Investigating the Potential of Renewable Energy in Community-based Disaster Risk Reduction and Development

Spyros Schismenos

BSc, MSc

Thesis submitted for the degree of

Doctor of Philosophy

School of Social Sciences

Western Sydney University

2023

TABLE OF CONTENTS

LIST OF FIGURES

DEDICATION

I dedicate this thesis to my grandmother, Chrysoula Kontova (1936-2022), who encouraged me to continue my studies and supported me to reach my dreams. I will never forget her wise words that guide the way I live my life "don't be content with just studying the world, put yourself in a position to change it for the better".

Efharisto Yiayia!

ACKNOWLEDGEMENTS

I would like to thank all my family and friends for being so supportive and helpful in this journey. My gratitude and thanks to my supervisory panel: A/Prof Garry J. Stevens (Western Sydney University), Prof. Dimitrios Emmanouloudis (International Hellenic University), A/Prof. Nichole Georgeou (Western Sydney University), A/Prof. Surendra Shrestha (Western Sydney University), and A/Prof. Biraj S. Thapa (Kathmandu University) for their mentorship, encouragement and infinite support. Special thanks to our research assistant supporting the study in Nepal, Mr Sushobhan Bhattarai (Kathmandu University), as well as all our study participants in Dhuskun and Aggitis. Lastly, I want to express my sincere appreciation to the School of Social Sciences Associate Dean, Higher Degree Research, Dr Peter Bansel, for his support, and all my colleagues at the Humanitarian and Development Research Initiative (HADRI), School of Social Sciences, Western Sydney University.

AUTHOR'S DECLARATION

The work presented in this thesis is, to the best of my knowledge and belief, original except as acknowledged in the text. I hereby declare that I have not submitted this material, either in full or in part, for a degree at this or any other institution.

SINGATURE	**DATE**
[redacted]	03 March 2023

LIST OF PUBLICATIONS

This thesis is based on a series of published articles:

Paper I
Schismenos, S., Stevens, G. J., Emmanouloudis, D., Georgeou, N., Shrestha, S., & Chalaris, M. (2020). Humanitarian engineering and vulnerable communities: hydropower applications in localised flood response and sustainable development. *International Journal of Sustainable Energy*, *39*(10), 941-950. https://doi.org/10.1080/14786451.2020.1779274
[IF: 2.01 – Q2 – SJR: 0.51 //2020]

Paper II
Schismenos, S., Stevens, G., Emmanouloudis, D., Georgeou, N., Shrestha, S., Katopodes, N., & Wali, N. (2021c). Humanitarian engineering for renewable energy and flood early warning in remote communities: a scoping review of enabling factors and sustainability. *Journal of Sustainable Development of Energy, Water and Environment Systems*, *10*(3), 1090406. https://doi.org/10.13044/j.sdewes.d9.0406
[IF: 2.40 – Q2 – SJR: 0.38 //2020]

Paper III
Schismenos, S., Stevens, G. J., Emmanouloudis, D., Georgeou, N., Shrestha, S., & Katopodes, N. D. (2021b). Using off-grid hydropower for community-led flood resilience: an integrated systems approach. *International Journal of Sustainable Energy*, 1-15. https://doi.org/10.1080/14786451.2021.1961773
[IF: 2.01 – Q2 – SJR: 0.51 //2020]

Paper IV
Schismenos, S., Stevens, G. J., Emmanouloudis, D., Georgeou, N., Shrestha, S., & Chalaris, M. (2021a). Humanitarian engineering at the sustainability-development nexus: mapping vulnerability and capability factors for communities at risk of water-based disasters. *Sustainability Science*, *16*(4), 1185-1199. https://doi.org/10.1007/s11625-020-00890-y
[IF: 5.55 – Q1 – SJR: 1.66 //2020]

Paper V
Schismenos, S., Stevens, G. J., Georgeou, N., Emmanouloudis, D., Shrestha, S., & Thapa, B. S. (2021d). Humanitarian and Developmental Research Engagement during COVID-19. *Social Science Protocols*, *4*, 1-14. https://doi.org/10.7565/ssp.v4.6487
[ISSN: 2516-8053 (Online)]

Paper VI
Schismenos, S., Stevens, G. J., Georgeou, N., Emmanouloudis, D., Shrestha, S., Thapa, B. S., & Gurung, S. (2022b). Flood and Renewable Energy Humanitarian Engineering Research: Lessons from Aggitis, Greece and Dhuskun, Nepal. *Geosciences, 12*(2), 71. https://doi.org/10.3390/geosciences12020071
[IF: 1.10 – Q2 – SJR: 0.32 //2020]

ABSTRACT

Access to disaster preparedness and energy resources that is equitable and sustainable provides a critical foundation for community resilience and development. However, small, riparian communities prone to water-based disasters often lack effective early warning systems and experience energy insufficiency: a ‘dual dilemma’ that often constrains their development. These issues are more common in low and lower-middle income countries where social and resource inequities are often more pronounced. However, small communities in high income countries often experience similar issues.

In recent years, there has been growing interest in community hazard resilience and sustainable development at the local level. Initiatives that accord with the principles of the Agenda 2030 for Sustainable Development and the Sendai Framework for Disaster Risk Reduction increasingly frame community resilience research and programming. However, there has been little research to date exploring energy and water hazard management within remote communities. Such research is an important element in progressing sustainable development at the local level - understanding community views, priority needs and solutions that are feasible and sustainable in their context. Humanitarian engineering is an appropriate vehicle for translating these views into proposed solutions and offers substantial benefits to interventions for sustainable development and disaster resilience.

Community-centered initiatives for off-grid renewable energy generation and flood response at the local level have the potential to support community hazard management and socio-economic growth. To do so effectively, they must support genuine community engagement and stakeholder synergies. The current study examined energy and flood response needs in riparian communities in Nepal and Greece and identified specific options which could be co-developed and sustained in these contexts.

Paper I presents evidence-informed technical criteria for the development of off-grid renewable energy and early warning hybrid systems, and more specifically, small-scale hydropower generators combined with flood warning systems. These are proposed as a vehicle for localised water hazard resilience and sustainable development in remote, riparian communities.

Paper II is a scoping review of the literature examining riparian communities in low and lower middle-income countries, and their use of off-grid renewable energy and flood warning systems. The findings highlight that it is important to consider institutional, environmental, social/ethical, economic and technical indicators in developing a comprehensive understanding of the success or failure of humanitarian and development interventions in such communities.

Paper III presents a review of the extant literature regarding best practice community engagement for localised renewable energy systems and flood early warning systems. It builds upon the previous studies (Papers I and II). It details a community-centered systems approach to localised hydropower and flood response within a framework of sustainable development. This evidence-informed strategy for community engagement can address multiple needs, including the intersecting needs of key stakeholder groups.

Paper IV details an exploratory investigation of community vulnerability and capability mapping that identifies communities with high water-based disaster risk and their associated needs. This mapping is based on objective and universal criteria, and can be used in cross-community comparisons.

Paper V presents a mixed method approach for humanitarian and development research engagement that allows the collection of information from both professionals and non-experts remotely. This enables research continuity and community access in intra and post-pandemic contexts in a flexible and cost-effective manner, and guided our study protocol (Paper VI).

Paper VI is informed by the previous studies (Papers I – V) and presents findings from our research on flood response and energy needs of two riparian communities in Nepal and Greece. The findings indicate combined functions are favoured and that the co-development of a hybrid unit for hydropower generation and flood warning is preferred compared to single-use market available options. The remote research approach (detailed in Paper V) supported effective participant engagement and data collection despite pandemic restrictions.

1. INTRODUCTION

> "Access to energy is fundamental to improving quality of life and is a key imperative for economic development. In the developing world, energy poverty is still rife. Nearly 1.1 billion people still have no access to electricity."
>
> (Energy Poverty Action Initiative - World Economic Forum, n.d.)

