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Building climate resilience through energy access? An empirical study on grid connectivity in the Indian Sundarbans

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ABSTRACT

Scholarly debates on energy and climate change have successfully foregrounded mitigation measures, but often overlook the role of energy in climate adaptation. Adaptation is of key importance to building resilience to climate change impacts, but its link with energy access has not been studied in detail. This study aims to address this research gap by examining the relation between electricity access and climate resilience in the context of Bally Island in the Indian Sundarbans. We deploy a qualitative research approach to investigate whether and how the electricity grid, installed to Bally in 2019, aids residents to build resilience against climate change impacts. Our case study highlights the importance of incorporating climate resilience into future energy planning. We find that benefits of electricity access can help people to become more resilient against climate change impacts. However, it is important to understand contextual limitations to building resilience with electricity. Our case study furthermore shows unintended consequences of grid connectivity that can negatively impact peoples' capacity to build resilience. For example, the untrustworthy electricity grid has led to the decline in popularity of solar PV systems, despite the fact that they are a more reliable alternative to the electricity grid. Therefore, we urge scholars and policy makers to consider the benefits, limitations, and unintended consequences of (planned) electricity measures on people's capacity to build resilience, especially in areas vulnerable to climate change.

1. Introduction

Resilience, adaptation, vulnerability, and human practices and processes related to it, are of increasing importance considering the daily reality of climate change for many communities around the world [1,2]. Given the increasing frequency and intensity of climate change impacts, scholars advocate for integrating resilience considerations into development policies and programs. For example, attention is given to the importance of taking adaptation action to prevent setting back progress on sustainable development [3]. Similarly, scholars have also argued that building climate resilience is only feasible if the Sustainable Development Goals will be reached [4]. Furthermore, the IPCC brings forward the idea of Climate Resilient Development, integrating climate resilience and sustainable development pathways [5]. One of the primary developmental measures, seen as crucial leverage for development by governments and non-governmental organizations, is electricity access [6–8]. In this paper we seek to understand the impact of electricity access measures on people's resilience, adaptive capacity, and vulnerability to climate change. We study this in the context of the Indian Sundarbans.

Residents of the Sundarbans are confronted with sea level rise, salinity intrusion, changing weather patterns, and an increase in intensity and frequency of severe cyclonic storms [9,10]. Sundarbans residents build resilience against these climate change impacts by adopting a variety of everyday adaptation practices [11]. Meanwhile, the islands in the Indian Sundarbans have been targeted by numerous electricity access projects, of which connection to the Indian electricity grid in 2019 was one of the most prominent measures [12].

There are several publications focusing on the Sundarbans and resilience to climate change impacts, proposing for example mangrove reforestation [13], rainwater harvesting practices [14], and even planned relocation [15]. However, in studies that foreground climate resilience in the Sundarbans, there is limited attention to role that energy access can play. We find that generally, little attention has been paid to energy access and its potential to aid in building resilience. Few studies focus on this combination, for example through reviewing the linkages between energy, disaster management and development in Odisha, India [16]; through analyzing energy poverty and its relation to growing

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heat stress in Sub-Saharan Africa [17]; and through studying the potential of electrification planning in Southeast Asian islands to withstand changes to the climate [18].

With this study, we aim to contribute to this emerging field of research by examining the relation between energy access and climate resilience in the context of Bally Island in the Indian Sundarbans. We adopted a qualitative approach to study the role of grid connectivity (the most recent energy access measure) in building resilience and adaptive capacity to climate change. With our analysis, we seek to answer the following empirical research question: *How does energy access relate to the resilience of Sundarbans residents to climate change impacts?* With energy access, we refer in this article primarily to grid connectivity as a measure to improve access to electricity.

Our case-study highlights the importance of including considerations of climate resilience into future energy planning. We find that benefits of energy access can help people to become more resilient against climate change. However, it is important to also understand contextual limitations to building resilience with electricity. Importantly, we find that the untrustworthy electricity grid has led to the decline in popularity of solar PV systems, despite the fact that they are a more reliable alternative to the grid in the face of climate-induced natural disasters. Finally, our study also sheds light on the unintended negative consequences that electricity measures can have on the capacity of residents to build resilience.

The remaining part of this paper proceeds as follows: first, we theoretically explore climate resilience and debates on electricity access in Section 2. We continue with an explanation of our research design in Section 3. In Section 4, we introduce and contextualize our case study of Bally Island. In Section 5 we present the results of our analysis, bridging the debates on climate resilience and electricity access through our case study. We discuss our results in Section 6 and provide concluding remarks in Section 7.

2. Resilience, vulnerability, and energy access

Resilience, adaptation, and vulnerability are three related concepts that are increasingly used to study human responses to climate induced natural disasters and slow impacts of climate change [1,19–21]. While the concepts are related, they have distinct disciplinary origins [20–22], and there are discussions among academics about the extent to which these concepts align [23].

There are approaches to resilience in which the primary focus is on how people and communities *bounce back* – resist, recover, and return to the baseline – after misfortune, stress, or external shock [24]. This focus stems from scholarly fields like ecology, physics, and mathematics, where *bouncing back* of ecosystems, subject, or objects is also the primary focus [21,22]. Such a view on resilience centralizes the *outcome* after a disaster. Scholars approaching resilience as an outcome also often suggest that vulnerability is the flip-side of resilience. In this line of thought, something can be seen as vulnerable to the extent that it is not resilient. While resilience (and adaptive capacity) are portrayed in positive terms, vulnerability is usually portrayed in negative terms as the *susceptibility to be harmed* [25].

There are also approaches to resilience in which the focus is not merely on *bouncing back* to the original state, but on *bouncing back better* to a state in which the community or individual is more resilient to future shock or stress. While this is still an *outcome* based approach to resilience, it is a longer term approach in which communities adapt in the face of sudden or chronic climate change impacts, while developing socio-economically (instead of merely returning to the baseline after external events) [22]. In addition, there is also a *process* based approach to resilience, in which the focus is on mechanisms of self-organization, the capacity to learn from experiences, to process information, and to adapt accordingly [23].

Scholars with this more encompassing view on resilience also argue against the 'flip-side' idea on resilience and vulnerability; they state that the relation is not necessarily symmetrical. While these scholars acknowledge that a resilient system is less vulnerable than a non-resilient system, they either perceive resilience as a subset of vulnerability; or they perceive resilience and vulnerability as fundamentally different concepts with some components in common. Furthermore, they perceive vulnerability to climate change as the social, physical or ecological vulnerability to (primarily) future risks [25]. For a more detailed account of this discussion, please refer to the analysis by Akter and Mallick [23].

While we acknowledge the nuances, in this article we assume that a reduction in vulnerability enhances the adaptive capacity of people and communities; and will aid them in building resilience against climate change impacts. Conversely, we also assume that an increase in capacity to adapt and build resilience lowers vulnerability to climate change impacts. In our analysis we focus on resilience primarily as an *outcome* in which communities adapt in the face of sudden or chronic climate change impacts, while ensuring socio-economic development. Adaptation is an important notion in many approaches to resilience. The term adaptive capacity refers to the ability to respond to actual or anticipated occurrences of climate change, or to cope with the consequences [26]. Drawing on McCarthy et al. [27], we consider adaptive capacity to be "*a function of wealth, technology, education, information, skills, infrastructure, access to resources, and stability and management capabilities*".

As we will further develop in Section 4, climate change impacts are felt by Sundarbans' residents in two ways: first as (the increase of) external shocks and disruptions like cyclonic storms; and second as slower (chronic) changes like sea level rise. This has an impact on their capacity and strategies to adapt and build resilience to climate change impacts.

2.1. Linking resilience and vulnerability to energy access

While the literature on energy access and resilience is limited [18,28], we find several linkages between both concepts. First, development and resilience are increasingly seen as co-dependent in the face of unprecedented climate change [29]. As highlighted by Sharma [16], e.g. because of "*weak governance and fragmented institutional arrangements, conflicting critical priorities, low levels of climate-proof infrastructure capacity, socio-cultural norms and practices, greater dependence on the natural environment, and limited financial resources*", developing regions are at a particular disadvantage in improving resilience to climate change impacts.

