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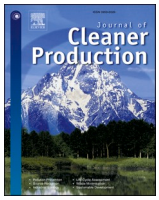

Assessing good governance principles of renewable energy megaprojects

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ABSTRACT

Australia has a net zero emission target by 2050. The transition from fossil fuel to renewable energy sources is critical to meeting this target and the construction of large-scale renewable energy projects is booming. These developments bring economic benefits, but their size means they can also have environmental and social consequences. Rural landscapes are particularly vulnerable because they are expected to be at the forefront of new large-scale renewable energy developments. Such projects are complex and, although they might be socially acceptable, need to be managed and governed well if they are to proceed smoothly. Good governance incorporates fairness, trust and transparency, aspects that foster public acceptance for renewable energy projects. While social acceptance has attracted substantial research, little is known about the public's views on the governance of renewable energy megaprojects. In Australia, a continent with abundant solar radiation and space, large projects are novel and our study aimed to assess which good governance principles the public considers to be most important if megaprojects are to be approved for construction in remote Australia. This insight can complement state and investors views on governance. We carried out an Australia-wide online survey that included a best-worst scaling (BWS) experiment and received 2223 valid responses, using an ambitious 12,000-ha solar megafarm planned for remote northern Australia as a case study. The most important governance principal for respondents was taking responsibility for environmental risk, followed by benefits such as cheap energy and jobs for the local community - governance principles referred to as responsiveness and participation. Accountability if something goes wrong was also perceived as important, but mainly by those respondents who lived in the jurisdiction that is the proposed host of the solar megafarm, and less so by people living in other places of Australia. Perhaps surprisingly, the governance principles of transparency, fairness and the rule of law were considered to be less important. Adhering to national regulations was also affected by the location of respondents, with those living closer to the proposed megafarm being least concerned about adherence.

1. Introduction

A sustainable energy transition requires the transformation of the energy sector as well as changing behaviour and perceptions of the society (Dobravec et al., 2021). Both can be facilitated through energy and climate policies developed by coordinating multiple levels of government, not through top-down activities from a national government but through a bottom-up approach. This includes the active participation of sub-national governments (Brondizio et al., 2009) as well as regulatory agencies and public and private firms and communities (Markard, 2018). More recently, there has been a call for local voices in addition to government agencies, to "reshape the economic and moral calculus of pushing the energy transition in renewable and other industries in specific directions" (Romero-Lankao et al., 2023). There is a growing recognition of the need to account for multiple perspectives in decision-making, so the public can shape the planning and construction of low-carbon energy systems through support of or opposition to infrastructure, policies and technologies (Demski et al., 2015; Rodríguez-Segura et al., 2023).

Understanding public perceptions of energy production systems is therefore important for informing energy-related business, research and in generating effective policy strategies (DeCicco et al., 2015). A lack of public acceptance, justice and trust slows the progress of renewable energy projects (Gross, 2007; Wüstenhagen et al., 2007; Hall et al., 2013; D'Souza and Yiridoe, 2014; Schram et al., 2024). Public acceptance is inherently related to project governance (Sovacool and

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Dworkin, 2015) and understanding how energy projects are managed and adhere to good governance principles is equally important to understand. Good governance has a positive influence on investment into renewable energy (Bellakhal et al., 2019; Murshed, 2024) and fosters economic growth and environmental quality (Rahman and Sultana, 2024). So far, however, while research on the public acceptance of renewable energy projects, in particular wind energy, is booming (Enserink et al., 2022), there has been little research on project development and the conditions under which renewable energy projects are constructed (Heffron and McCauley, 2017).

It has been argued that the renewable energy transition cannot happen without large-scale projects (Caggiano et al., 2024; Scovell et al., 2024). Australia, the focus of this study, aims to reduce greenhouse gas emissions to 43% of 2005 levels by 2030 and has set a target of achieving net-zero emissions by 2050 (Prime Minister of Australia, 2022). The energy production sector is responsible for approximately 70% of all emissions in the country (Australian Government, 2023). To decarbonise energy production in Australia requires renewables to contribute 82% to the national electricity mix by 2030, up from up from 27% in 2023 (IEA, 2023). Large-scale renewable energy projects are key to meeting these targets as an effective climate mitigation strategy.

Large-scale renewable energy projects, however, can be disruptive and locations need to be chosen carefully (Scognamiglio, 2016; Rediske et al., 2021). Most literature so far has focused on the construction of wind farms, which are often resisted by the public, in particular when they are to be built nearby (known as "not in my backyard" (NIMBY) (e.g. Devine-Wright, 2009; Petrova, 2013; Larson and Krannich, 2016). Resistance, however, needs to be placed in context (e.g. Devine-Wright, 2009; Petrova, 2013); in the US living near a wind farm was preferred over living near to coal, natural gas or nuclear power plants, and many also preferred living near a wind farm than to a solar farm (Firestone and Kirk, 2019).

While previous studies have shown that large-scale solar projects are preferred by the public over large-scale wind farms (Donald et al., 2021; Rodríguez-Segura et al., 2023; Caggiano et al., 2024), there is also evidence that public acceptance declines with the size (Cousse, 2021; Campos et al., 2023). This points to a need for a more nuanced understanding of social concerns about solar farms, particularly given the trend towards large farms, referred to as megafarms, which are often located or planned for in remote, but not necessarily rural, parts of the world. Where these megaprojects, in particular ground-mounted solar panels, are constructed in rural landscapes, they are expected to fuel conflict between rural populations and developers (Poggi et al., 2018; Sankaran et al., 2022; Nilson and Stedman, 2023; Rodríguez-Segura et al., 2023). This is partly because of land use opportunity costs, in particular when using fertile arable land as sites for the renewable energy projects (Bessette et al., 2024; Codemo et al., 2024).

Another point of discontent stems from the ways vast solar arrays alter a landscape (Scognamiglio, 2016; Zander et al., 2024) which can challenge place attachment. Many studies from rural locations have highlighted the inconsistency between large-scale solar farms and the traditional conception of the landscape and the rural heritage (e.g. Devine-Wright and Howes, 2010; Firestone et al., 2015; Fast et al., 2016; Sonnberger and Ruddat, 2017; Poggi et al., 2018; Hoen et al., 2019). However, most of these studies focus on relatively small projects in populated rural landscapes in Europe. What people really think about proposed solar megafarms in remote and sparely populated areas is largely unknown.

