

To answer sub-research question 1, we develop a model to estimate cost impacts. This model includes three key data inputs. First, we generated an average hardship customer and non-hardship customer profile to illustrate energy use patterns. This profile was created using energy data associated with 1806 hardship and 2988 non-hardship accounts for the 2021 calendar year. This data was provided in a non-identified form by Energy Australia, one of Australia's largest electricity retailers and generators. We used hardship customers, defined as people who have trouble paying their energy bills, as a proxy for low-income individuals (consistent with Dodd and Nelson, 2022). The first author aggregated the data associated within each group to create an average for each profile. Fig. 1 in the Appendix presents the data used for the analysis of hardship and non-hardship customer profiles.

Second, we identified costs associated with each kWh of energy used based on standard electricity charges in NSW (AusGrid, 2022). This included fixed charges (e.g., costs associated with electricity connection per household) of $0.32/day and variable charges (i.e., charges associated with each kWh consumed) of $0.088050/kWh. This data is presented in Table 1 of the Appendix with the relevant values highlighted in red. Using this data we deduced an average energy bill for both customer cohorts. Lastly, as CfDs are not yet included in NSW fixed or variable charges, we set a nominal fee of $0.01/kWh and assigned this to each customer cohort. Using these three inputs we estimate the cost impact through the following calculation: Total annual network charge = Daily fixed charge * 365 + Variable charge *Total consumption * 365 + Annual consumption * $0.01/kWh. We also then calculated the impact of shifting cost recovery to just the fixed charge.

To answer sub-research question 2 we developed a second model to examine the impact of a nominal CfD fee of $0.01/kWh on different household income groups within the AusGrid network in NSW (covering approximately half of Sydney and including Newcastle and Wollongong). We sourced average daily electricity consumption by NSW Local Government Area (LGA) (AusGrid, 2022) and median income by LGA (Australian Bureau of Statistics, 2020). This data is presented in Table 2 in the Appendix with the LGA in column 2, daily average electricity consumption (kWh) in column 3 and median income in column 9 (all highlighted in red text). We then deduced a proportional impact by calculating: (consumption * $0.01/kWh)/median income.

To answer sub-research question 3, we developed a final model to estimate the energy bills of solar PV versus non-solar PV households. As per sub-research question 1, we obtained NSW customer energy usage data and developed an average electricity profile. This data was provided by AGL Energy which is one of the largest electricity retailers and generators in Australia. The data included 350,000 non-hardship half-hourly consumption profiles and 1000 hardship half-hourly consumption profiles for the 2021 calendar year. The data was anonymised and standardised before being provided to the authors. This time we generated four profiles: (a) hardship customer with solar PV; (b) hardship customer without solar PV; (c) non-hardship customer with solar PV; and (d) non-hardship customer without solar PV. Fig. 2 in the Appendix shows these four average daily consumption profiles. Once these profiles were deduced we reapplied the calculation used in sub-research question 1 using Table 1 in Appendix 1 for network tariffs (Total annual network charge = Daily fixed charge ($0.32/day) * 365 + Daily variable charge ($0.088050/kWh) *Total average daily consumption * 365 + Annual consumption * $0.01/kWh) to derive an average annual energy bill that factored in a CfD fee for each profile.