In addition, Yadava and Sinha [30] argued that "*alleviating poverty, reducing climate change vulnerability and improving energy access are all interlinked and complementary to each other, forming an energy–poverty–climate nexus*". They find a significant association between vulnerability and poverty; poverty and energy access; and energy access and vulnerability in their study in Madhya Pradesh, India. This idea of an energy-poverty-climate nexus aligns with the finding that globally, climate vulnerability is highest for people living at the intersection of low socio-economic development; social marginalization based on race, class, ethnicity or gender; and historical and ongoing patterns of inequity such as colonialism [31]. Thomas et al. [32] argue that these factors influence climate vulnerability e.g. because of a lower (political) representation of marginalized groups, or because the increased exposure of certain social groups to environmental hazards reinforces their climate vulnerability.

Energy access, as one of the most prominent development interventions institutionally embedded as Sustainable Development Goal 7 [33], is likely to have an impact on- [3], and is impacted by- [4], resilience to climate change. Through its positive impact on socio-economic development, energy access can enhance people's capacity to build resilience to climate change impacts [16]. There is a big body of literature on the impact of electricity access on socio-economic development. For example, Ahmad, Ali & Basit [34] introduce their study by stating that "*access to modern energy, electricity in particular, is an* *indispensable ingredient of socio-economic progress and well-being*". Electricity access has been observed to enhance literacy rates in rural India [35,36]; enable access to need-based and user centric information through smartphones and computers [37,38]; increase livelihood opportunities and raising incomes in rural areas [39]; and increase a sense of security and safety in rural India [40]. Furthermore, previous research suggests that household electrification reduces time spent on women-dominated, time-intensive tasks (such as water or fuel collection and cooking) [41], as well as increase their labor participation [42].

Next to socio-economic development benefits, scholars recognize that energy access can play a crucial role in post disaster recovery [43]. Timely and reliable provision of services enabled by energy access, such as clean drinking water, healthcare, safety, healthy nutrition and further climate monitoring can strengthen short-term resilience to climate-induced natural disasters [16]. At the same time, energy access can also be impacted by climatic changes and resulting disasters, for example because energy infrastructures like hydropower are vulnerable to changes in rainfall patterns [44,45]. In a similar vein, there are articles focusing on mitigating and simultaneously adapting to climate change by connecting people to *off-grid, renewable electricity solutions*, often as an alternative to grid connectivity [46–48], to have a more stable supply of electricity in disaster prone areas – also in the context of the Sundarbans [49].

Despite the socio-economic development benefits and its role in post disaster recovery, improved electricity access does not inevitably increase resilience. The benefits of electricity access are often not equal for all members of a community or society, which can increase inequality and therefore also increase vulnerability to climate change impacts. For example, there are studies suggesting that power dynamics within households are an important boundary condition for socio-economic benefits [50], and that gender discrimination towards women is rather perpetuated instead of minimized through electricity access [51].

In the following section, we detail how we approached our study on the connection between grid connectivity and resilience in the context of Bally Island.

3. Research design

This study adopts a qualitative approach, with a focus on the role of grid connectivity in building resilience to climate change impacts for Bally residents. In the subsequent Section 4, we provide more details on the geological, geographical, and social context of Bally Island, through focusing on climate vulnerability and the energy landscape on Bally.

3.1. Data collection

Primary data collection for this study involved interviews and focus group sessions with residents of Bally Island, combined with observations. These methodologies were selected to emphasize the human practices involved in building resilience with electricity access. Interviews, focus group sessions, and observations are appropriate methods for highlighting these practices [52]. In addition, an explorative survey of 205[1] recipients was conducted. The responses to the survey have been used as input for the research design of the final research trip, and to understand whether out interviews and observations could be more widely observed on Bally. Other methods to triangulate our findings were conversations with Bengali scholars familiar with the Sundarbans; observations during a short stay with a Sundarban family; and extensive desk research including scholarly literature, grey literature, and any other (online) sources like videos.

We undertook three research trips, conducted in March, April and May 2022. All trips consisted of a three-day stay on Bally Island, together with a translator and a Bally guide, during which interviews were conducted and observations were being made. Interviews were recorded (with permission from the interviewees), transcribed, and used as input for the research design of the next trip. The transcriptions, 32 in total, have been coded inductively. Appendix 1 gives an overview of the interviews and focus group sessions conducted. Appendix 2 provides an overview of the survey design and responses.

Fig. 1 illustrates the iterative approach to this research, iterative referring to the process in which we went back to desk research in between interviews and observations, to create the approach for the new research trip.

During research trip 1 we used unstructured interviews to explore the island and its energy landscape. Our focus during trip 2 was on 12 main issues identified during trip one. Using description cards in English and Bangla, along with visual aids (see also Fig. 2), we analyzed the connection between these issues and energy and electricity access together with participants. Finally, the third research trip included focus group sessions and semi-structured interviews, with topic guides that were based on previously gathered data.

3.2. Reflection and limitations

As emphasized by Nielsen and D'haen [2], a careful reflection on qualitative methods and their limitations is imperative, which we pursue in this section. During the fieldwork, there were different positionalities and potential biases stemming from it. The interviewer (1st author of this paper) is a Dutch woman, trained as a social scientist, whose appearance, white skin and light hair, were visibly different from the people she interviewed. Never having visited the Sundarbans before, not speaking Bangla, and coming from a privileged position, thorough preparation and reflexivity were essential. The translator (3rd author of this paper) is a female Bengali environmental scientist who was not trained in social science methods. Finally, the research involved a male Bally resident, who had connections with NGO's in Kolkata, who was very concerned with development of Bally, and who worked in his own local NGO and as a solar awareness advocate. To mitigate potential biases stemming from these different positionalities, the interviewer, translator, and local guide engaged in reflective conversations throughout the research trips.

The interviewer, translator, and the guide all had a crucial role in conducting the research. The guidance and insights of the Bally guide were vital to perform this research. Especially during the focus group sessions, when interviewees discussed among each other, the role of the translator was of key importance. Furthermore, the translator and local guide contextualized the interviews and built trust and rapport with the interviewees. Trust and rapport were also important between the interviewer, translator, and local guide. The interviewer and translator were able to start from a base of trust quite naturally, still, attention was paid to reflection and connection throughout the fieldwork period. Furthermore, the translator played a crucial role in facilitating rapport between the interviewer and the local guide by translating casual conversations and jokes.

While we interviewed a large demographic variety (e.g. occupation; gender; location; and with and without solar PV systems), the local guide primarily selected people that he knew well for us to interview. While an advantage during the interviews, as these people trusted the local guide and seemed well at ease, this is also a clear selection bias: especially since our local guide is part of what he calls a 'solar-awareness' team. During the second and third research trip, we mitigated this bias through also interviewing people that our local guide had no prior connection with, and through triangulation.

Finally, we rely on people's explanations and memory to understand whether resilience and adaptive capacity of Bally residents has changed since grid connection in 2019. By chance, we experienced some light storms during the research that allowed us to observe the (electricity)

[1] The survey had 205 recipients; 87 women and 118 men. The survey was performed by 9 Bally inhabitants, both male and female, who are linked to a local NGO.