Our study therefore aims to capture public views about a solar energy megaproject, and more specifically to assess what citizens consider to be important in its planning and governance. To address our aim, we applied a stated preference method, best-worst scaling (BWS), to understand the relative importance of good governance principles in the construction of a renewable energy megaproject. As a case study, we used an ambitious planned project to build the world's largest solar farm in remote northern Australia, in the centre of the Northern Territory. The SunCable project, which is expected to have a capacity of 4 GW (GW) and possibly more, covers an area of 12,000 ha (SunCable, 2024). This makes it a megaproject because it would exceed the size and capacity of the largest existing solar farms by a large margin.

Our study makes two contributions. First it, contributes to a growing body of literature on large-scale solar farms. Although this study focuses on the preferred governance of a solar farm, public acceptance is linked to good governance (Sovacool and Dworkin, 2015; Bendik-Keymer, 2023), and our results can be indicative of acceptance, complementing studies concentrating solely on acceptance or rejection.

Second, our study contributes to the literature, so far rare, on renewable energy megaprojects in remote locations. Our case study differs from the narratives of large-scale solar farms in rural landscapes, which are relatively small compared to what is being proposed in remote Australia and what already exists in parts of the world (see section 2.1). Megaprojects are inherently complex (Turner and Xue, 2018), and their planning and governance are critical determinants of their success or failure (Denicol et al., 2020). The project management literature on megaprojects primarily focuses on the planning stages prior to funding and, while it addresses stakeholder engagement, it rarely includes view of the society at large (Bourne et al., 2023). This oversight is significant, as megaprojects are expected to provide multiple societal benefits (Turner and Xue, 2018; Lehtinen et al., 2019). Moreover, the discipline of project management, while discussing megaprojects, rarely considers the management of renewable energy megaprojects (Sankaran et al., 2022). We address this gap by discussing the tensions that may arise from the construction of megaprojects in remote locations, which, as evidenced in rural areas, can be significant and are potentially increasing.

The lessons learnt from our study are relevant beyond Australia, in regions and countries with similar sparsely populated remote areas that can be used to produce renewable energy. This includes not only solar farms but also onshore and offshore wind megafarms or combined solar and wind megaprojects. The results can also be relevant beyond the energy sector; the methods applied could be used to assess community concerns about the governance for any large-scale infrastructure development that might lead to tension in the community and for which public acceptance is required if they are to proceed unimpeded.

2. Material and methods

2.1. Large-scale solar farms in Australia and globally

Extensive ground-mounted solar arrays are the cheapest form of solar installation (Scognamiglio, 2016) and are considered inevitable if more than 50% of power needs are to be met by solar power by 2050 (Nijsse et al., 2023). Recently, many national governments, with China, India and the United Arab Emirates leading the way, are pushing for ever larger solar megafarms. Currently, the worlds' largest operating solar farm is in the United Arab Emirates with a capacity of 2.4 GW (Table 1), which is approximately 60% of the capacity of the proposed SunCable project in northern Australia. The project in the United Arab Emirates has overtaken the largest farms in India and China, although these two countries have added substantially to their solar production capacity in recent years with several installations of about one GW capacity. The largest solar farm in Africa (Marocco) has a capacity of 580 MW which is similar to the largest in Europe (Spain; 590 MW). The largest solar farms in the Americas are in Nevada (802 MW) and Mexico (794 MW) where there are many solar farms with capacities of between 200 and 500 MW (see, e.g. Lai et al., 2017). Planned solar megaprojects include the Terra Solar project in the Philippines (in Nueva Ecija and Bulacan), due to start in 2026 with a proposed capacity of four GW (Manila Bulletin, 2024), the extension to 5.0 GW of the Mohammed bin Rashid Al Maktoum Solar Park in the United Arab Emirates by 2030 (Government of Dubai, 2023) and the extension of up to ten GW of the Huanghe Hydropower Golmud Solar Park in China (PV-magazine 2019).

Table 1
The world's largest solar farms, in comparison to the proposed Sun Cable project.

Name	Country (region)	Start operation	Capacity (MW)	Area (km^2)
SunCable	Australia (Northern Territory)	2027	4000	120
Terra Solar	Philippines (Nueva Ecija and Bulacan)	2026	4000	35
Mohammed bin Rashid Al Maktoum Solar Park	United Arab Emirates (Saih Al-Dahal)	2023	2427	76
Bhadla Solar Park	India (Rajasthan)	2018	2245	56
Huanghe Hydropower Golmud Solar Park	China (Qinghai)	2020	2200	>5.6
Pavagada Solar Park	India (Karnataka)	2019	2050	53
Benban Solar Park	Egypt (Aswan)	2019	1650	37.2
Tengger Desert Solar Park	China (Ningxia)	2015	1540	43
Noor Abu Dhabi	United Arab Emirates (Sweihan)	2019	1200	8
Kurnool Ultra Mega Solar Park	India (Andhra Pradesh)	2019	1000	24
NP Kunta Ultra Mega Solar Park	India (Andhra Pradesh)	2016	978	32
Longyangxia Dam Solar Park	China (Qinghai)	2017	850	21
Copper Mountain Solar Facility	US (Nevada)	2021	802	16
Mount Signal Solar	US (California)	2018	794	16
Vilannuela Solar Park	Mexico (Coahuila)	2018	754	24
Rewa Ultra Mega Solar	India (Madhya Pradesh)	2020	750	6.4
Kamuthi Solar Power Project	India (Tamil Nadu)	2016	648	10
Noor-Ouarzazate complex	Morocco (Drâa-Tafilalet)	2016	580	30
Francisco Pizarro Photovoltanic Plant	Spain (Extremadura)	2023	590	13
Solar Star Projects	US (California)	2015	579	13

Australia, with plenty of both sun and space, is also increasing construction and planning of large-scale solar farms. Since 2018 more than 100 solar farms have been accredited by the Clean Energy Regulator (ARENA, 2023). However, none are close to the size of the planned Sun Cable mega solar farm in the Northern Territory of Australia, near a small settlement, Elliott (350 people), approximately 700 km south of Darwin, the capital of the Northern Territory. The proposed capacity of the Sun Cable project, specifically the Australia-Asia PowerLink (AAPowerLink), is around 17–20 GW. The project also includes a significant energy storage system with a proposed capacity of around 36-42 GW-hours (GWh). The electricity generated is intended to be transmitted via a high-voltage direct current undersea cable to Singapore, supplying up to 15% of Singapore's electricity needs (SunCable, 2024).