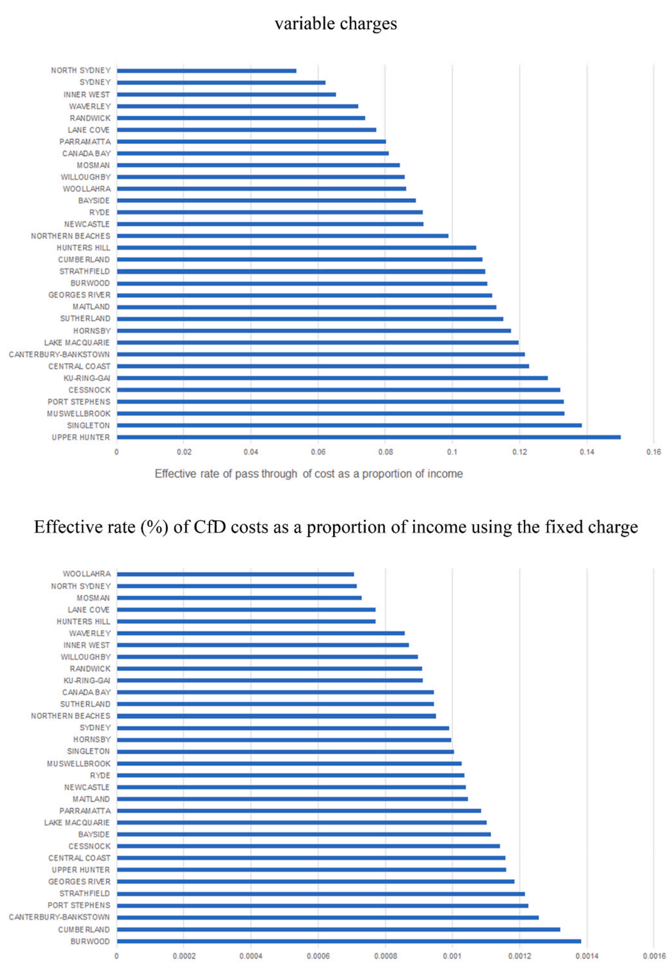

Fig. 1. Effective rate (%) of CfD costs as a proportion of income using the variable charge.

5. Results

Based on the three models, we identify three impacts of the cost recovery of CfDs via network charges. First, we find that hardship customers will pay higher costs than non-hardship customers. Second, we identify that households in low socio-status LGAs will pay disproportionally higher CfD costs relative to income. Last, we find that customers can partially avoid CfD costs by installing solar PV.

5.1. Hardship customer impacts

Table 1 shows that under a variable charge basis, the costs of CfDs

Table 1
Network bills for hardship and non-hardship customers.

	Hardship	Non-Hardship
Total Consumption (kWh)	8053.6 (kWh)	5675.9 (kWh)
Total network bill	$828.16	$618.81
Variable charges	$709.11	$499.76
Fixed charges	$119.04	$119.04
NSW Roadmap Impact (per $0.01 levied per kWh	$80.53	$56.75

Table 2
CfD and network charges for hardship customers with and without solar PV.[31].

	Hardship without solar	Hardship with solar PV
Total consumption (kWh)	9330.23 (kWh)	5871.89 (kWh)
Total network bill	$870.13	$591.73
Fixed charges	$119.04	$119.04
Variable charges	$751.08	$472.69
NSW Roadmap Impact (per $0.01 levied per kWh)	$93.30	$58.72
	Non hardship without solar	**Non hardship with solar**
Total consumption (kWh)	5609.15 (kWh)	5199.87 (kWh)
Total network bill	$570.59	$537.63
Fixed charges	$119.04	$119.04
Variable charges	$451.54	$418.59
NSW Roadmap Impact (per $0.01 levied per kWh)	$56.09	$52.00

will be over 40% higher for hardship customers ($80.53 per $0.01 levied per kWh) than non-hardship customers ($56.75). This is due to CfD costs being applied to the variable component of the network bill rather than the fixed charge.

For contrast we have calculated the increase in the fixed charge for all customers if the $0.01/kWh in CfD costs is recovered through the fixed rather than the variable charge. This is achieved by multiplying $0.01/kWh by the sum of all kWh for all residential customers in the AusGrid region and then dividing this by the number of customers. This would result in a total cost pass through of $56.80 per customer per year.

5.2. Impact by LGA

Fig. 1 shows the effective rate of CfD cost relative to average income by LGA. Notably, the top five LGAs in terms of effective pass through are Upper Hunter, Singleton, Muswellbrook, Port Stephens and Cessnock. Not only are these areas relatively less economically advantaged (all in the bottom half of the Index of Relative Socio-Economic Disadvantage published by the Australian Bureau of Statistics, 2021), they are also concentrated in the Hunter Valley. This is one of only a handful of regions in Australia that is particularly vulnerable to action taken to mitigate climate change (i.e., reduce emissions) due to their current reliance upon coal mining and electricity generation (see CPD, 2022). In contrast, Fig. 1 shows that the five LGAs with the least incidence of CfD costs are North Sydney, Sydney, Inner West, Waverly and Randwick. These inner-city communities are relatively well off (all in the top decile of the Index of Relative Socio-Economic Disadvantage published by the ABS) and unlikely to experience significant climate change mitigation costs.