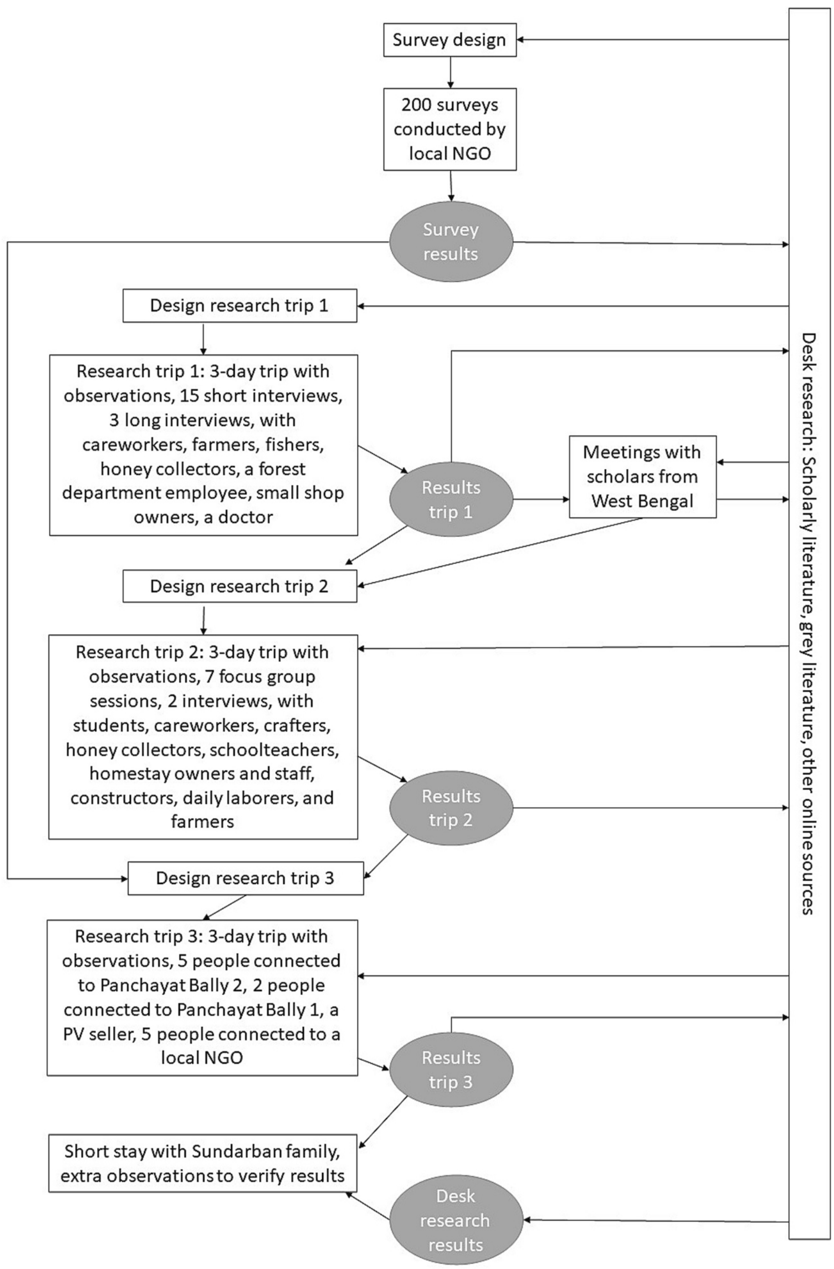

Fig. 1. Iterative qualitative research approach.

Fig. 2. Focus group session in which participants discussed together how the different issues, identified in the literature and during the first research trip, connected to each other and what the relationship is and could be with electricity or energy.

practices people mentioned during the interviews before. Through triangulation of our findings and through reflective conversations throughout the research trips, we aimed to mitigate these limitations.

4. Climate vulnerability and electricity access on Bally

The Sundarbans, an archipelago of islands in India (state of West Bengal) and Bangladesh, consists of both inhabited and uninhabited islands. The uninhabited islands are protected, and the mangrove forests are home to many species of animals and plants, including endangered species such as the Royal Bengal Tiger [53,54]. Bally Island is situated in the Indian Sundarbans, and is part of Gosaba Block in the south district of West Bengal (see also Fig. 3) [9,55]. On Bally, and the adjacent island Gosaba, residents can go to markets for food and a variety of articles.

Delta regions like the Sundarbans, characterized by a continuous interplay between water and land, are particularly vulnerable to climate change. In the Sundarbans, this interplay between water and land involves tides; frequent floods and cyclonic storms; changing landforms because of erosion, accretion, and inundation; and seasonal fluctuations in levels of water salinity around the islands [55]. Sea-level rise exacerbates flooding and increases water salinity around the islands as saline water intrudes further upstream in the delta. Additionally, climate change is observed to amplify the frequency and intensity of cyclones and floods in the Sundarbans [56], with notable examples being cyclone Aila (2009), Amphan (2020), and Yaas (2021). We will refer to the events amplified by climate change as climate-induced natural disasters.

The vulnerability of Bally residents to climate change is not only influenced by geographical and ecosystem factors but also by historical and socio-economic aspects discussed in the following Subsection 4.1. Subsequently, in Subsection 4.2 we describe the energy landscape on Bally and how this landscape has changed with grid connectivity. Both Subsections 4.1 and 4.2 are based on the empirical data that we gathered in the Sundarbans and have been triangulated with academic literature.

4.1. Climate vulnerability on Bally

Under normal conditions, the Sundarbans mangrove forests function as a stabilizing factor for the interplay between water and land, reducing the frequency of flood occurrences and protecting human lives and properties [57]. Deforestation during British colonial rule and before when Muslim *pirs* – holy men – were ruling, who both perceived the Sundarbans as '***wasteland***' that needed to be '***reclaimed***'[2] [58], has heavily increased the vulnerability of the Sundarban islands to the interplay of water and land. While the British colonizers realized near the end of their rule that the Sundarban mangroves were valuable, leading to legal protection of the remaining forest until this day [59], deforestation continued on the cultivated islands. Among current strategies to build resilience against climate change impacts is the reforestation of the mangroves [13].

British colonizers furthermore actively recruited people from other (Bengal) regions to settle in the Sundarbans. Before these efforts, the Sundarbans were only sparsely populated [58,60]. Population growth increased following the India-Pakistan partition and Bangladesh Liberation War, exerting additional pressure on the Sundarbans natural resources. Both population growth in the region and deforestation have increased vulnerability of the area, and therefore also of its residents, to climate change impacts.

Bally residents' capacity to build resilience is further hindered by low socio-economic development. The majority of Bally residents live below the poverty line [9], and essential services like mobility infrastructure, health care, and public resources are lacking. Social marginalization, particularly gender inequality and differences in income generation, creates differences in climate vulnerability among Bally residents. Firstly, gender inequality entails that women in Bally face lower education levels and are often subject to arranged marriages, leading them to live on other islands and engage in physically demanding labor to support their families. Secondly, there are differences in income generation, mainly related to landownership, rendering the ones without enough land to sustain their families more vulnerable to climate change. Most residents are small-scale farmers who sustain their families with their land for crops, livestock, and small ponds for fish and ducks.[3] However, their income generation is restricted as they have limited access to markets and urban areas. Households without sufficient land to

[2] Another way in which Western thinking still has influence on resilience and adaptation to climate change in the Sundarbans, is the artificial notion that there exists a clear boundary between water and land. These are materialized, for example into high, concrete dams. Such dams are criticized for giving residents a false sense of security, and actually increasing salinity intrusion as opposed to the traditional earther embankments. See Sen [61], for a more detailed account of this issue.

[3] Both the eggs and the fresh water fish are essential protein sources.