The Northern Territory (1.35 million km^2) is among the most sparsely populated inhabited regions of the world, with a density of 0.18 people/km^2, especially as 60% of the population of 245,000 (ABS, 2021a) live in Darwin (60%), 730 km north of the proposed development, and a further 11% in Alice Springs, 760 km to the south. However, while the share of Indigenous people nationally is 2.6%, in the Northern Territory it is 30%, meaning Indigenous cultures and values have a strong influence on planning for large-scale developments. To date, most large-scale developments in the Northern Territory have been for mining with around 20 large mines currently operational. Exploration continues and there are also plans for hydraulic fracturing ("fracking") approximately 100 km away from the proposed site for the solar megafarm (Northern Territory Government, 2024).

2.2. Data collection and sampling

Ethical approval for the survey was obtained from Charles Darwin University ethics committee (H22036). We used a split sampling approach so we could compare the views of those living in the jurisdiction in which the solar farm will be located, the Northern Territory, with those of people lived elsewhere in Australia (population 25.1 million of whom 67% live in coastal capital cities >2000 km from the proposed solar farm). For large wind farms, it has been shown that views and acceptance vary with distance to such projects (e.g. Devine-Wright, 2009; Hall et al., 2013; Larson and Krannich, 2016; other refs). This could result in potential "distant decay" effects (which means that negative impacts but also benefits of the solar farm decrease with distance; see, e.g. Knapp and Ladenburg, 2015). We argue that respondents from the Northern Territory might have a different view and different preferences for how the megafarm will be governed, just as we found with project acceptance (Zander et al., 2024). This is because some of the benefits from the solar farm, such as cheaper energy, tax generation and infrastructure investments, would flow into the Northern Territory community, as too will some of the costs such as remediation of any environmental damage.

To collect data from people living outside the Northern Territory, we commissioned a market research company (Dynata), which maintains a panel of 400,000 people from a wide range of socio-economic backgrounds living in Australia using online and offline sources. The online survey was registered with the company and people aged at least 18 were invited to take part. We bought data from 2500 respondents for a 15-min long online survey. The market research company sent a link to the survey to a sub-sample of their research panel based on our request that data be obtained from adults only, have an equal gender split and be representative to the Australian nation in terms of age and their distribution among Australia's states and territories. A 10% response rate was assumed, i.e., to receive 2500 responses, 25,000 panellists were contacted. Potential respondents only knew that this was a research survey, that it should take approximately 15 min and that they would be remunerated according to the company's rates upon completion of the survey. Data were collected between 8 December and December 22, 2022.

Because the Northern Territory population is so small, very few members of the Dynata research panel live there making a meaningful sample unobtainable through the commissioned online survey. We therefore augmented the sample obtained from the research company through a data collection strategy better suited for small cities. We distributed postcards with the survey description and link to the online survey across households in the capital of the Northern Territory Darwin region (Darwin where 58.7% of the total territory population live. This was done applying a "random walk' technique (Lemeshow and Robinson, 1985) by a research assistant. In total, 3000 postcards were printed and dropped in people's letter boxes.

2.3. Questionnaire

The online survey was designed in Qualtrics and was the same for respondents from inside and outside the Northern Territory. On the first page of the survey, we introduced the research team and informed respondents that the survey was voluntary, that the information was to be used only for research purposes and that the collected data were unidentifiable. Respondents were also informed that they could withdraw at any time by closing the browser. The subsequent questionnaire had five parts. The first part asked general questions about the proposed construction of the SunCable solar farm. It also included an information box for all respondents, no matter whether they had prior knowledge about the project or not.

The second part included questions about attitudes towards and perceptions about large-scale renewable energy projects in Australia, including questions related to public acceptance (see Zander et al.,

2024). For the current study, we included four statement questions based on existing literature to understand respondents' general attitudes, place attachment, and alignment with NIMBY attitudes for which responses were placed on a four-point scale ("Strongly agree", "Agree", "Disagree", "Strongly disagree"): "*The proposed solar farm is bold and innovative,*" "*The Northern Territory is the perfect place to have such a large-scale renewable energy project", "I* support *any large-scale renewable energy developments in Australia, as long as they are not built close to where I live.*" For the analyses, we grouped the two positive responses into one "Agree" responses and the two negative responses into one "Disagree" response. A fourth question explored respondent's concerns about large-scale solar projects: "*Overall, how would you rate your concerns about the proposed SunCable or any similar large-scale solar farm that might be built in any remote parts of Australia?*" with the possible responses on a four-point scale including "No concerns", "Slight concerns", "Moderate concerns" and "Significant concerns".

The third part included the BWS experiment. BWS experiments are commonly used to prioritise items while at the same time minimise response biases and manage respondent cognitive load (Flynn et al., 2007). Items can be goods, services or policies or, as in this study, governance principles and are presented as a list to respondents who are then asked to identify the best and worst item in the list (Schuster et al., 2024). Although we could have asked respondents simply to rank the seven principles or rate them on a scale, both these approaches are more prone to error and do not provide the nuanced insights available from a BWS experiment (e.g. Baumgartner and Steenkamp, 2001; Adamsen et al., 2013).

The fourth part was made up of questions on attitudes towards renewable energy and related environmental sentiments and behaviour. Respondents were asked to what extent they agreed with statements, with potential responses on a four-point agreement scale ("Strongly agree", "Agree", "Disagree" and "Strongly disagree"). The fifth part included socio-economic and demographic questions (age, gender, education, income, cultural background).