If we apply a fixed charge of $56.80 per customer as per the previous sub-section, instead of a variable charge of $0.01/kWh, the results change substantially. This is shown in the bottom of Fig. 1 with the mix of most and least impacted LGAs (as a proportion of income) varying significantly from variable charges in the top of Fig. 1. The communities in the Hunter Valley, such as Cessnock, Upper Hunter, Muswellbrook, Port Stephens and Singleton, are more evenly distributed through the chart and there is a narrower distribution across all of the LGAs.

5.3. CfD cost recovery and solar PV

Last, we find that customers can reduce CfD costs by installing solar PV. Table 2 shows that non-hardship customers can avoid ~$4 per annum on average by installing solar (based on the $0.01/kWh levy included in our model). Costs savings are even higher for hardship customers. For example, hardship customers with solar PV pay almost $300/annum less than hardship customers without solar PV ($591.73/annum compared to $870.13/annum). For every $0.01/kWh levied on consumers via volumetric network charges, an average hardship customer without solar PV will pay $93.30 per annum compared to just $58.72 per annum for non-PV hardship customers. Hardship customers without access to solar PV will pay around 60% more for each unit of passthrough of CfD cost recovery than customers with solar PV (assuming they continue to be passed through on the volumetric component of network charges).

6. Discussion

Based on our findings, the impact of costs of CfDs recovered by network charges on different customer groups could be viewed as a regressive form of taxation used by state governments to fund renewable energy commitments. We discuss the implications of our findings in the following sections.

6.1. Emerging social equity issues

We build on existing CfD research to show that this policy mechanism is inequitable and disproportionately affects vulnerable hardship customers who tend to have higher energy usage (Nelson et al., 2019; Simshauser and Nelson, 2014). Policy makers ought to consider our findings in the context of the policy being implemented.

Specifically, our research reveals that when CfD costs are distributed through variable use charges, hardship customers end up shouldering 30% more of the associated costs compared to standard households. This disparity is a result of their higher energy consumption. Conversely, we have demonstrated that implementing an average fixed rate of $56.80 would distribute costs evenly (though not equitably) among all customers. CfD charges are designed as such to implicitly function as a regressive form of taxation. To establish a more equitable solution, it would be more appropriate to adopt a framework similar to that of the progressive Australian taxation system.[4] One such model would have low-income hardship customers earning $18,201 – $45,000 per annum pay a contribution toward public policy of 19c for each $1 over $18,200 earned while conversely high income individuals earning $180,001 and over per annum pay 45c for each $1 over $180,000 (Nelson et al., 2019; Simshauser and Nelson, 2014). While these taxation costs would be spread across public spending (e.g., health and education as well as renewable energy initiatives) they illustrate the proportional difference between this scenario and the CfD approach where hardship customers pay a greater or equal contribution to renewable energy policy.

We also show that fixed subsidies and underwriting policies like CfDs prioritises profits over social equity. CfDs aim to reduce the cost of capital for energy generators, and this approach is inequitable when policy costs are recovered through variable charges, given the higher consumption patterns of hardship and vulnerable consumers.

This becomes even more concerning as these communities are also likely to bear the brunt of the expected mitigation costs (Nelson et al., 2012). In Fig. 1, we highlight the presence of regional inequity in both scenarios (variable and fixed charges) regarding the distribution of CfD costs across Local Government Areas (LGAs). In the variable scenario, LGAs with low socioeconomic status, such as the Hunter Valley region (which will be particularly affected by the transition to renewable energy), bear the highest proportion of these costs. Conversely, in the fixed scenario, there is a narrower spread of outcomes across all LGAs and the communities within the broader Hunter Valley region are more evenly dispersed through the results. From the perspective of social equity it is equally important that policymakers take into account the disparities in energy consumption and income across the NSW AusGrid geographical

[4] Australian taxation rates are as follows: 0 – $18,200 Nil; $18,201 – $45,000, 19c for each $1 over $18,200; $45,001 – $120,000; $5092 plus 32.5c for each $1 over $45,000; $120,001 – $180,000, $29,467 plus 37c for each $1 over $120,000; $180,001 and over $51,667 plus 45c for each $1 over $180,000.

network when designing and implementing renewable energy policies.