> "Disaster risk reduction is about more than responding to emergencies; it's about doing development right so people are safer in the first place. If it's not risk-informed, it is not sustainable development."
>
> Jo Scheuer in (Lee, 2015)

1.1 Overview

Extreme weather events increasingly threaten human populations. Water-based disasters, such as heavy rainfalls and torrential floods are frequent and affect communities in multiple ways, including fatalities, displacement, financial and income losses, and damaged infrastructure (Wahlstrom and Guha-Sapir, 2015). Populations with limited resource capabilities, such as those in low and lower-middle-income countries (L/LMICs) have substantially higher vulnerability to such impacts (Kim, 2012). The primary focus of this thesis is on such communities - small, rural/remote mono-economies in L/LMICs situated in riparian areas with high flood risk estimates (Hallegatte et al., 2020). Related vulnerability characteristics that we examine are energy insufficiency and limited disaster risk resilience capabilities (Jessel et al., 2019; Sufri et al., 2020). While such vulnerable communities are commonly found in L/LMICs, small riparian communities in high income countries may also be vulnerable, particularly during extreme weather events. Recent floods in Australia (May, 2022) and Europe (Oltermann, 2021) highlight that flood extremes can affect everyone. Oltermann (2021) identifies that the lack of effective localised flood early warning systems (EWS) in Germany was a contributing factor to poor community and service response at the local level. On the basis of such examples, the current study includes examination of communities in both low and high-income countries for comparison purposes.

According to the 2030 Agenda for Sustainable Development, energy sufficiency at the local level is one of the most crucial factors for increasing capabilities in vulnerable populations (Howells et al., 2017; United Nations, 2016). Community-led disaster response is equally important, according to the United Nations Sendai Framework for Disaster Risk Reduction (Pearson and Pelling, 2015). This is particularly the case since L/LMICs lose substantially higher proportions of their gross domestic product to disaster events each year, and this is a key factor undermining their development potential (Kim, 2012). As such, initiatives that that can support low-cost, sustainable energy generation and hazard early-warning may critically advance sustainable development at the local level (International Renewable Energy Agency, 2019; Phillips, 2017). This concept accords with the principles of World Economic and Social Survey 2018: Frontier Technologies for Sustainable Development (Kamperman Sanders et al., 2018) and highlights the importance of harmonised humanitarian and development interventions (so-called 'disaster mainstreaming' within development) in communities residing in flood-prone areas.

While the literature showcases many community-based projects in renewable energy and early warning, there is little information regarding the development of combined and hybrid systems which integrate these key functions or community perceptions of the feasibility of such options (Baudoin et al., 2014; Ikejemba et al., 2017; Schismenos et al., 2021c). Such an analysis can inform researchers, government authorities, development and humanitarian agencies, as well as communities themselves, as to the viability and cost-benefit of such systems in these contexts. To the authors' knowledge, there has been no such study of combined systems for sustainable development and flood resilience at the local level. While some researchers (Azid et al., 2015; Intrieri et al., 2012; Schöne et al., 2011) have examined solar energy use in EWS, there are no published data regarding other off-grid renewable energy systems (i.e. hydropower) powering localised EWS for community response.

This thesis is based on a series of published papers examining how humanitarian and development research projects can best be conducted in small, riparian communities with the support of both local community members and professionals. Its primary focus is an examination of community perceptions of preferred energy sources and EWS and the feasibility of system integration and co-development. It details reviews of the background literature (Papers I and II), preparatory sub-studies of community selection and engagement (Papers III-V) and interview findings with community stakeholders in Nepal and Greece (Paper VI).

Paper I (Schismenos et al., 2020) is a technical analysis and examines which off-grid hydropower and flood warning types are optimal in vulnerable communities, and whether this information supports the development of stand-alone or combined/hybrid system for power generation and flood warning. Paper II (Schismenos et al., 2021c) presents review findings regarding community-based renewable energy and EWS and specific indicators of the success or failure of these systems. Paper III (Schismenos et al., 2021b) presents a systems approach for community engagement in humanitarian and development research and the co-development of related outputs/assets throughout their life cycle. Papers II and III include detailed reviews of literature in the respective areas of remote community energy sufficiency and flood resilience; these provide the evidence base for the community study that is the focus of the current research. Paper IV (Schismenos et al., 2021a) develops an evidence-informed vulnerability and capability mapping tool for the identification of communities that are in greater need of energy and flood warning improvements. Paper V (Schismenos et al., 2021d) presents our research design for assessing community vulnerability that was applied remotely in two pilot communities - Dhuskun, Nepal and Aggitis, Greece. Paper VI (Schismenos et al., 2022b) presents the results and potential applications of our study findings in these communities. The six publications that make up this thesis are available in Supplementary Materials. Figure 1 details the study process flow and outcomes, in the form of published papers.

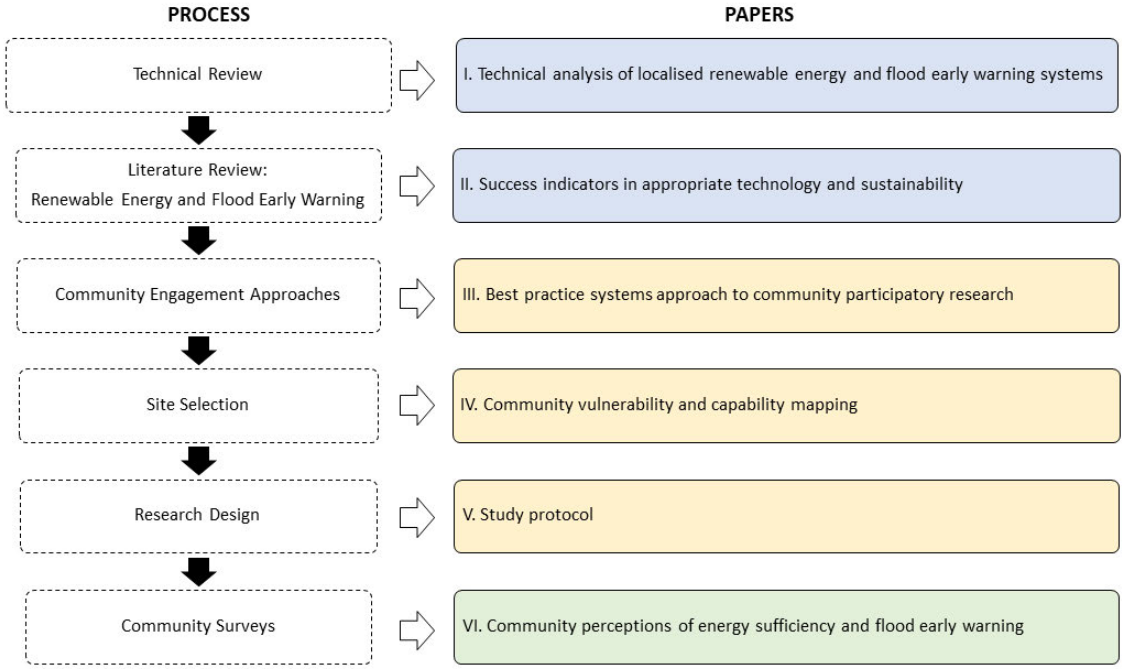


Figure 1. Study process flow chart and outcomes

Figure 1 presents all major items in colour variations. These represent the different stages of the study:

- Blue: Findings based on data from literature searches
- Yellow: Methodology and planning
- Green: Study execution, site data collection and findings

1.2 Research Themes and Background Literature

1.2.1 Communities vulnerable to water-based disasters

The experienced severity of disasters is mediated by the aggregate vulnerability and capability levels of affected populations, the former usually defined as the extent to which an individual or a group is predisposed to experience losses in relation to a hazard event (International Federation of Red Cross and Red Crescent Societies, 2007). The United Nations Office for Disaster Risk

Reduction defines vulnerability as “the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard”. It is one of the defining components of the common disaster risk formula (Disaster Risk = Hazard × Exposure × Vulnerability / Capability). In this conceptualisation, vulnerability is directly mediated by the response assets and capability level of the affected population (United Nations International Strategy for Disaster Reduction, 2009, p. 30).

Our primary focus is on water-based disasters, such as floods and storms. This is because these are the most frequent type of natural disasters and associated with the highest cumulative number of people affected (Centre for Research on the Epidemiology of Disasters, 2020; Wahlstrom and Guha-Sapir, 2015). The Overall Water Risk Map (Figure 2) developed by the World Resource Institute’s Aqueduct tool (Aqueduct, n.d.) presents evidence that L/LMICs experience the greatest risk of water-based disasters. At the same time, these countries are more likely to experience energy insufficiency, as detailed in the Population Without Access to Electricity 2019 Map (Figure 3) developed by the International Energy Agency (International Energy Agency, n.d.). This is somewhat perverse in that many such regions possess the natural resources needed for energy generation and self-sufficiency. For example, Africa has the physical characteristics required to develop a range of renewable energy applications and substantially increase its energy supply (Ahlborg and Hammar, 2014; Ngowi et al., 2019). Sub-Saharan Africa in particular, has the local atmospheric and hydrogeomorphological conditions required for hydropower and solar power installations. However, its relative lack of resources, infrastructure and political will to establish such systems on a sustainable basis, sees it as one of the least developed regions globally and with major electrification problems (Ahlborg and Hammar, 2014; Ikejemba et al., 2017; Quansah et al., 2016).