2.4. BWS design

Choosing an appropriate design for the BWS experiment is a crucial first step. We applied the objective case (Case-1) BWS design which is the simplest and most practical approach among three common approaches (Louviere et al., 2013, 2015). Case-1 is used when the aim is to measure a set of items "on an underlying, latent, subjective scale" (Louviere et al., 2015). Respondents are then asked to choose the best and the worst item from the list of items, not once but repeatedly in subsets, called BWS tasks.

In a second step, we defined the items that populate the BWS tasks. Here the items were the good governance principles. The United Nations defines good governance from a human rights perspective as "the process whereby public institutions conduct public affairs, manage public resources and guarantee the realisation of human rights" (OHCHR, 2024). While there is no internationally agreed definition of "good governance", there are different topics and principles that good governance should entail. The Human Rights Council, for example, has identified five key principles of good governance: transparency, responsibility, accountability, participation and responsiveness (to the needs of the people). A similar set of principles is suggested by the United Nations Economic and Social Commission for Asia and the Pacific which includes eight principles, extending the mentioned six to equity and inclusiveness, consensus oriented as well as effectiveness and efficiency (UNESCAP, 2009). Similar principles are used to govern natural resources with good governance characterised by projects involving stakeholder participation, transparency of decision-making, accountability of actors and decision-makers, rule of law and predictability, efficient and effective management of natural, human and financial resources, and fair and equitable allocation of resources and benefits (PROFOR and FAO, 2011; Bhatta et al., 2022). Based on these principles, we identified seven good governance principles that are pertinent to renewable energy megaprojects. The seven principles (see Table S1 in the Supplementary Materials for a detailed description and justification) were:

1. Secure the affordability of energy supply in the region (Responsiveness/Effectiveness)
2. Provide economic benefits such as jobs and upskilling to the region (Participation)
3. Bear no or minimal risk to the environment (Responsibility)
4. Be based on a transparent stakeholder consultation process (Transparency)
5. Pay a fair share for the resources and services used (e.g. for land use) (Fairness/Equity)
6. Led by an Australian-based developer and adhere to all Australian regulations (e.g. tax, worker rights) (Rule of law)
7. Ensure developer is fully accountable if something goes wrong (Accountability)

These seven good governance principles were then combined into different tasks. The most common design for case-1 BWS experiments is the balanced incomplete block design (BIBD), which we applied here. This design implies that the allocation of items within the design is balanced, i.e. each item occurs the same number of times, and also occurs the same number of times together with the other items (co-occurrence) (Louviere et al., 2013). To prioritise all seven principles, there were few combinations available which would provide a BIBD (Louviere et al., 2015). Using the R software and the package *crossdes* (Sailer, 2015), we generated a BIBD with seven different BWS tasks with three principles each to be traded off against one another. In this design, each item occurred three times across all of the seven tasks assigned to a respondent. Each respondent was asked to make seven choices and to choose the most and least important principles seven times, thereby seeing each item three times. The associated question was as follows:

> What do you consider the most and least important issue for a regional government when making decisions about large-scale renewable energy projects such as solar farms?

The reason why we asked about regional government, in our case the Northern Territory government, is that this level of government, rather than the national government, acts as the principal intermediary between developers and citizens. Policymakers can attract investors and support the realisation of renewable energy projects, aiding it financially until it is competitive (Romero-Lankao et al., 2023). They can also ensure all stakeholders adhere to good governance principals in that process.

2.5. Data analysis

Data obtained from a BWS experiment was analysed using a counting approach (Louviere et al., 2015). First, we counted the number of times each item was selected as the Best (B), here most important, and the number of times it was selected as the Worst (W), here least important, across all respondents. The difference between B and W is the BW score. If this score is positive, it means that respondents have, overall, chosen an item as most important more often than as least important, and vice versa. Given that each item occurred three times, the maximum score for one item could have been most important was +3 (three times chosen as most important) and the minimum score −3 (three times chosen as least important). To facilitate interpretation of the scores, we calculated the ratio scales, which are the square roots of the BW scores (see Aizaki, 2023), then standardised them in relation to each other (Marley and Louviere, 2005) to produce scores between 0 and 1. The most highly valued governance principle had a score of 1 with all others being expressed as a proportion of the highest ranked principle. The R package support.*BWS* (Aizaki, 2023) was used to analyse the data obtained from

the BWS tasks. To test the significance of differences in mean scores among different categorical variables such as gender and 'living in the NT', Kruskal-Wallis (KW) rank sum and chi-squared tests were applied. To test for differences in the ordinal variables education, age and income, and the mean scores, non-parametric Spearman's rank correlation rho tests were applied.

3. Results

3.1. Sample description

As commissioned, we obtained 2500 responses, but discarded 277 because they were incomplete. As per our aims, we differentiated between those who lived in the Northern Territory and those living in the rest of Australia, most of whom were from the densely populated south and east (Table 2). In the final online sample, there were slightly more female than male respondents (50.7%). Only adults were asked to participate in the survey, as specified in the ethics clearance, and the median age bracket was 36–40 years (category 5). The age and gender distribution of our sample therefore corresponded well with the national median age of 38 years and a 50.7% share of females within the population (ABS, 2022a). The share of respondents identifying as Indigenous was, at 5.9%, slightly higher than the national share of 3.2% (ABS, 2022b). All relevant statistics are presented in Table 2.

A greater share of people in the Northern Territory knew about the proposed construction of the solar farm before the survey than those living elsewhere ($\chi^2 = 86.89$, df = 1, p-value <0.001). A large majority of respondents (~87%) considered the proposed solar farm to be bold and innovative, with a slightly higher (significant at the 10% level of significance) share of people living in the Northern Territory holding this view than did people from the rest of Australia (Table 2). A similarly high percentage (89%) agreed that the Northern Territory is the perfect place to have such a large-scale renewable energy project with a much higher share thinking this among Northern Territory residents (98%) than those from the rest of Australia (88%; $\chi^2 = 10.59$, df = 1, p-value = 0.00113). Approximately 70% of respondents agreed that they supported any large-scale renewable energy developments in Australia, as long as they are not built nearby, with no significant difference between the two samples. Less than a quarter of respondents were concerned about the proposed solar farm or any similar megafarm that might be built in any remote part of Australia, also with no significant difference across the two samples.