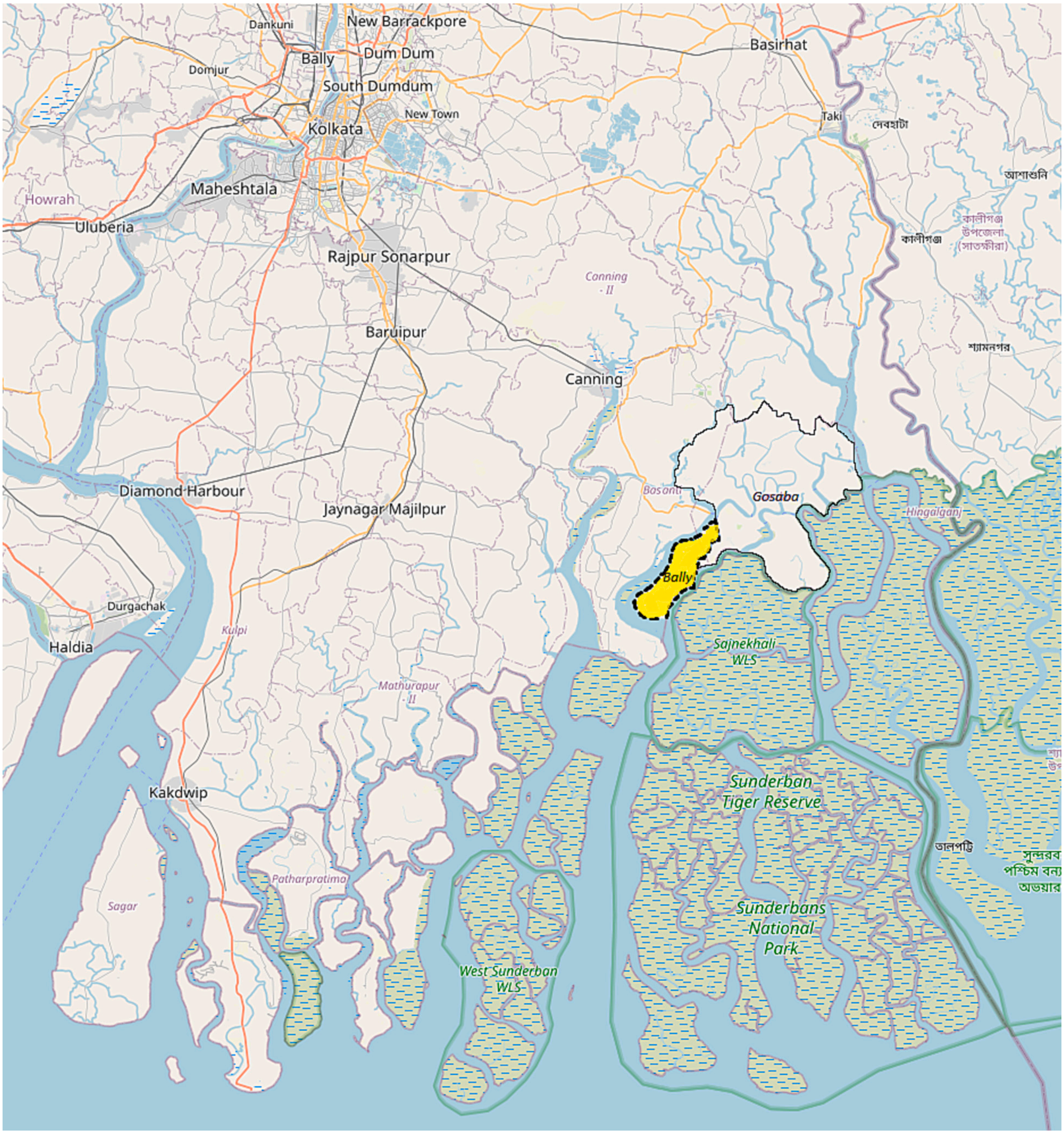

Fig. 3. Bally Island is situated in Gosaba block and borders the uninhabited mangrove forests of the Sundarbans. Kolkata is the closest big city, as is shown on the map. Figure is taken from OpenStreetMap and modified. OpenStreetMap is open data, licensed under the Open Data Commons Open Database License (ODbL) by the OpenStreetMap Foundation (OSMF).

sustain themselves are less resilient, as they depend on the mangroves for fishing, crabbing, and honey collection, exposing them to the risk of wildlife attacks, particularly by snakes, crocodiles, and tigers [54]. These attacks can result in significant medical debts or the loss of the main breadwinner. It's worth noting that while some caste discrimination persists in the Sundarbans, it does not lead to inequalities to the extent seen in other regions of India, based on interviews, observations, and readings.

Finally, the exposure to climate change impacts can also be observed to reinforce climate vulnerability in the Sundarbans. Salinity intrusion leads to lower crop yields, contamination of ponds (killing freshwater fish), and it also materializes in peoples bodies; affecting e.g. their (mental) health [62]. Furthermore, the seasons and rainfall patterns in the Sundarbans have become more erratic and less trustworthy, again having a negative impact on crop yields. Importantly, the amplified frequency and intensity of cyclonic storms demands that much of peoples' limited amount of resources is invested in 'bouncing back' after these external shocks. This leaves Bally residents with less resources to increase their wellbeing and socio-economic development and leaves them equally, or even more, vulnerable to future natural disasters.

Despite these challenges, Bally residents have employed various strategies to build resilience against climate change impacts. For example, rainwater harvesting projects and migratory labor are well-known resilience strategies [11,14,62]. In addition, scholars have shown how strong social networks in the Indian Sundarbans play an important role in dealing with and bouncing back after disasters [63].

Through our research, we also found electricity to be an important resource used by Bally residents to build resilience. Before we detail in Section 5 the extent to which electricity can aid in building resilience, we first shortly describe the energy landscape on Bally Island.

4.2. Energy landscape on Bally Island

The energy landscape on Bally is quite diverse. There are many different energy services that Bally residents use.

In terms of mobility, many modes of transport are non-motorized. Walking and cycling are the most common ways of getting around the island. The ferries connecting Bally to other islands are petrol-driven, but fishers often use non-motorized boats to navigate the rivers and creeks of the Sundarbans. While there are many shops, markets and services on Bally and neighboring islands, residents have to travel to Kolkata for a hospital or industrial area. Despite the short distance of only 100 km from the heart of Bally to the center of Kolkata, the commute from door to door takes about 4–5 h (walk or toto to ferry, ferry to local bus, local bus to railway station). As a result, commuting to Kolkata for work is rare, and instead Bally residents engage in migratory work in Kolkata, Mumbai or New Delhi, for example.

People who stay on Bally do make use of electric or motorized tools in their work, for example irrigation pumps and electric tools for food processing, woodworking tools, or electric spray painting tools. With regards to cooking, we observed (which was confirmed in the survey and through interviews) that all households had access to gas stoves. Nonetheless, due to the availability of cow dung, dried twigs and leaves, and other biomass for free, households primarily cook on their woodstove (a type of clay stove that is often referred to as chulah in India, or matir unun in West Bengal). Gas stoves, together with one LPG tank, were distributed among all Bally households by the government of West Bengal, and LPG refills can be bought on the island.[4] We spoke with a woman who had purchased an electric stove. She preferred cooking on her electric stove, because it took her a great deal of time to gather biofuel, and because of the unhealthy fumes associated with the woodstoves. Despite this preference, the cost of electricity ended up being the reason that she still primarily cooked on her woodstove.

4.2.1. Electricity access

About 50 % of Bally inhabitants own an off-grid solar PV system, since 2019, all Bally residents are connected to the Indian electricity grid [12], and some residents (mainly who work in the tourism sector) use petroleum aggregates as a back-up for the electricity grid.

Before grid connectivity, electricity access interventions revolved around off-grid solutions, primarily solar PV. The first solar PV home systems were installed in Gosaba block in 1997, initiated by the Ramakrishna Mission (RKM) [64]. Later, RKM was appointed as the working NGO to implement a cooperative program between the Ministry of New and Renewable Energy and the United Nations Development Program.[5] Some Bally residents took a solar PV installation course which was provided for free by the RKM in Narendrapur, Kolkata (T3.L.I2). These residents became part of what they call a solar awareness campaign, which proved to be a very successful strategy to the rollout of solar PV systems in Gosaba and other Sundarban districts. About half of Bally households have adopted off-grid solar PV systems, that include a solar panel (often a small PV panel of e.g. 53 watt peak[6]), cables, and an acid-lead battery, but no converter; and they provide just enough electricity for lights, fans, charging of phones, and occasionally a television.