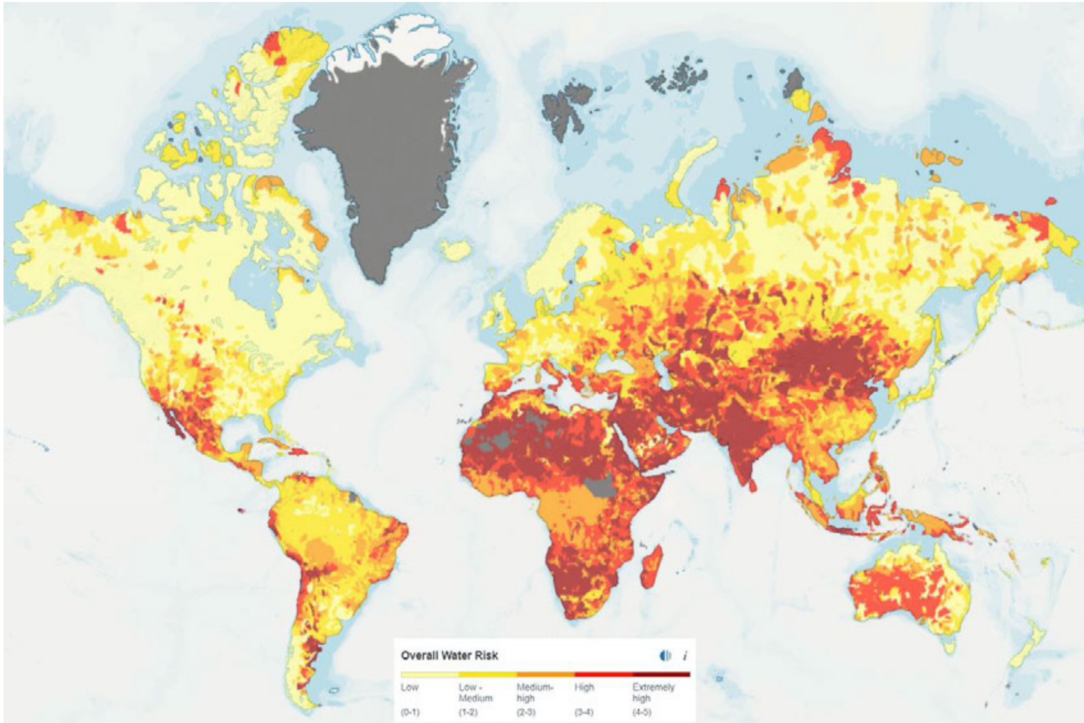


Figure 2. Overall water risk map

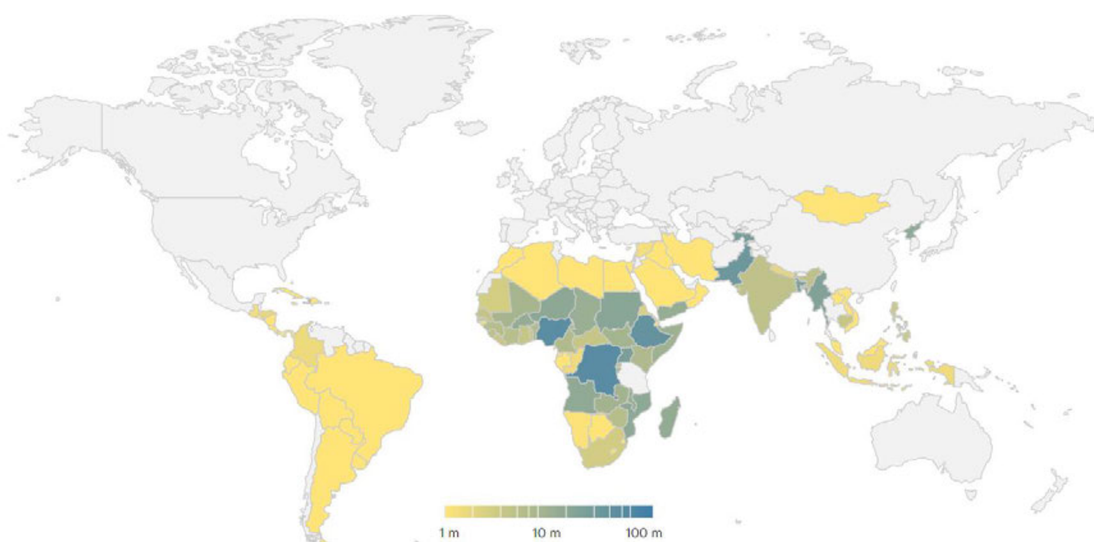


Figure 3. Population without access to electricity 2019 map

According to the United Nations Office for Disaster Risk Reduction, a combination of physical, social, economic, and environmental metrics determines vulnerability levels - these metrics are commonly used in hazard risk mapping (United Nations International Strategy for Disaster Reduction, 2009, p. 26). Furthermore, political, cultural, historical, psychological, and institutional elements could also be taken into consideration as complementary factors (Twigg, 2004). Such metrics are important for predicting the potential consequences of a disaster and directing the establishment of disaster resilience and response resources at the local level.

In this study, communities defined as vulnerable to water-based disasters have one or more of following risk characteristics:

- Physical, including remote, rural areas (small settlements such as villages or towns); insufficient flood warning (minor or no EWS or other warning mechanisms); power insufficiency (off-grid and/or unstable power supply) under normal and/or extreme conditions (United Nations Department of Economic and Social Affairs, 2022); poor telecommunications (no mobile phones or landlines in residencies).

- Economic, including low/lower-middle income (based on minimum wage, purchasing power per capita) (World Bank, 2022); lack of income diversification.

- Environmental, including high flood risk probability, located in riparian or deltaic ecosystems.

1.2.2 Identifying priority needs within vulnerable communities

When documenting vulnerability factors, needs assessments that allow community participation, are the most reliable and precise (Ostadtaghizadeh et al., 2015; United Nations International Strategy for Disaster Reduction, 2009, p. 23). Georgeou and Hawksley (2020) argue that genuine community participation is critical in humanitarian and development research as it offers the best means of capturing a diverse range of perspectives and incorporating these into solutions intended to improve community well-being. Community participatory approaches are also useful in other fields of research, including medical (Tapp et al., 2013) and engineering (Mazzurco and Jesiek, 2017). In studies in the field of engineering, science and technology, practitioners often have highly developed technical skills but may have less experience with the transferable or 'soft-skills' needed for effective community engagement and participatory research (Gosink et al., 2003). A shift in mindset away from a rigid 'expert' approach and positioning within the research process to a genuine people-centered participatory approach is therefore required.

Making this shift will broaden the framing of the research problem and allow non-technological perspectives to have greater representation in agreed solutions (Georgeou and Hawksley, 2020). Downey (2005) posits that such processes result in greater collective knowledge and a power shift towards increased equity between stakeholder groups and researchers when identifying/prioritising needs. One example of people-centered planning can be observed in a case study in Sri Lanka, where the development of EWS occurred with the proactive engagement of local communities. This collaboration allowed the professionals involved to understand that participating communities had a range of flood-related concerns, and that low income and lack of experience and training were also important. Given this information, the project proposal was adjusted to address community priorities (e.g. the communities received training so they can detect floods on their own) (Baudoin et al., 2016).