Table 2
Sample description.

Characteristics	All (n = 2223)	Local (within NT) (n = 124)	Rest of Australia (n = 2099)
Female respondents (%)	51.3	40.3	50.7
Age category (median)	5	5	5
Identified as Indigenous (%)	5.9	7.3	5.9
Education category (median)	3	4	3
Annual household income category (median)	3	4	3
Knew about the proposed construction before survey (%)	25.7	61.3	23.6
State:			
New South Wales (NSW)	28.8		30.6
Victoria (VIC)	26.3		27.8
Queensland (QLD)	19.6		20.7
Western Australia (WA)	8.9		9.4
South Australia (SA)	7.1		7.5
Tasmania (TAS)	2.2		2.3
Australian Capital territory (ACT)	1.6		1.7
Northern Territory (NT)	5.5	100	0
Agree that the proposed solar farm is bold and innovative (%)	87.4	93.0	87.7
Agree that the NT is the perfect place to have such a large-scale renewable energy project (%)	88.5	97.6	88.0
Support any large-scale renewable energy developments in Australia, as long as they are not built close to where they live (%)	70.4	68.6	70.5
At least moderately concerned about the proposed SunCable or any similar large-scale solar farm that might be built in any remote parts of Australia (%)	23.6	25.0	23.5

Age categories: coded from 1 (18–24) to 11 (older than 70).
Annual household income categories: coded from 1 (up to AUD 25,000) to 8 (more than AUD 200,000).
Level of education categories: coded from 1 (completed Year 11 or below) to 4 (University degree, completed or currently enrolled).
NT = Northern Territory.

3.2. BWS results

Overall, respondents thought that the safety of the environment was the most important issue, followed by the provision of affordable energy to people in the region and that the project is being led by an Australian-based developer (Fig. 1).

Across all respondents, only two governance principles received negative scores, Fairness and Transparency, meaning that these two were more often chosen as least than as most important. However, people from the Northern Territory also valued Rule of Law negatively (Fig. 1). Overall, Responsiveness was 88%, Rule of Law 81%, Participation and Accountability both 79% and Fairness 71% as important than Responsibility (std. ratio scale; Table 3). Transparency was less than half as important than Responsibility.

Residents of the Northern Territory had significantly lower scores for Rule of Law (KW $\chi^2 = 13.12$, df = 1, p-value = 0.0003) and significantly higher scores for Participation (KW $\chi^2 = 8.50$, df = 1, p-value = 0.0036) than those from the rest of Australia. Living in the Northern Territory was also negatively associated with Responsibility, albeit on a 10% level of significance (Fig. 2), while it had a slight positive effect on Accountability. Otherwise, the state of residence had little effect on respondents' preferences, with the exception of those living in Tasmania who had a significantly lower mean BW score for "Participation" (−0.11; see Fig. S3 in the Supplementary Materials for all location-specific mean BW scores.

Gender also played explained some differences in preferences. Women assigned statistically higher scores to Responsibility (KW $\chi^2 = 61.33$, df = 1, p-value <0.0001) and lower scores to Accountability (KW $\chi^2 = 28.23$, df = 1, p-value <0.0001). In fact, the mean score for all women for Accountability was negative (−0.04). Indigenous people assigned lower importance to Rule of Law (KW $\chi^2 = 10.72$, df = 1, p-value = 0.0010) and higher, albeit still a negative value, for Transparency (KW $\chi^2 = 15.35$, df = 1, p-value <0.0001).

Age was positively associated with assigning high importance to Rule of Law and Accountability, both at a 1% level of significance, while negatively associated with high importance for Transparency and Responsibility (both at the 1% level of significance) as well as for Responsiveness and Participation (at a 5% level of significance). Education played a minor role, with education positively associated with mean scores for Transparency and negatively with mean scores for Rule of Law. The higher the income of respondents, the higher the mean scores for Transparency and Participation, and the lower mean scores for Responsibility and Rule of Law. All correlation test statistic results are presented in Table S2 in the Supplementary Materials.

Respondents who thought about the proposed solar farm as bold and innovative and those who thought that the Northern Territory is the perfect place for such a project assigned higher scores to "Responsibility" and "Participation" (Fig. 2). "Accountability" was negatively associated with considering the project as bold and innovative and to NIMBY sentiments. People who expressed support for large-scale renewable energy projects as long as they are not built nearby

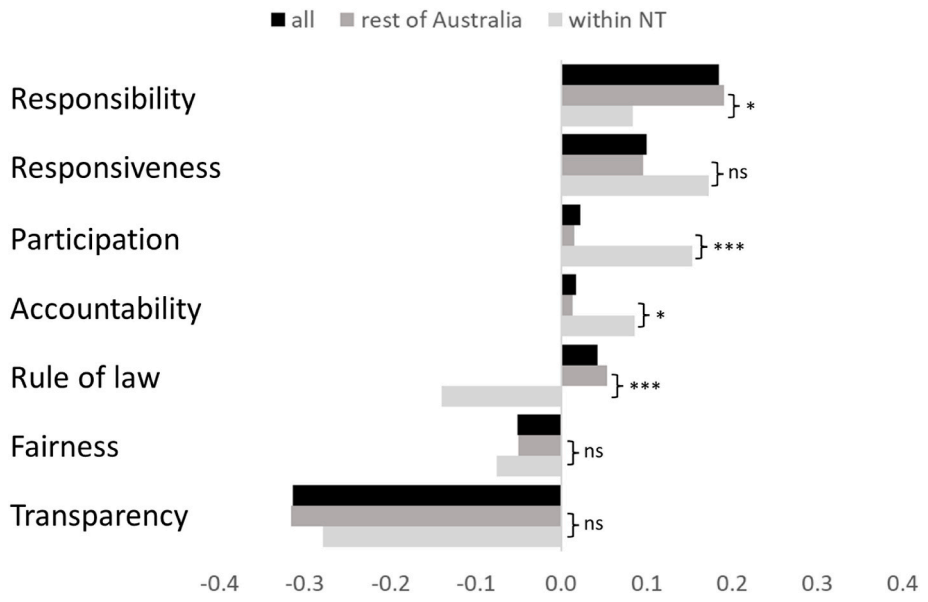

Fig. 1. Mean standardised BW scores (n = 2223)
NT = Northern Territory.