Despite awareness campaigns since 1997, and availability of solar PV sellers, installers, and maintenance workers on Bally Island, solar PV systems have only been adopted by about 50 % of Bally households (T3.L.I5). In contrast, the expansion of the electricity grid, which Bally residents refer to as the ‘current grid’, to Bally Island provided electricity in almost every home in a very short span of time. This also had a consequence for the of solar PV systems: since the connection to the electricity grid in 2019, sales of solar PV systems have dropped to practically zero (T3.L.I2). While many who already owned solar PV systems, still use these systems as a back-up for the untrustworthy grid, others stopped repairing or replacing (parts of) their solar PV systems (the grid is untrustworthy in the sense that it is associated with daily power outages, and the grid shut down in anticipation of-, during, and in the aftermath of cyclonic storms). As we will reflect upon in Section 5.3, the decline in adoption and use of solar PV system can partly be explained by the subsidy that the Government of West Bengal has put in place for use of current electricity to support scheduled caste and scheduled tribes’ families. This means most households on Bally can use 75 units per three months for free, allowing them to use 2 lights and 2 fans during these months.[7]

The current grid also changed the energy landscape on Bally in other ways: since grid connectivity, there are electric vehicles (toto’s) on the island, electric irrigation pumps, electric machines to make labor less physically intensive, and drinking water pumps running on grid electricity. All these changes have different impacts on the resilience and adaptive capacity of Bally residents, which we will elaborate in the following section.

5. Grid connectivity impacting resilience

Our research reveals that electricity services, available to all Bally residents since the extension of the current grid, are used as resources to enhance their resilience against climate change impacts. However, there are clear limitations to the potential of grid connectivity to enhance resilience. Furthermore, we also find unintended consequences of the current grid that increase vulnerability, and consequently decrease resilience to climate change impacts. Therefore, we argue that it is vital to include considerations of climate resilience into future electricity planning.

5.1. Energy services for building resilience and adaptive capacity

As we also found in Section 2.1, there is a relationship between access to electricity and socio-economic development. Our findings underpin the literature in this regard: residents told us that electricity increases their perception of safety (street lanterns), helps in education and income generation (lights, fans, information provision, motorized devices), and has health benefits (store medicine, fans, information provision). To give one example: electric lights help individuals to work in the evenings, which could help them increase their income, but it also allows them to take a break on a hot day. Considering that the climate is warming in the Sundarbans, this is both a strategy to improve wellbeing, as well as an adaptation strategy.

During our interviews, Bally residents reflected upon the electricity services that they needed during and in the aftermath of natural disasters. They mentioned three crucial energy services: (1) access to communication and information systems; (2) pumping out saline water

[4] See also the Pradhan Mantri Ujjwala Yojana subsidy scheme [73,74].

[5] The Ramakrishna Mission (RKM) in Narendrapur acted as the working NGO to identify the beneficiaries of PV systems, provide trained personnel to install and maintain the systems, collect the loan repayments, and to expand the program by working with other funding organizations [75].

[6] In comparison, in the Netherlands the watt peak of most solar PV panels is about 400, of which Dutch households often have multiple installed on their roofs.

[7] In comparison, the average Dutch household uses 775 kWh every three months.

in the aftermath of a cyclone or flood; and (3) the reconstruction of houses, roads, and embankments.[8] First, communication and information systems are key to spreading information about storm forecast; to warn people about a storm approaching; to get in touch with family, relatives, friends, acquaintances, and authorities just after a disaster; and to help locate where support is needed, and guide aid in the right direction (T1.L.I1).

Second, an essential energy service is pumping out the saline water in the aftermath of a cyclone or flood, before it infiltrates in the ground and contaminates groundwater. Considering the long-lasting impacts of salinity intrusion on agricultural yields (T1.L.I1), pumping out saline water quickly is indeed a crucial service. Third, the (re)construction of houses, roads and embankments was often mentioned as a possibility for the current grid to help building resilience. Use of electronic tools and equipment can speed up the reconstruction process, making it easier for Bally residents to bounce back after a (climate induced) natural disaster (T3.L.I1).

5.2. *The benefits of the current grid in building resilience*

The expansion of the current grid to Bally Island has certain benefits over the solar PV systems common on Bally, that can increase the capacity of residents to adapt or build resilience to climate change impacts. First, grid connectivity, in combination with subsidized use of electricity (Section 3.2), has rapidly increased the number of households that have access to electricity, and the associated electricity services that enable socio-economic development.

Second, next to increasing the number of households that have access to electricity, the current grid has a higher kWh power than the solar PV systems have, which has opened the door for new electricity services. For example, all over the island, water pumps running on current electricity are installed, providing clean drinking water (T1.L.I1). A pharmacist explained that current electricity enabled him to store medicine in a refrigerator, which was previously not achievable with solar electricity (T1.L.I18). Current electricity is also used e.g. by farmers, construction workers, and craftworkers, to alleviate physically hard work (T2.L.I3; T2.L.I5; T3.L.I5). Socio-economic development benefits as increase in income, improved education, bodily health, and a feeling of security stemming from grid connectivity improve wellbeing of Bally residents. Hence, grid connectivity provides benefits that can help increase residents' capacity to be resilient and adaptive.

5.3. *Untrustworthy current grid and decline in solar PV popularity*

However, the current grid does not provide a reliable supply of electricity. Importantly, power outages especially occur in anticipation of-, during-, and in the aftermath of natural disasters. After a disaster it can take months before people have access to current electricity again. Bally residents also expressed that after a cyclone, "*there was a disconnection of electricity services and it took quite a long time to restore it* (T2.L.I6)[9]", and the grid as such needs to be repaired before it can be used again. When the current grid is shut down, it cannot provide the electricity services crucial when cyclonic storms occur: communication and information; pumping out saline water; and reconstructions (Section 5.1). Some Bally residents think that the grid operator is too careful and stated with frustration "*as soon as the sky becomes cloudy the electricity connection gets immediately interrupted* (T3.L.I4)[10]". Yet, several interviewees, including a teacher and an employee of the forest department, emphasized the electrocution danger of using current electricity during a storm (T2.L.I7, T1.S.I12).

Solar PV systems are therefore crucial to creating a more reliable and timely access to important electricity services. The acid-lead batteries allow for up to a week of usage. It is exactly because of the trustworthiness of the solar PV systems that many place high value on these systems, as a schoolteacher explained to us: "*the sun will always shine; this is the eternal truth* (T2.L.I7)[11]". Unfortunately, not every family has access to solar electricity, leading to inequality in resilience and adaptive capacity. Barriers to installing solar PV systems are mainly financial, and in addition, residents like one of the honey collectors we spoke with fear that the solar PV panels would get stolen (T1.S.I16).

However, and importantly, the absence of significant upfront costs and subsidies for low-income families (see also Section 4.2.1) make using current electricity economically preferable, rendering solar PV systems less viable for many households.[12] Since the grid extension to Bally, the number of households with a working PV system is decreasing. The adoption of solar PV systems stagnated: a solar PV seller explained that the sales dropped from +− 200 per year before 2019 to 1 or 2 per year after 2019 (T3.L.I2). In addition, broken systems are often not repaired or replaced, resulting in solar PV panels laying on roofs in obsolescence. While many residents with working solar PV systems confidently stated they would repair or replace (parts of their) solar PV system to keep it working (T1.M.I15), we also met many people who did not want to (re-) invest in a solar PV system. A female care worker explained that this is mainly due to reparation costs (T2.L.I3), her household was not willing to spare the seven to eight thousand rupees to repair batteries (80 to 90 euros), especially considering they already had access to current electricity.

As such, residents of Bally increasingly choose to accept the untrustworthiness of the electricity grid over (re-) investing in a solar PV system. Studies on *electricity infrastructures* often advocate for off-grid electricity solutions (decentralized electricity access) as a more reliable, and therefore more stable, alternative to grid connectivity (centralized electricity access) [44]. In line with this, we find that the increased reliance on the untrustworthy current grid decreases resilience for some Bally residents.

5.4. *Contextual limitations to benefits of electricity access*

Next to the untrustworthiness of the current grid, and the decline of solar PV popularity, there is also untapped potential for energy services to have benefits with regard to resilience, adaptation, and socio-economic development. The socio-cultural- and environmental context on Bally create limitations to building resilience with energy services and grid connectivity.