In our analysis we also demonstrate that households have the potential to mitigate their exposure to CfD costs through the adoption of solar PV. This presents an alternative policy approach to address the inequalities highlighted concerning hardship customers and LGA CfD contributions. Existing literature indicates that low-income households and regions tend to have lower solar PV adoption rates, making it unlikely for them to avoid CfD payments by this means without additional policy interventions (Chester, 2014; Dodd and Nelson, 2022; Simshauser and Nelson, 2014). The literature identifies various barriers to solar PV adoption, with two prominent ones being limited access to capital for installation and the requirement of homeownership, which ensures a return on investment and the right to install the system (Chester, 2015; Tidemann et al., 2019). Considering these factors, policymakers could explore strategies to accelerate the uptake of solar PV among hardship and low-income consumers, aiming to reduce costs associated with CfDs.

By facilitating the adoption of solar PV among low-income households, policymakers can help alleviate their financial strain and reduce their dependence on traditional energy sources. Research studies have consistently shown that low-income households in Australia face a greater proportion of their weekly income being allocated towards energy costs when compared to higher-income households (Independent Pricing and Regulatory Tribunal, 2015; Nelson et al., 2019; Simshauser et al., 2011). Factors such as housing conditions, household composition, and individual circumstances significantly influence household energy consumption, with higher-income households generally consuming more electricity (Boeri et al., 2020; Dodd et al., 2020). Vulnerable low-income households, particularly those with more children, lack of solar PV installations, and either renting or paying off a mortgage, are at a higher risk of facing financial hardship due to energy bills (Nelson et al., 2019). In order to address these challenges and mitigate the burden of CfD payments, it is crucial to ensure that these disadvantaged households have access to a more equitable CfD cost mechanism and/or solar energy solutions.

6.2. Emerging recommendations

Based on the abovementioned implications and discussions of our findings we deduce three recommendations to support greater equity related to CfDs as summarized in the following section.

6.2.1. Policy recommendation 1: shifting CfD costs to government balance sheets

If governments choose to persist with CfD-style policies, it would be advisable to fund CfD costs through government balance sheets rather than network tariffs. In Australia, taxation revenue is progressively collected from individual taxpayers, making it likely that the impacts on households would be equitable if these costs were recovered through government funding. This approach is particularly crucial when considering regional impacts and the incidence of cost recovery. Concentrated impacts of climate mitigation policies in specific geographic regions, such as the Hunter Valley, could be further exacerbated if CfD costs are recovered through network charges, leading to an additional burden on these communities already facing the brunt of climate change mitigation economic impacts.

[3] To check the consistency of the data provided, the authors contrasted the annual kWh consumption figures with those provided by the Australian Energy Regulator. The figures are relatively consistent – see page 25 for solar PV and non-solar PV consumption figures: https://www.aer.gov.au/system/files/Residential%20energy%20consumption%20benchmarks%20-%209%20December%202020_0.pdf, Accessed online on 9 October 2022.

6.2.2. Policy recommendation 2: incorporating fixed network charges in cost recovery

The majority of Australian households have network tariffs structured with two parts: fixed charges (daily) and variable charges (per kilowatt-hour). This structure creates inherent cross subsidies among different customer cohorts. Recovering CfD policy costs through network charges effectively magnifies these inequitable outcomes for consumers. Consideration ought to be given regarding how tariff designs that recover CfD costs (if kept) impact social equity. For example, our findings show that greater use of the fixed charge would be one way in which a more equitable distribution of costs could occur. However, there are other means to enhance equity as now explored.

6.2.3. Policy recommendation 3: pivot policy support for solar PV toward low-income and hardship customers

In policy recommendation 3, we suggest that if CfD cost recovery continues to be achieved via network tariffs, priority be given to providing low-income individuals with access to solar PV. Recent studies, such as the one by Dodd and Nelson (2022), have demonstrated that solar PV is economically viable for the average household. Urgent re-evaluation of solar PV subsidies, like the Australian Government's Small-scale Renewable Energy Scheme (SRES), is recommended to assess their necessity, effectiveness, efficiency, and efficacy. As highlighted by the Australian Competition and Consumer Commission (ACCC, 2022), these policies are not only regressively funded but also result in lower overall retail tariffs for solar PV households.