Table 3
Calculated Best (B) and Worst (W) scores (n = 2223).

	aggregated						disaggregated	
	B	W	BW	std. BW	ratio scale	std. ratio scale	mean BW	mean. std. BW
Responsibility	2943	1714	1229	0.18	1.31	1.00	0.55	0.18
Responsiveness	2617	1952	665	0.10	1.16	0.88	0.30	0.10
Rule of Law	2472	2187	285	0.04	1.06	0.81	0.13	0.04
Participation	2248	2098	150	0.02	1.04	0.79	0.07	0.02
Accountability	1974	1860	114	0.02	1.03	0.79	0.05	0.02
Fairness	2055	2398	−343	−0.05	0.93	0.71	−0.15	−0.05
Transparency	1226	3326	−2100	−0.31	0.61	0.46	−0.94	−0.31

Std. = standardised; Ratio scale = squared BW.

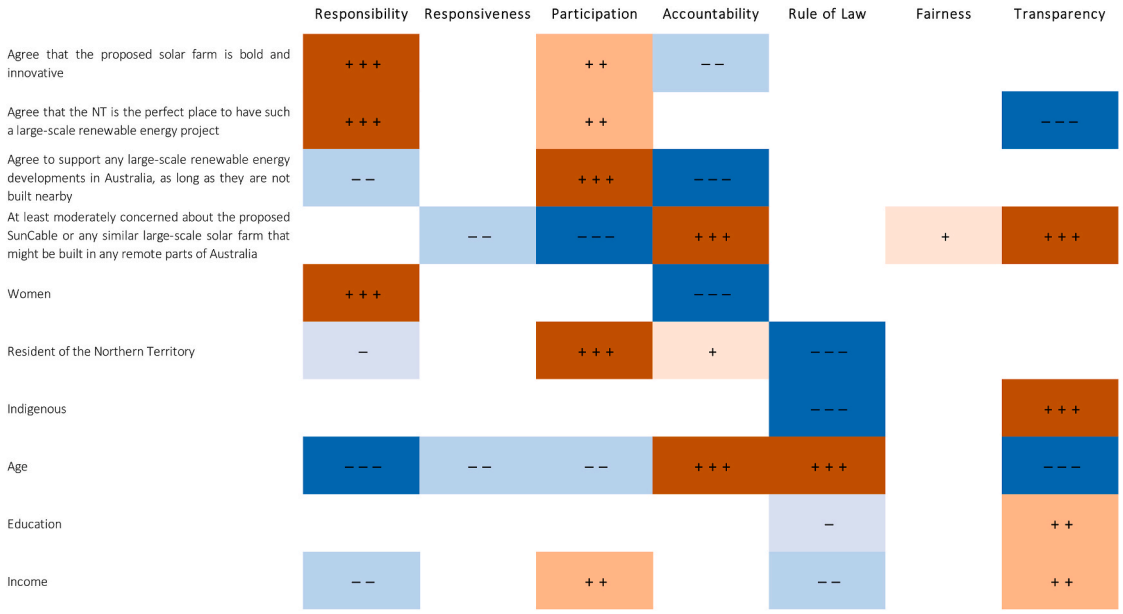

Fig. 2. Impact of attitudes and concerns on mean BW scores (n = 2223).

(NIMBY sentiment) also regarded "Responsibility" and "Accountability" as less important than those not supporting this statement. Higher levels of concern for such a project were associated with high scores for "Accountability", "Transparency" and "Fairness" (at a 10% level of significance) and low scores for "Responsiveness" and "Participation".

4. Discussion and policy implications

Understanding of how the public views the governance and management of large-scale renewable energy projects has been little explored in the literature. For megaprojects even less is known even though their complexity, size, longevity and social impact means their governance structure ought to be transparent to society (Denicol et al., 2020). Our study of a megaproject in remote Australia complements the expanding body of research on the public acceptance of renewable energy, including large-scale solar projects, which are deemed unavoidable if energy transitions are to be successful (Caggiano et al., 2024; Scovell et al., 2024). Some relevant studies have highlighted the role of single governance-related issues such as fairness (distributional justice) related to the location of projects (Wolsink, 2007; Heffron and McCauley, 2017; Liebe et al., 2017; Firestone et al., 2015; Fast et al., 2016; Hoen et al., 2019). Others have focused on trust, which can increase public acceptance of large-scale solar projects (e.g. Carlisle et al. 205). Transparency, another element of good governance, has also often been singled out as important determinant of public acceptance (Campos et al., 2023). However, no studies so far have considered the whole suite of good governance principles simultaneously.

Planned solar farms are increasing in capacity as benefits are scaled with size. Such projects require large areas of land on which to erect vast numbers of ground-mounted solar panels. While solar energy production is often preferred over other sources of renewable energy (Donald et al., 2021; Rodríguez-Segura et al., 2023; Caggiano et al., 2024), very large solar farms have started to generate social conflict, particularly in local communities that see their rural "idyll" being replaced by "photovoltaic landscapes" (Poggi et al., 2018; Scognamiglio, 2016; Nilson and Stedman, 2023; Bessette et al., 2024; Schram et al., 2024). Importantly, understanding of public acceptance of megaprojects needs to occur well in advance of construction and operation if these are to proceed smoothly (Dolter and Boucher, 2018; Heffron et al., 2021). Our case study from remote Australia differs from existing large-scale solar farms given construction is planned for lands with low agricultural productivity and a very sparse population. The landscape in such areas is perceived very differently, to, for example, rural Europe, the US or southern Australia in which most studies of solar farm acceptability have been undertaken. This is evident from a study by Zander et al. (2024) related to this one in which the respondents living closest to the proposed solar megafarm had the most positive views and emotions, mostly based on the prospect of local economic benefits and the potential reputation of the Northern Territory as a renewable energy powerhouse.