1.2.3 Factors affecting energy selection and use in vulnerable communities

Energy availability under both normal and hazard conditions is a key element for sustainable development (Howells et al., 2017) and the related need for resilience against natural disasters (Phillips, 2017). Access to reliable power sources, such as renewable energy provides multiple benefits, particularly to the communities with limited capabilities. Off-grid renewables provide multiple benefits to vulnerable communities in L/LMICs which often lack reliable energy and resources to support hazard planning and response (International Renewable Energy Agency, 2019). Among the available off-grid options, diesel generators are well-known and widely used. Yet, despite their advantages as portable and low-cost units, they may not satisfy remote communities in the long term. Williamson et al. (2019) found several reasons for this. Firstly, diesel generators require large amounts of fuel which can be costly. Secondly, they cause health and environmental impacts due to fuel consumption and waste production (carbon dioxide and greenhouse gas emissions, water and soil recourses pollution, etc.). Thirdly, fuel may not be easily accessible in remote locations. Lastly, diesel generators require regular maintenance - if they break down communities may not be able to repair them on their own as the required parts may not be available in local markets and/or end-users may not have the technical skills or equipment to fix them. As a result, such systems can remain unavailable for weeks or months before repairs can be secured (Nerini et al., 2014; Williamson et al., 2019). These drawbacks are key factors driving interest in off-grid renewable energy systems such as solar, wind and hydropower, which are more environmentally sustainable (Kirubi et al., 2009), and increasingly cost-competitive when compared with fossil-fuel-based options (Williamson et al., 2019).

The selection of appropriate renewable energy systems is determined by evaluation criteria such as adaptability in different environments, system autonomy, affordability, durability in local atmospheric and hydrogeomorphological conditions over time, readily-sourced materials, environmental and health impacts (Baudoin et al., 2014; Gurung et al., 2011; Ikejemba et al., 2017). A comprehensive review of these selection processes and criteria in L/LMIC contexts is presented in Schismenos et al. (2020). For example, solar energy is a popular off-grid energy option, but due to its establishment costs (a substantial array of panels such as small solar park would be required to power a community), limited supply of parts (some replacement components may not be available in local markets), and lack of continuous power generation (e.g. during night hours), it may not be a suitable option for remote communities. Wind and hydropower turbines often present similar weaknesses (high establishment costs, limited materials supply, environmental impacts and noise pollution that may discourage nearby communities) (Jobert et al., 2007; Ikejemba et al., 2017; Kelly-Richards et al., 2017).

On the basis of understanding local conditions, financial sustainability and stakeholder awareness, Williamson et al. (2019) argue that small, off-grid hydropower is the renewable system with the highest value proposition for off-grid communities. Among the types of hydropower, localised smaller-scaled (i.e. pico-level) systems, which include portable, and isolated (remote) hydropower systems all have high potential (Haidar et al., 2012). In the US alone, smaller-scaled hydropower stations comprise about 75% of the number of all hydropower plants nationwide (Johnson, 2015). Ma (2018) states that “nearly 82,000 small hydropower plants operate or are under construction in 150 countries", this translates to 10 small-scaled hydropower plants for every large one. At a broader level, this accords with international data which shows hydropower is the most widely used renewable energy source for electricity generation. In 2015, it supplied 71% of the total renewable electricity globally (World Energy Council, 2016, p. 5).

Hydropower varies in scale (large, centralised, small and isolated) and can be combined with water supply services (e.g. irrigation and flood control systems). The latter provides multiple socio-economic benefits to end-users (Gielen, 2012). Localised smaller-scaled systems have minimal environmental impacts and are a cost-competitive solution for electrification in rural communities (Gielen, 2012; Ioannidou and O'Hanley, 2018). If combined with EWS and designed appropriately, they can address a number of basic energy needs under normal conditions (e.g. power home appliances), as well as under extreme conditions (e.g. power outdoor sirens and emergency lights), while also acting as localised flood detectors (Schismenos et al., 2020). For reasons such as these, they represent a feasible option for vulnerable communities.

1.2.4 Flood early warning systems in remote communities – success and failure indicators

The EWS allow the early prediction of extreme weather events with sufficient lead time for response. Lead time could be from a few seconds to several weeks, depending on the type of the event, system type and capabilities. Flood EWS are crucial, especially for rapid inundation (so called 'flash flood' events) in areas where vulnerable populations reside (Shrestha Pradhan, 2020). For example, a flash flood that peaks at 2 a.m. in a remote community with no surveillance/warning system can result in significant losses, including loss of life. A similar flood hazard occurred in Afghanistan in 2020 and resulted in more than 100 fatalities (News Agencies, 2020). According to the World Bank, EWS hydrometeorological investments for L/LMICs have a cost-benefit ratio of US$ 4-36, where the long-term establishment/maintenance (preparedness) costs are compared against water hazard impact (recovery) costs (Hallegatte, 2012). However, in order for an EWS to be effective and end-user focused, it needs to comprise the elements of risk knowledge, monitoring and warning, information dissemination and communication, and response capability (Basher, 2006). Despite the variety in types and designs, the standard action process is the same: input scanning, event detection and output(s) (Waidyanatha, 2010). The simple example below details surveillance regarding water level and siren activation. More complex systems may utilise multiple inputs, event thresholds and outputs.

water level sensor → level threshold reached → warning siren activates

Over the years, improvements in frontier (emerging) technologies such as drone and sensor technology have increased the reliability of input and output data. For example, the numerical weather prediction, increases or modifies the forecast horizon based on the accuracy and availability of input data (Bauer et al., 2015). This allows the display of multiple weather scenarios and prepares the emergency responders more effectively. The Hyogo Framework for Action includes an international policy approach for the promotion of early warning programs as a key element in building social and disaster resilience of vulnerable populations against common weather threats. (United Nations Office for Disaster Risk Reduction, 2005). While this is a promising framework which is guiding action, a lot more must be accomplished at the local level for the forecasting to become timely and more accurate.

Extreme, short-lived weather phenomena may often trigger flash floods and debris flows in small areas. While these events develop at different space and time scales, the current conventional rainfall, streamflow and sediment discharge observation systems seem unable to monitor them accurately. For example, the Meteoalarm[1] collects and displays hydrological and meteorological warnings, however, it is not designed to support warning for flash floods (Alfieri et al., 2012). This is because the local atmospheric, hydrological, geomorphological and environmental factors in generalised EWS are poorly investigated or not considered (Alcántara-Ayala and Oliver-Smith, 2019; Alfieri et al., 2012). This leads to a plethora of uncertainties in warning and alert management that often reduce the effectiveness of EWS (Alfieri et al., 2012; Schismenos et al., 2022a). In general, the most common approaches for the early indication of rainfall and floods require the comparison of the latest precipitation observations and weather forecasts in order to

[1] http://www.meteoalarm.eu

pre-define reference or warning thresholds. However, as the forecast uncertainties for the operational efficiency of EWS are high, the challenges of detecting local severe precipitation below the resolution of most available numeric weather prediction models are significant (Alfieri et al., 2012). A solution to this problem can be found in the use of community-centered systems formulated based on end-users' accrued knowledge of local atmospheric and hydrogeomorphological conditions and existing capabilities that manage these, or may be further developed to do so (Twigg, 2004).

The United Nations Framework Convention on Climate Change and the International Centre for Integrated Mountain Development have showcased the successful use of community-based flood EWS in the Hindu Kush Himalaya region (Shrestha Pradhan, 2000; United Nations Framework Convention on Climate Change, 2020). These are low cost and simple in their operation and use. A flood sensor detects rising river water levels; when critical thresholds are reached, signals are sent to the receiver and then warnings are disseminated to agencies and nearby communities. Significantly, local communities participated in the development of these EWS (i.e., they jointly determine flood thresholds). Douvinet et al. (2021) note that in communities where energy supply and telecommunications may not be stable, there is some evidence that outdoor sirens appear more reliable than other warning signals (e.g. mobile phone, radio and television warnings).

1.2.5 Humanitarian engineering: a community-centered approach

The common perception that renewable energy and EWS represent a ready 'step change' for many vulnerable communities must be tempered with recognition of the structural inequities and forms of environmental injustice often experienced by communities in L/LMICs (Stewart et al., 2002). Humanitarian and development actors can play a pivotal role in supporting their use within longer term, community-led development. At the same time, initiatives in this area also risk the 'short-termism' of narrowly conceived technical solutions with little ongoing support in resource-constrained environments. For example, renewable energy projects in Sub-Saharan Africa have failed, or have been shown to have sub-optimal long-term outcomes due to bad management and planning, and lack of maintenance and local stakeholder involvement

(Ikejemba et al., 2017). These are central considerations in the emerging practice of humanitarian engineering (Gosink et al., 2003).