Our analysis in the previous section establishes that installing solar PV significantly reduces energy bills. When CfD policy costs are recovered through network charges, this effect is accentuated. Hence, policymakers should consult earlier recommendations, such as those by Dodd and Nelson (2022), to redirect policy support for solar PV installation toward low-income rental households and hardship customers (also see Tidemann et al., 2019). Current policies lack adequate focus on spatial distribution, and support for solar PV installation could be better targeted at customers facing barriers to installation, such as renters who encounter difficulties due to split incentives.

6.3. Limitations and areas for future research

Our study has some limitations that highlight directions for future research. First, the findings of our study are based on a specific sample of hardship and non-hardship customer accounts from Australia in the year 2021. While we made efforts to create average profiles and capture diverse energy usage patterns, the generalisability of our findings may be restricted to the specific sample and time period we examined. To enhance the applicability of the research, future studies could expand the model to assess the implications of Contract for Difference (CfD) mechanisms in different contexts.

Second, our modelling process relied on various assumptions and simplifications to estimate the cost impacts and distribution of CfD cost recovery. These models may not fully capture the complexities and nuances of real-world energy consumption patterns, network charges, and renewable energy policies. Specifically, when analysing the impact of CfD cost recovery on different socio-economic communities, we used average electricity consumption and median income data at the Local Government Area (LGA) level. This approach may overlook regional variations within LGAs, potentially leading to less accurate assessments of the distributional impacts. Future research should address this limitation by considering regional disparities and incorporating more sophisticated modelling techniques.

Third, since CfDs are not currently included in the fixed or variable charges in New South Wales (NSW) due to the scheme only being implemented in 2022, our study assigned a nominal fee of $0.01/kWh to estimate the cost impact. However, this assumption may not reflect the actual implementation and dynamics of CfD cost recovery mechanisms, which can vary in the future and across different jurisdictions. It is important for future studies to consider the evolving nature of CfD cost recovery mechanisms and their potential regional variations.

Last, our study primarily relies on quantitative data analysis and modelling. Future research can add qualitative aspects. For example, policymaker and energy retailer perceptions play a crucial role in understanding the need for, and the feasibility of, implementing the recommendations derived from our analysis (e.g., see Dodd and Nelson, 2019). Future research could explore policymakers and energy retailers' understanding of, and response to, information on the regressive nature of current CfD cost recovery mechanisms and their disproportionate impact on vulnerable and low-income customers.

To gain a more comprehensive understanding of the social equity implications associated with renewable energy policies, future research should address these limitations by including a broader sample, employing more intricate models, accounting for regional variations, and conducting qualitative investigations.

7. Conclusion and policy implications[5]

In conclusion, our research highlights the equity implications of CfD-style policy costs in Australia's renewable energy sector. The findings demonstrate that the current approach to recovering CfD costs through network charges has regressive effects, disproportionately affecting vulnerable hardship customers with higher energy usage. This creates an implicit and regressive tax burden on low-income households, exacerbating their financial strain and hindering their ability to adopt renewable energy solutions like solar PV. We suggest that this inequity could be reduced by amending CfD costs from variable to fixed charges. It could also be reduced by facilitating greater access to solar PV for hardship customers.

While our research provides valuable insights into the equity implications of CfD-style policies and offers policy recommendations, it is important to acknowledge the limitations of our study. The findings are based on a specific sample and time period, and the modelling process involved assumptions and simplifications. Future research should aim to expand the model to different contexts, consider regional disparities, incorporate more sophisticated modelling techniques, and include qualitative investigations to provide a more comprehensive understanding of the social equity implications of renewable energy policies. By addressing these limitations and implementing the recommended policy changes, policymakers can work towards a more equitable and sustainable renewable energy sector, ensuring that the benefits of clean energy adoption are accessible to all, particularly those facing financial hardship and vulnerability.

CRediT authorship contribution statement

Tim Nelson: Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Tracey Dodd:** Methodology, literature review, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

[5] Authors note – the editorial office asked us to change this heading to conclusion and policy implications.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.enpol.2023.113829.

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