4.1. Responsibility and Responsiveness

Across all respondents, the scores were positive for five of the seven good governance principles tested in the BWS experiment (Fig. 1). Responsibility and Responsiveness stood out as the two principles with highest value for all respondents. Responsibility was phrased as "Bearing no or minimal risk to the environment" and as such this finding was not surprising. The concern for negative environmental impacts of large-scale renewable energy projects are well documented (e.g. Delicado et al., 2016; Suškevičs et al., 2019; Campos et al., 2023; Klok et al., 2023). For solar farms, these concerns have mainly related to protected land, watercourses and wildlife (Scognamiglio, 2016; Poggi et al., 2018; Bessette et al., 2024) but can also relate to potential harm to cultural sites and heritage (Sward et al., 2021). Cultural concerns may have been relevant to the respondents to our Australian survey because the continuing legal and cultural connections of Indigenous people to lands in the Northern Territory is well known. Many people in southern Australia would immediately consider the impacts on Indigenous people of proposals to change land use in this part of Australia. Although the suggested solar megafarm will not be constructed on land with formal Aboriginal rights, being pastoral land leased from the Government, cultural connections to land persist regardless of state tenure, particularly in remote Australia (Bishop et al., 2012; Bawaka Country, 2022). A study of small-scale solar systems with First Nations people in Canada highlighted the need to include First Nations communities in solar energy programs and the legal context of land ownership by First Nations people (Dolter and Boucher, 2018). With many more very large solar megafarms likely to be built in remote Australia, there will be benefit from developing a suite of good governance principles that are accepted by Indigenous people as well as non-Indigenous people and to ensure they are adhered to in solar farm planning and construction.

Responsiveness was explained as "Securing the affordability of energy supply in the region", i.e. a direct benefit to people living in the region. Energy prices in Australia, as in many countries, constitute a substantial proportion of household budgets and contribute to energy inequality and poverty (Hammerle and Burke, 2022) so it was unsurprising that the prospect of cheap energy was welcomed (Demski et al., 2018; Hanger et al., 2016; Brennan and van Rensburg, 2020). It was also not surprising that respondents living in the Northern Territory assigned even higher scores to this principle than those living further away. The proposed solar farm is expected to provide a certain share of the energy produced into the local Darwin grid. However, to whom this energy will be distributed at what price, is not known.

Many previous studies have found that perceived economic benefits and environmental costs are the two main drivers of public acceptance by Northern Territory residents, countering the NIMBY concept (e.g. Hanger et al., 2016; Brennan and van Rensburg, 2020), suggesting that the BWS was an appropriate tool and well understood by people who made these choices in our experiment.

Those who were concerned about the proposed solar farm had lower scores for principles that bring benefits to the community, ("Participation" through employment and "Responsiveness" through cheaper energy). These people were probably sceptical about the impact of the solar farm and whether these benefits would actually eventuate as promised. In contrast, respondents who considered the project to be bold and innovative, and those who thought that the Northern Territory is the perfect place to site the project, had higher scores for "Responsibility" and "Participation".

4.2. Rule of law, Participation and Accountability

Rule of Law, Participation and Accountability all had marginally positive mean BW scores. It is with these mid-ranking principles that a difference between the two samples was most apparent. Rule of Law was described as "Being led by an Australian-based developer and adhere to all Australian regulations (e.g. tax, worker rights)". This principle was negatively valued by respondents from the Northern Territory but ranked as third most important principle by people in the rest of Australia. This result was surprising, since studies have shown that large-scale renewable energy projects are more accepted when they are owned and operated by local communities and companies rather than by foreign entities (Caggiano et al., 2024).

There is also evidence that local people are more concerned about justice and governance of large-scale renewable energy projects since they are more likely to be directly affected, in a positive and negative way (Susskind et al., 2022). One reason why Northern Territory residents were indifferent towards the Rule of Law may have been because they knew more about the proposed project. Although the BWS questions were not directly about this project, but similar ones, local people would have been more exposed through local media to the planning process that has already occurred and the media about the potential benefits of the project. They may have been sceptical that construction

would ever proceed, given many other failed mega-projects in the region, and want the projects to proceed, no matter of the rule of law, fairness or transparency, because the alternative land use currently being debated (Williams et al., 2017) involves hydraulic fracturing (fracking), a fact highly likely to be known by local people. It is common that people weight proposed developments and land uses against alternative uses (Wolsink, 2018). In the more populated regions of southern Australia, the alternative land is more likely to be farming and mega projects competing with food production, this is not the case in remote central Australia.

It was also surprising that accountability was not higher valued. Accountability was defined as "Ensure developer is fully accountable if something goes wrong". It might be that people already considered this covered when they chose "Responsibility" as most important principle which also implies that nothing ought to go wrong. This principle is particularly important for the end of life of the vast amounts of solar arrays used, the disposal or recycling of which is only now becoming an issue in long-established solar markets (Chowdhury et al., 2020).

Participation, defined as "Proving economic benefits such as jobs and upskilling to the region" was particularly highly valued by people from the Northern Territory. Public acceptance is often highest for projects that deliver benefits to respondents and their community (e.g. Bidwell, 2013; Hanger e al., 2016; Brennan and van Rensburg, 2020). For the Northern Territory with a high share on Indigenous people (26.3%, compared to the national average of 3.2%; ABS, 2021a), these projects always have the hope of engaging Indigenous people for whom employment and training participation rates are relatively low.

4.3. Fairness and transparency

The two principles with the lowest and consistently negative scores were Fairness and Transparency which in both cases were surprising results, although it should be noted that all scores are relative - Fairness and Transparency are still likely to be important on their own, just less important than the other governance measures. Fairness was described as "Paying a fair share for the resources and services used (e.g. for land use)" and Transparency as "Being based on a transparent consultation process". Both are important concepts in the process of building large-scale renewable energy projects (Klok et al., 2023). However, in the existing literature, fairness in regard to renewable energy projects mostly refers to distributional fairness or justice, i.e. the fair distribution of projects across regions and social groups which is important for wind turbines/farms (Wolsink, 2007, 2018; Heffron and McCauley, 2017; Liebe et al., 2017).