Hill and Miles (2012), and Sheroubi and Potvin (2018) define humanitarian engineering as the urgent or longer-term application of engineering concepts appropriately designed, installed, and used to support populations with need. Humanitarian engineering aims to approach engineering/technology aspects with community needs as its primary focus (Hill and Miles, 2012). It takes into consideration the context of the community in terms of culture, local and 'traditional' knowledge, socio-political influences on decision making processes and institutional structures, as well as existing strengths (Gosink et al., 2003; Mazzurco and Jesiek, 2017; Sheroubi and Potvin, 2018). It supports disaster resilience mechanisms, and contributes to sustainable livelihood and socio-economic development (Mazzurco and Jesiek, 2017). This conceptualisation of humanitarian engineering is informed by, and overlaps with, two related fields; development engineering (also known as engineering for development), which investigates solutions to social challenges through science and technology (Nilsson et al., 2014), and global engineering, which aims to address ongoing challenges worldwide (e.g. poverty, water sanitation, and energy) as a practical driver of increased equity (Thomas, 2019).

Humanitarian engineering solutions can be considered practice elements of 'development-relief' transitional frameworks within the humanitarian and development sectors, including community resilience programming (Mosel and Levine, 2014), and as a sub-set of global approaches which address challenges to humanity as a whole. A major difference with other engineering practices is that humanitarian engineering proactively seeks the co-development of solutions with end-user populations using appropriate technologies, 'traditional' knowledge, and local views (Gosink et al., 2003; Mazzurco and Jesiek, 2017).

Despite the benefits regarding humanitarian engineering detailed above, other authors have described issues affecting its professional training and practice translations. Vandersteen et al. (2009) highlight the benefits of applying humanitarian engineering principles in disaster resilience and development works for professionals, particularly young practitioners and students. These include pedagogical and occupational advantages, including international placements, design engineering practice in different contexts, and interpersonal skills. However, the authors also argue that such international services and their management may contribute to poor or adverse outcomes. Concerns noted by the authors include poor training for engaging with different cultures and in unfamiliar areas, and a lack of inter-cultural competence and communication skills. Similarly, Arshad-Ayaz et al. (2020) discuss failures in humanitarian engineering interventions from a socio-technical perspective and conclude that such initiatives often fail not only due to flaws in the design process or faulty equipment but also the privileging of ‘professional opinions’ which may ignore local conditions, knowledge and capabilities.

1.2.5.1 Addressing common risks in humanitarian and development engineering research

Despite the advancements in science and technology for humanitarian and development projects, proposed solutions are not always sustainable at the community level for a range of reasons. Ikejemba et al. (2017) found project sustainability issues were often similar across different countries and commonly related to (i) differences in culture and understanding between stakeholder groups, (ii) political agendas, (iii) stakeholder co-operation, (iv) planning and implementation, (v) maintenance and (vi) public acceptance and inclusion perceptions. Thus, it can be inferred that forms of research and development engagement which lack cultural sensitivity are a key factor that hinders the acceptance and longer-term success of such solutions by local communities. Cultural sensitivity can be defined as an interpersonal stance that is not self-focused, but other-oriented. It conveys genuine respect and a lack of superiority (of the technical practitioner / ‘expert’) with respect to the cultural backgrounds and lived experiences of community members (Hook et al., 2013; Owens and Hekman, 2016). A culturally sensitivity approach uses the language and mores of local culture, leveraging its strengths to identify community priorities for change and context-appropriate strategies to achieve them. In order for an intervention to be effective and sustainable, it is necessary to engage communities at a deeper level - a level that facilitates change in the life of the individual, the family and the community as a whole (van Stam, 2013). This approach was appropriate as our cross-cultural, interdisciplinary research emphasised the development of long-term support or implementation of sustainable solutions in vulnerable communities (Hook et al., 2013).

1.2.5.2 A systems approach to humanitarian and development engineering research

Meadows (2008) defines a systems approach (also known as systems thinking) as a holistic approach to analysing a complex system's parts, their interrelation, and functions over time within the context of a larger (holistic) system. Systems approaches are applied in a wide range of disciplines including engineering, medicine, environmental science, development economics, political science and in the humanities (Arnold and Wade, 2015; Meadows, 2008). Arnold and Wade (2015) posit that systems-based conceptualisation and management of programmes typically involve several common processes. The first is the identification of the involved systems (or sub-systems) and their characteristics, interconnections and functions/purposes. Then, the formation of these systems by combining or grouping independent, interacting elements, as well as the formation of synergies (interaction of different elements) that produce an effect. Familiarisation of the interacting systems, predication of outcomes and planning ahead in order to understand changes and unforeseen outcomes, allow formulation of the 'bigger picture'. This understanding can support information analysis, logical thinking, testing and problem solving; minimising system complexity conditions that may affect decision-making and results.

Our consideration of cultural sensitivity and partnership, detailed above, guided examination of a systems approach to research in this area and how this could inform the current study. Applying systems thinking to community-centered renewable energy and flood resilience solutions could help community stakeholders and humanitarian and development practitioners identify risks and to co-develop technology-informed projects that address local needs. It could also improve overall behavioural insights (social, economic, psychological, cognitive) and their applications in remote communities with limited capabilities. This is essential for understanding how different communities and in-community groups make choices, select options based on priority attributes, and maintain long-term interest in newly introduced interventions.

Such approaches in humanitarian and development research posit that a full understanding of the constituent elements of a given system (e.g. a diverse community), and their interactions, are needed to understand likely outcomes or outputs from such systems (Arnold and Wade, 2015). This could include, for example, the success of a technical intervention to address a specific community problem. Unlike 'traditional' analysis where systems are broken down into smaller, constituent elements and analysed separately, this approach is preferred when large, multi-element systems are evaluated as a greater array of influencing factors, their interaction, and systemic effects on outcomes that can be more readily determined. Thereafter, interventions can be tailored to accommodate system 'needs' and effects, increasing their likely success and sustainability (Bahill and Gissing, 1998; Frank, 2002). The specific application of this approach within the current study is further detailed in Section 2.3 and Schismenos et al. (2021b).

1.3 Study Context

Our study has an international focus, as it involves three universities (Western Sydney University, Australia; Kathmandu University, Nepal; and International Hellenic University, Greece) and engaged community participants in Dhuskun, Nepal and Aggitis, Greece. It addresses both social and technical concerns and considers community members and their needs as its core focus. This is consistent with the principles of Human-Centered Design (HCD), a design process framework for increasing a system's workability and acceptability to user groups (Anderson, 1988). This framework is an ISO standard ('human-centred design for interactive systems') and includes i) contextual design, ii) cooperative design, and iii) participatory design (Anderson, 1988; Duque et al., 2019). Participatory design focuses on the views of users in the identification of appropriate design, with stakeholders typically working through phases of consultation; co-design, co-development and final implementation and maintenance that are community-led (Lee et al., 2017). Sanders and Stappers (2008, p. 6) argue that the notions of co-design and co-development (also called co-creation) are often confused and treated synonymously. They define co-design as "collective creativity that is applied across the whole span of a design process". In a broader sense, it can refer to "the creativity of designers and people, not trained in design, working together in the design development process". Co-creation is referred to as "any act of collective creativity that is shared by two or more people" with questions like 'who, when, and how' to vary.

Proponents of HCD argue that all stakeholders (developers and end-users) should be involved throughout the stages of a design intervention and work together to shape a widely accepted solution. For example, Sanders (2006) highlights that non-professionals should not only participate in the co-design process but “drive it to the extent that they are capable and willing” (p. 13). For example, Fernhaber et al. (2018) adapts this participatory design process to co-design sustainable and accessible solutions to healthy and affordable food supplies for a community in Indianapolis, Unites States.

In our study, we follow a similar co-design concept. Our study participants drive the research development. Within the HCD framework, the current study would be conceived as involving a process of community consultation, with its findings having the potential to support later co-design/co-development processes with community partners. The HCD approach is commonly used in humanitarian engineering research and among practitioner groups, such as the Engineers Without Borders, due to the coherence and value it provides to longer-term community engagement strategies (Engineers Without Borders, n.d.).