The socio-cultural context influences the extent to which electricity access can enable socio-economic benefits. For example, a lack of financial resources to invest in electronic devices, constraints the use of devices like fridges and medical equipment like scanning machines, which could be used to improve health and minimize dysentery infections. Furthermore, some socio-cultural factors like gender inequality or discrimination can lead to marginalization, which leads to vulnerabilities. This marginalization can be reinforced by electricity access. For example, we observed that labor of women is rarely supported by electrical devices, while labor of men is. Typical 'female' work like cooking, collecting cooking fuel, and sorting produce, can be relieved with different types of energy usage, but often isn't. However, typical 'male' work is often assisted by electrical devices, increasing the inequality between men and women. There is one exception: the water

[8] While mentioned as a strategy to become more resilient against climate change by Bally residents, high concrete dams also risk to perpetuate climate vulnerability, see Sen [61].

[9] Translated from the quote: "বিদযুৎ পরিষেবার সংযোগ বিচ্ছিন্ন ছিল এবং এটি পুনরুদ্ধার করতে বেশ দীর্ঘ সময় লেগেছিল।".

[10] Translated from the quote: "আকাশ মেঘলা হওয়ার সাথে সাথেই বিদযুৎ সংযোগ বিচ্ছিন্ন হযে় যায়।".

[11] This is a direct quote, as this interview was partially conducted in English.

[12] A similar dynamic was also found by Hellqvist and Heubaum in the context of the Bangladesh Solar Home Systems program [76].

pumps running on electricity minimize the time that women need to walk to get water, however, this is not a household decision but a governmental decision.

Furthermore, the environmental context also poses limits on the socio-economic benefits that can be enabled by electricity access, and climate change also reinforces vulnerability. As we reflect upon in Section 3.1 and 3.2, the remoteness of Bally to markets and urban areas creates limited opportunities for income generation. In addition, we find that the socio-economic benefits of electricity access cannot make-up for problems created by the remoteness of Bally: there is a lack of teachers and English education on the island, and many men and women (temporarily) move to cities for daily labor (like construction or cooking), parents with enough money send their children to better schools near Kolkata, and the brightest students who became doctors, teachers, or scholars, conduct their profession in Kolkata or even further away.

5.5. Unintended negative consequence of electricity services to building resilience

While electricity services are crucial to enabling adaptive capacity and building resilience, there are also unintended negative consequences of such energy service on the capacity to adapt and build resilience. A potential unintended consequence is the depletion of groundwater sources. Since the current grid was extended to Bally, the government installed pumps running on electricity throughout the island to create better access to freshwater. In addition, increasingly farmers use electric irrigation pumps. Combined with private freshwater handpumps that some people already owned, and private handpumps that reach deeper levels of groundwater that were recently installed, more fresh water is being used than can be replenished.

According to one of our female interviewees who co-owned a tourist lodge with her family, the groundwater depletion is partially a result of unsustainable water practices: "*The water that Bally residents formerly used only for drinking is now being used for other tasks, like washing utensils and clothes* (T2.L.I9)[13]". Depletion of the aquifers on Bally makes Bally residents more vulnerable to climate change. As Chowdhury, Chakraborty and Lodh [62] explain, overuse of groundwater in Gosaba amplifies the process of salinity intrusion. This process also decreases the water quality: "*seawater is intruding into the groundwater, causing pollution of surface water and a rise in* [other pollutants and] *salinity content in groundwater of that location*".

While we cannot say with certainty that there is a strong connection between groundwater depletion and grid connectivity on Bally, it is likely that increased access to clean water through grid connection is linked to increased use of water and unsustainable water practices. Already in 2015, an IRENA study indicated there is a risk of over-pumping due to the adoption of electricity powered water pumps [65]. The study states [65]: "*In India and China, for instance, where a substantial number of solar PV-based pumping systems have been deployed, additional risk associated with excessive water use has emerged*".

5.6. Improving resilience and reliability of energy services

Bally residents have multiple ideas on how to enhance their capacity to build resilience and adapt. Among these ideas is the improvement of electricity access and reliability of energy services. Panchayat[14] members, and also members of the solar awareness campaign (who were trained by RKM, see also Section 4.2) argue for the installation of solar power plants on the island as a back-up facility. One of the Panchayat members on Bally 2 explained that: "*yesterday, after a small storm, there was a power cut for the whole night and a solar power plant in this case could be very helpful* (T3.L.I1)[15]". However, he added that: "*as there is electricity all around the island, through grid connectivity, the government does not want to invest extra in solar power plants, but there are huge problems with power cuts on this island* (T3.L.I1)[16]".

This proposed strategy, to diversify the energy landscape to increase the stability of supply, is especially promising considering the decline in popularity of solar PV systems. Diversity and diversification are often mentioned and pursued as resilience strategies [66]. Much like biodiversity creates resilience in ecosystems, there is literature on, for example, crop diversification to create resilience in the food system [67], and flood risk management diversification [68].

On Bally, such a diversification strategy is already successfully used to ensure more stable access to cooking fuels. As explained in Section 4.2, residents of Bally Island (should) all have access to a gas stove, but generally prefer using their woodstove because it is free of cost. However, gas stoves are valued as a reliable alternative to cooking on biofuel, especially in times of need, "*for example when someone is unwell, and they need to prepare food right away, or when it is monsoon season and the leaves or wood become soggy from heavy rain* (T3.L.I5)[17]". In addition, "*the gas can be easily moved from one place to another after a natural disaster* (T3.L.I5)[18]". This practice is sometimes referred to as 'fuel stacking' in literature on energy access [69], and our research shows that in disaster prone areas, fuel stacking can be a resilience strategy.

There are also ideas on how to mitigate the negative unintended consequence of groundwater depletion (mentioned in Section 5.5) with use of electricity. Grid connectivity does not automatically increase groundwater depletion and thus vulnerability. One of our interviewees explained that on a neighboring island, the West Bengal government started a project to convert pond water into drinking water, also using current electricity (T2.L.I9). The interviewee suggested using electricity in the same way, to oppose the depletion of drinking water.

However, Bally residents and Panchayats face limited financial resources and a lack of political influence, which means that their ideas for building resilience on Bally are rarely implemented. While officials of the West Bengal government pay visits to Bally and the Panchayats, Panchayat members see only a limited number of their own proposals and ideas getting implemented on Bally (T3.L.I1). This leads to frustration, and limits the capacity to build resilience through energy services.

6. Discussion

The value of energy access in building resilience and adaptive capacity to climate change impacts is considered only very scarcely by scholars and policymakers [18]. While literature on energy access provides nuanced insights into the developmental premise of energy, their relationship with resilience to climate change impacts is often overlooked [16,18,28]. The discussions foregrounding climate change in the context of energy often focus on the contribution of energy use to global warming, and the need to *mitigate* climate change through foregrounding the need for a rapid transition away from the use of fossil fuels [16]. However, we have seen in our case study that, while Bally residents are generally very concerned about changes in weather patterns, salinity intrusion, and increase in floods and cyclonic storms, they do not express

[13] Translated from the quote: "বালির বাসিন্দারা যে জল আগে শুধুমাত্র পানীয়রে জন্য ব্যবহার করত তা এখন অন্যান্য কাজে ব্যবহার করা হচ্ছে, যেমন পাত্র এবং কাপড় ধোয়ার জন্য।".

[14] Panchayats are village councils. On Bally, there are two: the Panchayat of Bally 1 and the Panchayat of Bally 2.

[15] Translated from the quote: "গতকাল, একটি ছোট ঝড়রে পরে, সারা রাতের জন্য বিদযুৎ বিচ্ছিন্ন ছিল এবং একটি সৌর বিদযুৎ কেন্দ্র ছিল, এই ক্ষেত্রে খুব উপকারী".

[16] Translated from the quote: "যেহেতু দবীপের চারপাশে বিদযুত রয়ছে, গরিড সংযোগের মাধ্যমে, সরকার সৌর বিদযুৎ কেন্দ্রগুলিতে অতিরিক্ত বিনিয়োগ করতে চায় না, তবে এই দবীপে বিদযুত কাটা নিয়ে বিশাল সমস্যা রয়ছে।".