We defined fairness as a good governance principle differently because, unlike smaller projects, these mega projects are not as numerous and are predominantly constructed in sparsely populated areas. This is why we defined fairness as the developer and investors paying a fair share for the resources and services used. This could be for the land needed for the solar farm itself, which might not always be privately owner, but, as in the case of SunCorp, could be land leased from the government or traditional owners. It can also refer to paying a fair price for using land for building the overhead power lines from the proposed solar farm to the grid, for storage facilities and for any other associated infrastructure, and also for services sourced from the local communities. One reason why fairness was not regarded as important might have been its relation to Rule of Law, described as "Being led by an Australian-based developer and adhere to all Australian regulations (e.g. tax, worker rights)", a principle valued in the mid-range (see previous section).

Transparency was expected to be regarded as highly important since transparent consultation processes contribute to trust which, when lacking, is one of the main impediments to the public acceptance of renewable energy projects (e.g. Bell et al., 2005; Gross, 2007; Devine--Wright and Howes, 2010; Carlisle et al., 2015; Goedkoop and Devine-Wright, 2016; Campos et al., 2023). Many studies suggest that communities and stakeholders need to be engaged in a transparent way using a "co-production" approach to secure social acceptance and to improve energy justice (Sonnberger and Ruddat, 2017; Wolsink, 2018; Dolter and Boucher, 2018; Campos et al., 2023; Klok et al., 2023). Our results suggest that respondents though that Transparency and Fairness in this case were less important than the other governance indicators and that, as long as these types of renewable energy megaprojects deliver economic benefits and do not harm the environment, they should go ahead. Backing this up is the fact that those expressing concern about the project placed higher scores on "Transparency", "Accountability" and "Fairness" than those more sanguine about its construction. Interestingly, those who thought that the Northern Territory is the perfect place had lower scores for "Transparency" and these were also the people living in this jurisdiction.

Almost 98% of people living in the jurisdiction where the mega-project is to be built agreed this region was the perfect place, defeating any NIMBY sentiments. This might be partly because the proposed project is a solar farm and not a wind farm. Wind farms which are visible from a large distance, can disrupt scenic beauty and views and can be noisy, which means that many wind farm project's adverse impacts are geographically determined, making spatial planning inevitable to increase acceptance (Rand and Hoen, 2017; Peri et al., 2020). Solar farms do not have the same location impacts, especially in remote places. Solar farms in remote parts of sparsely populated Australia might therefore be of less concern to people and the spatial planning process, although there are potential concerns for land titles and the maintenance of Indigenous cultural land. The other reason is likely to be that, although living closer to the proposed development than those people surveyed online, most people living in the Northern Territory are still a long way from the development sites which is about 30 km from the closest permanent dwelling.

4.4. Study limitations

One shortcoming was that we were unable to survey people at the small settlement of Elliott, 30 km from the proposed site of the solar farm. This community has 120 private dwellings and nearly 300 people of whom about 85% are Indigenous (ABS, 2021b). The appropriate survey mode for including these households, in-depth interviews, was beyond the scope of the study which aimed to assess the preferences of a sample drawn from people across the country. Instead, we were limited to reveal differences across the broader Australian public and those who lived in the Northern Territory, the jurisdiction in which the solar farm is to be built.

We have also not specifically consulted Indigenous people across the whole of the Northern Territory or Australia. While the proportion of Indigenous people participating in the online survey (5.9%) was double the national percentage in the population (3.2%; ABS, 2021a), suggesting substantial interest, the percentage of Indigenous respondents from the Northern Territory (7.3%) was below the percentage of people identifying as Indigenous people in this jurisdiction (26.3%, ABS, 2021a). While our results did reveal an effect of Indigeneity on the preference of some of the principles (Rule of Law and Transparency), because of the small number of Indigenous respondents, these results need to be considered with caution. More research is needed using culturally appropriate participatory and co-led consultation processes. To incorporate local actor views about renewable energy projects, participatory processes such as citizen assemblies, listening sessions and committees have been proposed to help identify opportunities and barriers (Romero-Lankao et al., 2023). While this is a shortcoming in understanding local community views on the governance of the proposed solar megafarm, it also points to a major research gap that needs to be addressed in future studies before the construction goes further ahead.

5. Conclusions

With the proposals of new renewable energy megaprojects in many countries, including Australia, new landscapes of solar array or wind turbines will be created. These new solar landscapes can create tension and social and environmental disruption unless processes involved in their planning and construction follow sound governance principles. Adhering to good governance principles during the whole process from planning to operating, is likely to increase justice and public acceptance of these renewable energy mega projects. In this study, we conducted an Australian-wide online survey using a best-worst scaling (BWS) experiment to gauge respondents' preferences for a range of good governance principles. The applied BWS experiment proved to be a simple and effective method for gauging preferences and for assessing the relative importance of the set of seven good governance principles.

As a case study, we used the world's largest proposed solar farm (12,000 ha of solar arrays) which it is planned to construct in remote northern Australia. The results showed that residents of the Northern Territory, the jurisdiction as the prosed solar farm, care most about economic benefits, participation and responsiveness, i.e. providing jobs and cheap energy. These preferences for direct benefits were traded-off for principles concerning the rule of law, fairness and transparency, all of which were deemed less important. Those living in other regions in Australia, mostly in the populated southern parts, prioritised responsibility, instead, i.e. keeping the environmental risks at a minimum. This suggests that currently there are minimal concerns about solar mega projects, such as that planned for the Northern Territory in northern Australia, and that there is likely to be little social resistance. Our results suggest that people in Australia are less concerned about consultation as long as the project bears no or minimal risk to the environment and that economic benefits flow to the community and society as a whole. The results can be useful for the required energy transition and the future of renewable energy megaprojects in remote parts of Australia.

CRediT authorship contribution statement

Kerstin K. Zander: Writing – review & editing, Writing – original draft, Visualization, Software, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Rabindra Nepal:** Writing – original draft, Validation. **Stephen T. Garnett:** Writing – review & editing, Writing – original draft, Validation, Conceptualization.

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.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2024.143848.

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