Our initial research plan involved the primary researcher visiting the two communities for on-site interviews and data collection. Due to the COVID-19 restrictions, international travel was prohibited. Through a process of virtual consultations with local participants (i.e. homeowners, business owners, farmers, academics, university students, renewable energy professionals, and emergency responders), it was agreed that interviews and data collection could be completed remotely, with interviews conducted over two phases. Our review of the humanitarian engineering research literature found no direct examples of the use of this method within such studies, including COVID-19 or pre-COVID contexts. However, remote data collection techniques (e.g. via phone and internet communication technologies) were found to be successful when used in the broader humanitarian sector. A study by Foster (2010) found that remote data collection for mobile health/eHealth purposes (use of mobile phones and web-services to obtain health-related data from patients) in L/LMICs is feasible, particularly within smaller-scaled studies, as they are more manageable by researchers who conduct research remotely. Foster (2010) indicated that data collection techniques used in mobile health/eHealth services could find applications in humanitarian engineering research studies. Chiumento et al. (2018) interviewed study participants with interpreters online (via Skype and Adobe Connect) in post-conflict areas, and indicated that online interviewing has potential in humanitarian research. However, both studies highlighted the need to actively manage issues such as researcher rapport-building with participants (e.g. sufficient time and processes), managing/interpreting silences, and addressing practical challenges (e.g. poor connection, power failures and having/communicating plans for these). These issues were considered and addressed in our study (Schismenos et al., 2021d).

As previously stated, the research was conducted during COVID-19 restrictions. This limited some interactions between the primary researcher and study participants including the decision to conduct the study using remote research methods. Despite these restrictions, there were a number of contact points and activities between the research team and study participants. For example, in Nepal, our project officer made regular contact with participants by phone and email and updated them regarding the research progress, preparation for interviews, setup and location of interviews, etc. The same activities for the Greek participants were organised by the primary researcher who is a native Greek speaker. This series of steps contributed to broader engagement with participants and built trust between them and the research team.

1.4 Study Aims

The primary aim of this study was to determine community perceptions of priority energy and flood resilience needs in communities with high flood vulnerability and energy insufficiency. A further aim was to compare community sites in lower and higher income country contexts but which otherwise experience similar hazard and risk factors. To achieve this, we investigated whether market available energy and flood warning systems or conceptual prototypes designed for local-level applications are an acceptable solution for panel members. Our final aim was to determine whether remote research is acceptable to participants when conducting interviews regarding community needs and the feasibility of proposed solutions, particularly at an initial program consultation phase.

The study collected three streams of contributing data, with the final cross-country analysis involving primary data collected from our community panels in Nepal and Greece. This approach provided a ‘triangulation’ of the available data, with our secondary data analyses (stream one and two) informing the framing, response options and research questions of the final study (Denzin, 1978; Nancy Carter et al., 2014):

1. technical feasibility (systems features/requirements)
2. operational best practice[2] (including case study examination of program success and failure and related indicators)
3. cross-country comparison of community perceptions of off-grid renewable energy and EWS for flood hazard management

Triangulation is an important aspect of this study as it facilitates validation of data through its cross verification from different sources – technical analysis, literature review of best practice options and participant perceptions of priority needs and feasibility (Denzin, 1978).

This series of inter-related studies addressed the following research questions:

Paper I:

a) What are the technical requirements and respective benefits of localised renewable energy (hydropower) and EWS?

b) What is the evidence such systems can:

- i) achieve sustained use,
- ii) be successfully combined or integrated to support ongoing dual function, and
- iii) be co-developed with community stakeholders?

Paper II:

What does the available literature indicate are the elements of efficient and sustainable off-grid renewable energy systems and localised EWS within remote, riparian communities experiencing energy insufficiency and flood risks?

[2] Defined as an intervention or policy implemented in a real-life setting, favourably assessed in terms of adequacy, equity, effectiveness and efficiency related to processes and outcomes (Stepien et al., 2022)

Paper III:

What factors are associated with effective community engagement processes and program outcomes in humanitarian engineering consultation and programming?

Paper IV:

What internationally recognised, comparable, and evidence-informed metrics can be utilised within community vulnerability and capability mapping and that can:

i) evaluate one or more communities in pre and post-hazard phases,
ii) identify communities with potentially greater need for energy development and hazard management resources,
iii) provide accessible and standardised information as part of community consultation, risk assessment, and mitigation planning, and
iv) determine the effectiveness of humanitarian and development program interventions in a single community over time?

Paper V:

Can remote research methodology be effectively utilised for humanitarian and development research engagement during COVID-19 and other restrictions to in-situ engagement?

Specifically:

i) does it support delivery of such a research program and information capture,
ii) does it provide sufficient access and is it acceptable to study participants, and
iii) what are its limitations and benefits when compared to in-situ community interviews?

Paper VI:

What do Dhuskun and Aggitis panel members perceive to be:

i) key vulnerabilities regarding flood risk and energy supply in their community, and
ii) the most useful assets for their community (system type and attributes of market available and community-developed options)?

1.5 Cross-cultural Research: Ethical Considerations and Protocols

1.5.1 Context and ethical issues

Due to the uncertainty regarding COVID-19, especially in crowd gatherings and traveling, we decided all data collection should be completed remotely. This was both an ethical and practical response to allow safe continuation of the research. It also enabled community members to have continued access to research consultation and a voice in longer-term changes and benefits such research can potentially bring to their communities. We proposed panels of community and professional study participants in a low-income country (i.e. Dhuskun, Nepal), and a high-income country (i.e. Aggitis, Greece). This plan was evaluated within the School of Social Sciences, Western Sydney University, and approved by the Human Research Ethics Committee (detailed below).

Study participants were informed that the current study would not provide direct support for any identified solution/preference and nor would the communities themselves be required to commit funds for any such development or implementation. The cost estimates of the respective systems were outlined for participant consideration. While it influenced some deliberations, most participants perceived that government and/or not-for-profit organisations would likely fund suitable systems. As such, cost considerations were unlikely to have affected participant final preferences in a substantial way.

1.5.2 Positionality statement

My positionality statement was developed using the Positionality Map approach of Jacobson and Mustafa (2019). I live and work on the traditional lands of the Darug, Tharawal, Eora and Wiradjuri Peoples, where I do my research as a faculty member at Western Sydney University. My ancestors are Caucasian and I come from a European and Mediterranean family.

My positionality for this process relates to my cultural and educational background. I was born and raised in Greece and received a Greek education. Classical Greek values and ideals such as Arete (virtue) and Synergia (synergy) are fundamental principles of the way I live my life and engage with other people. These are deeply rooted in my belief for bettering the world. My educational background is in engineering, emergency and disaster management and social sciences. Throughout the years, I have obtained cross-disciplinary knowledge and experiences from not only my educators and books but also my travels in different countries.

My life experiences and the way I live my life are core elements of my interest in studying humanitarian engineering in my PhD degree. During my studies I learned how to connect with culturally and linguistically diverse people and share local knowledge around the world. This is a direction I enjoy and plan to continue working on in the following years.

1.5.3 Research requirements and protocols

With regards to ethics governance and protocols, all ethical elements of the research followed the ethical standards expressed in the National Statement – Australian Government, National Health and Medical Research Council. These were detailed in our approved Human Research Ethics Application (HREC Approval Number: H14269) and published study protocol paper (Paper V).

Key requirements, provisions and data security were addressed as follows:

- All study participants were 18 years old or older.
- All information for participants was available in English, Greek and Nepali.
- The participants could withdraw at any time without any consequence.
- Personal and demographic information was requested. However, during analysis, a unique code (i.e. pseudonyms) was generated to identify participants. Thereafter, all data were in de-identified form and pseudonyms were used in any reporting of the data.
- All collected data are stored at the secure online server (OneDrive) at Western Sydney University. These will be kept for a period of five years after the completion of this research.
- The researchers are committed to disseminate and communicate the study findings and results to the participants. This was done in ways that permitted scrutiny and contributed to public knowledge and understanding.

2. CONTRIBUTIONS OF PAPERS

Contributions to study design and publications

The study design was developed by the primary researcher in consultation with the lead supervisor and subsequently with the full supervisory panel. All jointly published papers followed the same approach: the structure of each article was developed by the primary researcher in consultation with the lead supervisor. Draft versions of the paper were then developed by the primary researcher and reviewed by the full supervisory panel. The feedback of the panel was then used by the primary researcher to develop the final draft of the papers. All authors reviewed and approved the final drafts of all papers submitted for publication.

2.1 Paper I: Renewable Energy for Disaster Risk Reduction: A Technical Analysis

> **Aim:** To review the extant literature regarding localised renewable energy, particularly small-scale hydropower and flood warning systems, their technical features and co-development.

This study (Schismenos et al., 2020) is a cross-asset analysis of renewable energy systems, particularly off-grid hydropower, and flood warning applications at the local level in order to confirm whether their combined use is technically feasible.