[17] Translated from the quote: "যেমন কেউ অসুস্থ হলে এবং তাদের এখনই খাবার তৈরি করতে হবে বা যখন বর্ষাকাল হয় এবং ভারী বৃষ্টিতে পাতা বা কাঠ ভিজে যায়।".

[18] Translated from the quote: "উপরন্তু প্রাকৃতিক দুর্যোগের পরে গ্যাস সহজেই এক স্থান থেকে অন্য স্থানে সরানো যায়।".

concerns about fossil fuel consumption. Their daily reality involves practices focusing on building *resilience*.

The novelty of our approach is that resilience and adaptation are not ancillary issues in our study of energy access: they are central. Although publications in this field are limited, we have found several linkages between energy and climate resilience in this literature that are relevant to our case study. For example, socio-economic development and resilience are increasingly perceived as co-dependent [16,30]. In studies on energy access, scholars recognize the crucial role of energy services in post-disaster recovery [43]. Additionally, other studies foreground the negative impact that climate change can have on energy infrastructures and energy access [46–48].

These different elements, identified in the literature, come together in our case study of the extension of the electricity grid on Bally Island. We find that socio-economic benefits like increase in income, improved education, bodily health, and a feeling of security, are indeed helpful for Bally residents in building climate resilience. Some energy services are crucial in the face of natural disasters, like access to information and communication systems; pumping out saline water in the aftermath of a flood; and speeding up the process of reconstruction after destructive cyclonic storms.

The electricity grid has a special role in this: as opposed to the previous situation with only solar PV systems, it increased access to electricity on the island, and it provides a higher kWh potential. However, the electricity grid is untrustworthy, particularly in the face of climate-induced natural disasters, and has contributed to a decline in the popularity and use of PV systems. Despite the potential of grid connectivity for socio-economic development, the increased dependency on the unreliable electricity grid also reduces residents' adaptive capacity in the face of climate-induced natural disasters. Furthermore, there are contextual limitations to building resilience with energy services. This is also in line with previous literature on energy access, in which evidence is found that energy access can reinforce vulnerabilities due to factors such as gender discrimination or power dynamics within households [50,51]. Additionally, we found that electricity services can have unintended negative consequences, such as the depletion of groundwater due to increased access to clean drinking water.

Building on these findings, in Fig. 4 we highlight eight important impact categories of energy measures on people's capacity to building climate resilience, structured in three key dimensions: benefits, limitations, and unintended consequences.

These empirical findings add to the emerging field of research that emphasizes the relationship between energy access and resilience. The eight impact categories of energy measures on climate resilience emerged from our case study, but are also representative of different elements of energy access and resilience that can be found in the

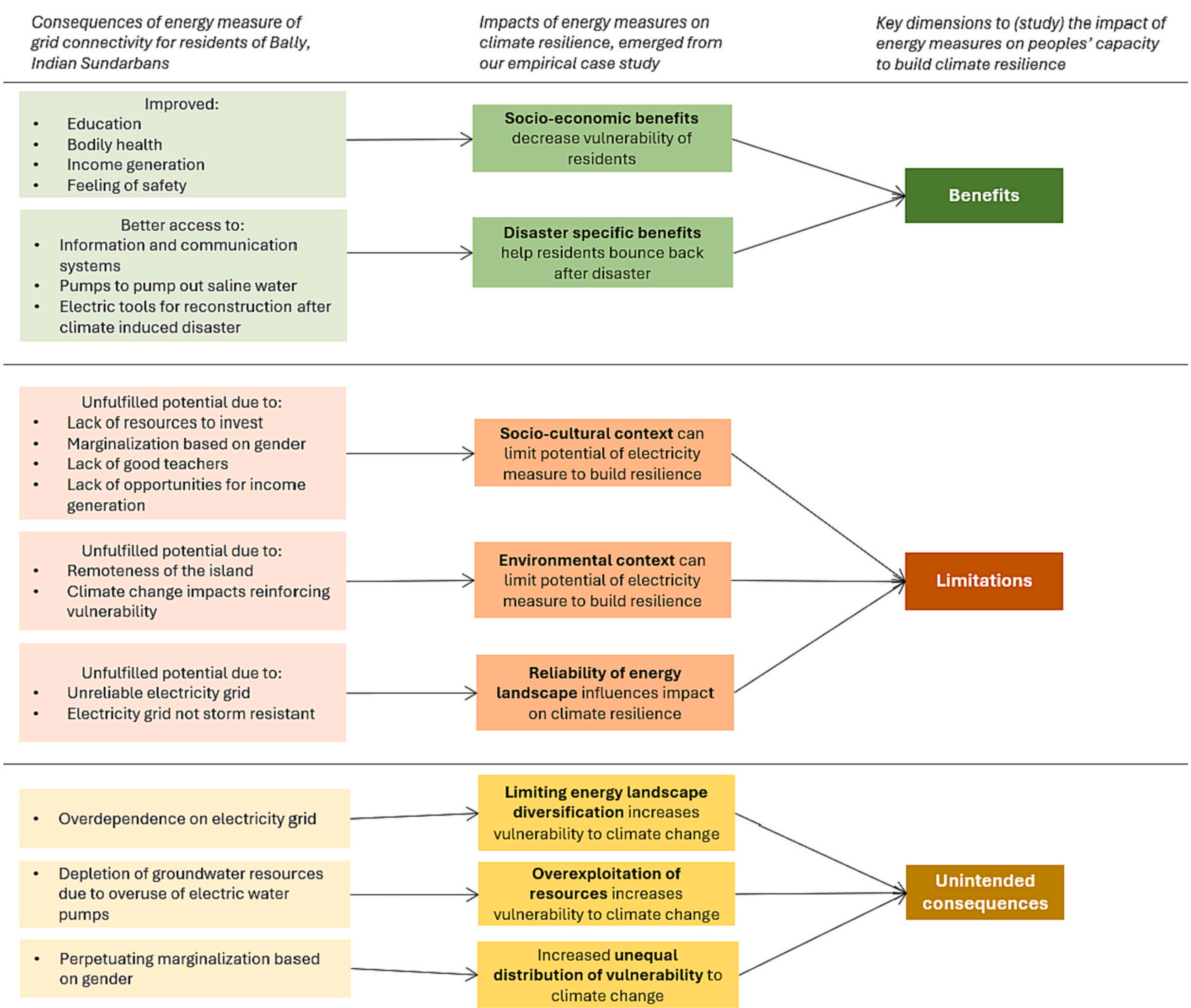

Fig. 4. Key dimensions to study the impact of energy measures on people's capacity to build climate resilience, developed inductively by our empirical study on Bally Island in the Indian Sundarbans.

emerging literature on this topic. Our findings are especially relevant in regions where the interplay between water and land is prominent, like delta regions, coastal regions, and islands. Nonetheless, we believe that in planning and evaluating (future) energy measures, it is essential to take into consideration the benefits, limitations, and unintended consequences that these measures can pose on the capacity of residents to build resilience against climate change impacts. The eight impact categories that we identify can be used as a starting point to analyze, implement, or evaluate considerations of resilience in electricity planning also in other areas vulnerable to climate change.

7. Conclusion

Through our research we emphasize the importance of considering the impact of development measures, notably electricity planning, on peoples' capacity to build resilience to climate change impacts. A mere focus on the developmental premise of electricity access projects is too narrow and short-sighted considering the unprecedented impacts of climate change. Through our case-study, we find much potential for electricity access to aid residents in building resilience against climate change, provided that energy supply is reliable, and that negative consequences are mitigated.

Critical scholars in the field of resilience, adaptive capacity, and vulnerability to climate change highlight that top-down adaptation interventions can perpetuate, redistribute, and create new sources of vulnerability [70–72]. While not an adaptation intervention, we find that increased electricity access, and specifically grid connectivity, can indeed lead to perpetuating and creating new sources of vulnerability. The electricity grid is not reliable, limiting its potential to contribute to resilience and adaptive capacity. Moreover, considering that the electricity grid on Bally Island is fossil fueled, it also cannot contribute to the mitigation of climate change. There are options to improve the energy security of Bally residents, for example by supporting the electricity grid with solar microgrids, or other innovative approaches.