While the study identified individual case studies which detailed criteria for the longer-term sustainability of small-scale hydropower (e.g. Ikejemba et al., 2017; Gurung et al., 2011) and EWS (e.g. Baudoin et al., 2014) as separate units, we found no published data regarding community-focused renewable energy systems (i.e. hydropower) powering localised EWS for community response.

Our findings indicate that localised hydropower and EWS typically fulfil 16 criteria that correspond to the needs and capabilities of vulnerable communities, for example, affordability, durability, output sufficiency and low environmental impact. Collectively, these factors affect the acceptability and sustainability of longer-term solutions These are presented in Table 1 (Appendix 1a). Other major findings indicated that the local riparian conditions (e.g. water velocity, river head, seasonal conditions) are key determinants of the type and technical specifications of a hydropower generator selected for a given site.

The available data regarding flood warning type, indicate that outdoor warning means, such as local sirens, lights and signs are the most appropriate for vulnerable communities. This is because such devices are low cost, autonomous, durable against weather extremes, can reach people in a relatively wide range (local-scale level), and do not need high maintenance or complex repairs and can be easily relocated if required (Schismenos et al., 2020). This analysis provides practical information that can support the work of humanitarian engineers, government and non-government agencies and riparian communities facing flood risks and energy insufficiency.

There are specific benefits for vulnerable communities when using small-scale hydropower and outdoor EWS. Our technical review found pico-level hydropower and EWS technical apparatus are compatible and feasible for combined use. The development of a combined or hybrid prototype with such features is warranted, given its potential to simultaneously improve energy supply and flood response capabilities. While technically feasible, such a development proposal would need to be explored with community members who would be potential end-users, and who would prefer such systems over other assets they regard as priorities, including locally developed and/or market available options (single asset or combined). As background to such an enquiry, it is important to investigate and confirm indicators that can affect asset sustainability in the long term. This can help guide and rationalise options that may be considered with end-user communities (e.g. local/adapted, market available and conceptual). Paper II is a scoping review of the available literature on community-based renewable energy and EWS, and details success and failure indicators reported in L/LMICs.

It should be noted that Paper I was undertaken as part of the first iteration of the research plan and presents technical information available in the literature for energy generation and flood early warning. This was an important first step to confirm the feasibility of combined services (energy and flood warning) at a theoretical and technical level and ensured that the community appraisals were based on technical options that were valid and evidence-informed. As such, Paper I remains relevant to the study research questions, irrespective of the changes in design and interview methods that occurred later due to the pandemic. It adds to our knowledge regarding the combination of services and, for that reason, was maintained among the research outputs.

2.2 Paper II: Localised Renewable Energy and Early Warning Systems: A Scoping Review

> **Aim**: To review the extant literature regarding the sustainability, and associated factors, of community-based renewables and EWS installed in L/LMICs.

We used the four-stage framework for scoping analyses developed by Arksey and O'Malley (2005) to conduct a comparative analysis of renewable energy and EWS studies. This approach has not previously been undertaken with studies of these respective systems. Such an analysis can inform researchers, government authorities, development, and humanitarian agencies, and end-user communities, as to the selection, potential interoperability, and sustainability of such systems in these contexts.

The review (Schismenos et al., 2021c) found 14 peer reviewed and 'grey'[3] literature studies that met the study inclusion criteria; success and failure indicators regarding appropriate technology and sustainability outcomes of localised renewable energy systems or EWS in remote communities in L/LMICs. The study employed recognised definitions of appropriate technology (Bauer and Brown, 2014) and sustainability (Ilskog and Kjellström, 2008) in determining the success or otherwise of the reviewed programs, but also incorporated the case study authors' contentions as to what constituted successful outcomes, given the evolving nature of this field. Most papers (12/14) were case studies presenting lessons learned from the installation and

[3] Other scholarly studies such as reports, working papers, and dissertations, both published and unpublished (Adams et al., 2017)

maintenance of renewable energy systems (off-grid hydropower, solar panels, wind turbines) with the remainder consisting of case studies for the effectiveness of different community-focused EWS (outdoor sirens, SMS alerts). No studies or information about renewable energy and flood early warning as combined systems was identified.

The findings indicate that despite the differences in socio-cultural, economic and environmental conditions, many communities in L/LMICs have similar needs (e.g. unreliable energy infrastructure) and lack similar capabilities (e.g. insufficient funds to develop and/or maintain needed assets). Many case studies shared either the same or similar indicators for system failure and/or success. Failure indicators frequently related to a lack of pre, intra and post-installation support, primarily in management, lack of community technical know-how, insufficient funding for system installation and maintenance, and limited or poor system services (Ikejemba et al., 2017; Kelly-Richards et al., 2017). Common success indicators included long-term and equitable community participation, particularly across all stages of the system life cycle (design, development, deployment, maintenance and de-commission), equitable socio-economic benefits to community groups, technology familiarisation and system ownership by end-users (Ahlborg and Hammar, 2014; International Renewable Energy Agency, 2019).

The findings of this review can be used by development professionals focusing on community resilience, energy sufficiency and sustainability in L/LMICs. The study itself provides a guide for technical intervention development in rural areas as it presents those indicators required for appropriate technology and sustainability mapping for localised renewable energy and flood warning installations. These are presented in Table 2 (Appendix 1b) and detailed in Schismenos et al. (2021c).

With respect to the primary researcher's doctoral research, this paper informed the research team about pre, intra and post-installation community perceptions of off-grid renewable energy and flood hazard management at the local level. Proactive and broad-based engagement from the early stages is an important finding and is associated with increased community interest and overall system sustainability. These findings emphasise the importance of understanding best practice approaches for community engagement and co-development of appropriate solutions and formed the basis of our literature review of this topic which is detailed in the next section (Paper III).

2.3 Paper III: Best Practice Community Engagement for Flood Resilience and Energy Development

Aims:

1) To review the available literature regarding best practice community engagement for off-grid energy generation and distribution management and water-based disaster response.
2) To use the extracted themes to develop a community-focused systems approach for Participatory Action Research in these focal areas.

Our literature review of best practice for community engagement (Schismenos et al., 2021b) identified six L/LMIC case studies regarding off-grid renewable energy systems and three case studies on EWS where technology-focused interventions were undertaken at a community level. Three primary themes derived from this review: i) practices supporting community participation for reliable energy supply and flood warning, ii) identification of community energy and flood resilience priorities via comprehensive consultation and needs assessment, and iii) co-development for the sustainability of suggested solutions by end-users. Other key factors associated with the success of the interventions included synergy between community and professional stakeholders (Gurung et al., 2011), familiarity with technology and suggested processes (Ikejemba et al., 2017), low cost and system maintenance (Baudoin et al., 2014).

In addition to the primary outcomes (energy and early warning) these interventions were linked with other reported community benefits. For example, Arnaiz et al. (2018) found that communities in Bolivia with installed micro hydropower systems reported livelihood improvements, including the creation of more jobs for the operation and maintenance of the system, and education outcomes, with children being able to study more hours (during evenings) and schools using computers and projectors for workshops and other educational activities.

Community engagement for assessing needs and co-developing solutions is central to our study. By taking into consideration these best practice themes, we developed design thinking process maps that could inform community engagement in humanitarian engineering research and development. These maps are presented as graduated steps of increasing specificity, from general engagement frameworks and priority setting (Figure 4), through to needs analysis for hazard preparedness (Figure 5), and co-development and prototyping of agreed solutions (Figure 6).

Our community engagement framework was adapted from Georgeou and Hawksley (2020) and is presented as a process map for initial engagement and understanding community priorities (Figure 4). This framework is informed by the principles of Participatory Action Research, including the right for research study participants to have access to, and be actively engaged in, the design and development of research processes (Hall, 1981; Vollman et al., 2008). This is particularly the case as research processes and outcomes may potentially affect their region and ‘life norms’ (Vollman et al., 2008), making community members primary stakeholders in these endeavours. For example, this may support integration of actions (planning, executing, observing, evaluating) as part of social and educational initiatives which aim to improve the well-being of those involved in research studies (Hall, 1981).