Therefore, we strongly recommend scholars and policymakers to implement, analyze, or evaluate resilience considerations in electricity planning, with a focus on human practices of resilience and adaptation. We urge them to consider the benefits, limitations, and unintended consequences of energy measures on peoples capacity to building resilience. The eight impact categories that we identified Fig. 4 (socio-economic benefits; disaster specific benefits; socio-cultural context; environmental context; reliability of the energy landscape; energy landscape diversification; overexploitation of resources; and unequal distribution of vulnerability) are a starting point for such efforts. These analyses are crucial to understand the (potential) negative consequences of energy projects and policies on resilience, so that they can be mitigated. Moreover, the outcomes of such analyses are important to adjust and make use of energy infrastructures, to capitalize on the reinforcing potential between energy access and resilience.

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CRediT authorship contribution statement

Natascha van Bommel: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Conceptualization. **Johanna I. Höffken:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Indrani Chatterjee:** Writing – review & editing, Methodology, Investigation.

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

The data that has been used is confidential.

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Appendix 1. Overview of interviews and focus group sessions

Interview nr.	When	With whom			
		N people	Age(s)	Gender(s)	Occupation(s)
T1.L.I1	Trip 1	2	45 & 55	Men	Local Guide & Hotel Owner
T1.S.I2	Trip 1	1	30	Woman	Care worker*
T1.S.I3	Trip 1	1	50	Woman	Farmer
T1.S.I4	Trip 1	1	42	Man	Fisher
T1.S.I5	Trip 1	1	45	Man	Farmer
T1.S.I6	Trip 1	1	36	Man	Farmer + seed seller
T1.S.I7	Trip 1	1	32	Man	Middleman/Reseller crops
T1.S.I8	Trip 1	1	51	Man	Teacher
T1.S.I9	Trip 1	2	46 & 52	Man & Woman	Fishers
T1.S.I10	Trip 1	1	48	Man	Fisher
T1.S.I11	Trip 1	1	23	Woman	Bike repair shop owner
T1.S.I12	Trip 1	1	54	Man	Forest department employee
T1.S.I13	Trip 1	1	/	Man	Cafe owner
T1.S.I14	Trip 1	1	27	Woman	Care worker*
T1.M.I15	Trip 1	3	26, 52, 34	2 Women, 1 Man	Farmers
T1.S.I16	Trip 1	1	41	Man	Honey collector
T1.S.I17	Trip 1	1	28	Woman	Care worker*
T1.L.I18	Trip 1	1	58	Man	Pharmacist
T2.L.I1	Trip 2	4	60, 63, 58, 50	Family, 2 women & 2 man	Pharmacist, Farmer, Care worker*, NGO worker

(*continued on next page*)

(*continued*)

Interview nr.	When	With whom			
		N people	Age(s)	Gender(s)	Occupation(s)
T2.S.I2	Trip 2	1	68	Man	Basketweaver
T2.L.I3	Trip 2	2	38 & 20	Mother & Son	Idol maker & Care worker*
T2.M.I4	Trip 2	1	42	Man	Teacher
T2.L.I5	Trip 2	6	37, 18, 37, 72, 43 & 60	Family, 2 women, 4 men	3 Farmers, Student, Careworker, Constructor
T2.L.I6	Trip 2	2	24 & 55	Women	Care workers*
T2.L.I7	Trip 2	1	36	Man	English teacher
T2.L.I8	Trip 2	2	55 &59	Man	Honeycollector and his friend
T2.L.I9	Trip 2	5	50, 60, 30, 24, 31	1 Woman, 4 Men	Family running a hotel
T3.L.I1	Trip 3	4	42, 52, 50, 45	1 Woman, 3 men	Panchayat members Bally 2
T3.L.I2	Trip 3	1	26	Man	PV system seller
T3.L.I3	Trip 3	3	36, 42, 34	Men	Solar Awareness team
T3.L.I4	Trip 3	2	38 & 48	Woman & Man	Panchayat Bally 1
T3.L.I5	Trip 3	1	45	Man	Local Guide

* refers to: While the women that we interviewed referred to themselves as housewives we have opted for the gender neutral term care worker.

Appendix 2. Survey design and approach

Survey Bally Island, South 24 Parganas.

Sl no.	Subject	Questions	Answer (mark all correct options)
Theme 1: Socio-economic context			
1	Personal details	a. What is your gender? b. What is your age?	☐ Female ☐ Male ☐ Other
2	Location	Where on the island do you live?	
3	Livelihood	What is your occupation?	☐ Fishing ☐ Foraging wood ☐ Foraging honey ☐ Housewife ☐ Agriculture ☐ Tourism ☐ Other
4	Household	Who lives in your household?	
5	Education	What is your level of education, and that of your household?	Own level: ………………………… Partner's level: …………………… Sons in school: …………………… Daughters in school: ………………
Theme 2: cooking and lighting			
1	Stove	a. What type of stove do you have?	☐ Clay/mud stove ☐ Cement stove ☐ Electric stove ☐ Gas stove ☐ Other: ………………………………..
		b. Is your stove inside or outside?	☐ Inside with a chimney ☐ Inside without a chimney ☐ Outside ☐ Other: ………………………………..
2	Stove fuel	a. What fuel do you use for your stove?	☐ Wood ☐ Kerosene ☐ Electricity ☐ Gas ☐ Other: ………………………………..
		b. How do you get this fuel?	☐ Buy on the island ☐ Collect in the woods ☐ Other: ………………………………..
3	Collecting wood/ biofuel	a. If applicable: who in your household collects wood/biofuel	☐ I ☐ My partner ☐ My parents ☐ My parents in law ☐ My son(s) ☐ My daughter(s) ☐ Other:……………………………………
		b. How much time do you/your household members spend on collecting wood/biofuel?	………………………………… hours a day …………………………………… hours a week
Theme 3: use of electricity and electricity generation			
1	Appliances	a. Do you have appliances in your home that use electricity? b. If yes, what appliances do you have?	☐ Yes ☐ No ☐ Lights ☐ Fridge ☐ Electric stove ☐ Television ☐ Mobile phone ☐ Computer ☐ Fan(s) ☐ Air Conditioning ☐ Other:……………………………………
2	Electricity grid	a. Are you connected to the electricity grid?	☐ Yes, with a stable connection ☐ Yes, with an unstable connection ☐ No
		b. If not, would you like to be connected?	☐ Yes ☐ No ☐ Why: …………………………………………… ……………………………………………
3	Electricity generation	a. Do you generate your own electricity? b. If yes, how?	☐ Yes ☐ No ☐ Solar PV panels ☐ Aggregate ☐ In case of aggregate, room to explain which fuel ………………………

(*continued on next page*)

(*continued*)

Sl no.	Subject	Questions	Answer (mark all correct options)
		c. If you generate electricity through solar PV, what is the capacity?	Installed capacity is .... kWp Surface area is ....
		d. If you generate electricity, can you also store it?	☐ Yes ☐ No ☐ Why: ....
		e. If you do not generate electricity, would you like to do this?	☐ Yes ☐ No ☐ Room for explanation: ....
		f. What would you need to be able to generate your own electricity?	☐ Money ☐ Space ☐ Knowledge ☐ Access to materials ☐ Other: ....
Theme 4: mobility			
2	Transport	b. What is the top three of transport modes that you use most often?	.... Walking .... Using a/my bicycle .... Using a/my bicycle rickshaw .... Using a/my motorcycle .... Using a/my motorcycle rickshaw .... Using a/my boat .... Using a/my car .... Using a/my tractor .... Other: ....
		c. What are your top three reasons to travel?	.... Work .... To farm .... To go fishing .... To forage (e.g. wood or honey) .... To go to the market .... To visit people .... To visit a religious place .... To go shopping .... For education .... For Leisure .... Other: ....
		d. How often do you travel?	.... times a day .... times a week
		e. How much is the distance that you usually travel?	.... km a day .... km a week

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