Canlas and Karpudewan (2020) describe this method as “truly responsive and committed in providing solutions to real world problems”. One example of successfully implementing this method is presented by Gautam and Phaiju (2013) who use this method to understand community perceptions for flood early warning and discuss potential solutions in West Rapti River Basin of Nepal. However, Bergold and Thomas (2012) and Springett et al. (2016) argue that studies using Participatory Action Research may lack quality, as they often fail to demonstrate detailed methodological planning. De Oliveira (2023) highlights the risk that having a group of study participants with different life experiences and perceptions may not permit a shared understanding on what the problem is and how it can be addressed holistically by a larger community. Other challenges identified by Mackenzie et al. (2012) include access limitations to research settings (e.g. geographic locations, facilities and schedules), and the complexity of research methods, terminologies and processes which may discourage study participants to engage or genuinely express their opinions.

In our study, we were mindful of these limitations and addressed them, as detailed below, to ensure full access and support of interview participants and to gather authentic and detailed perceptions of the phenomena examined. Our methodological approach, analysis, and study findings are available online and published in peer-reviewed journals (summarised in thesis, p. viii). The selection of participants was based on specific inclusion criteria (detailed in Papers V and VI), including the representation of specific community groups. A Delphi method of two rounds was adopted in our approach i) to confirm local priority needs and ii) to then discuss preferred solutions. This allowed the research team to minimise any assumptions and, through discussions, understand local vulnerabilities, capabilities and preferred solutions. We completed all interview rounds in local languages (e.g. Greek, Nepali) or English so study participant could express themselves without difficulties. We also provided orientation sessions before each round to familiarise interviewees with the processes and terms used, and employed a project officer in Nepal to provide project liaison, execution and interpretation.

This framework is also informed by co-development frameworks such as HCD, commonly used in humanitarian engineering (Duque et al., 2019). The present map uses a systems approach in which it considers the diverse range of community stakeholders that exist in most contexts and inclusion strategies to ensure their perspectives are represented in humanitarian and development initiatives. For example, the perspectives ascertained during ‘problem stating and solving’ phases can vary markedly based on the experiences of different cohorts (e.g. women, Indigenous or minority groups, individuals with disabilities or mobility issues etc.) and these need to be actively canvassed during early engagement.

A process map for identifying community priorities in hazard contexts is presented in Figure 5. This uses the example of a community with potentially high flood risk and low energy capacity and strategies to ensure community participation regarding priorities and potential solutions. This map can guide researchers investigating other community vulnerabilities (e.g. wildfire or drought exposure) and resources (e.g. water supply). Figure 6 presents an exemplar integration of these community engagement strategies extended to the operational aspects of prototype development, where such processes are indicated through the engagement process. This figure is adapted from

Bahill and Gissing (1998) and uses their SIMILAR model (State, Investigate, Model, Integrate, Launch, Assess, Re-evaluate) to detail an exemplar technical co-development of a hydropower generator combined with EWS to address flood risks and energy capacity challenges.

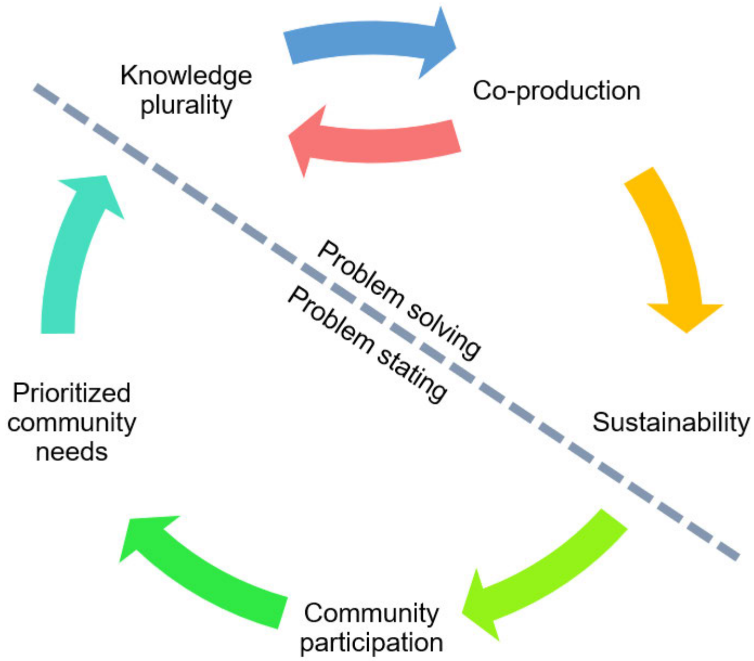


Figure 4. Process map for identifying community needs and agreed solutions; adapted from (Georgeou and Hawksley, 2020)

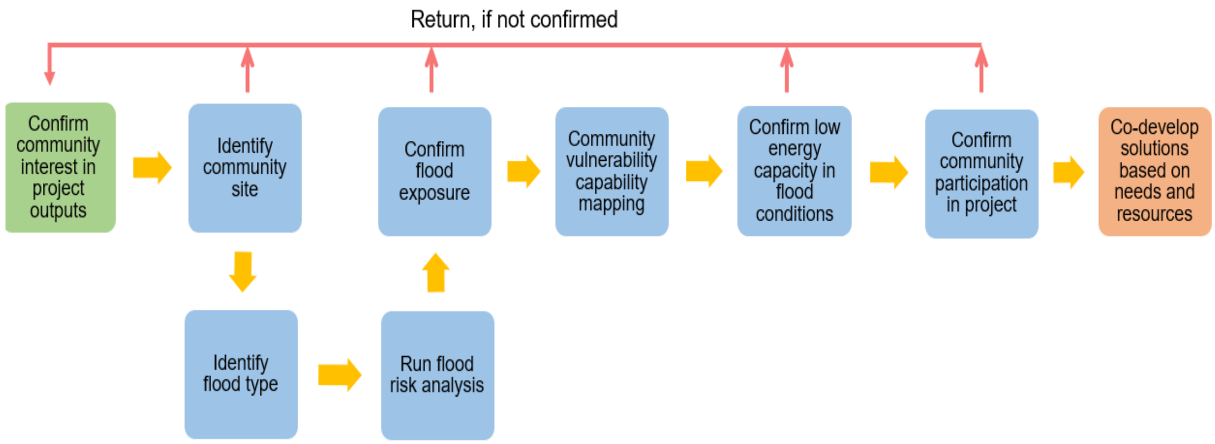


Figure 5. Process map for community participation and priority needs regarding flood and energy-related issues

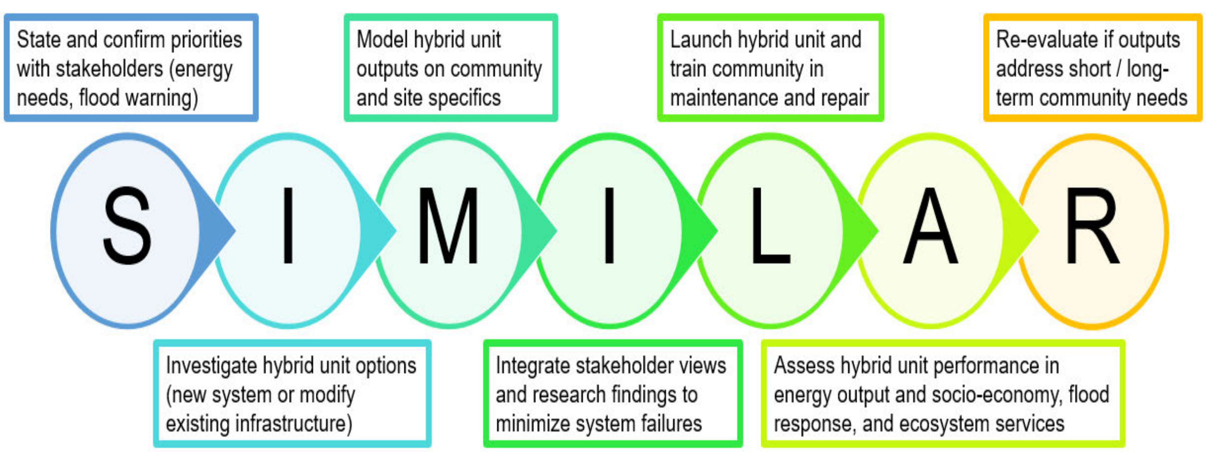


Figure 6. Process map for co-developing an intervention to address flood and energy-related issues; adapted from (Bahill and Gissing, 1998)

The engagement frameworks presented in this paper canvas a wide range of stakeholder views throughout a development process and address pragmatic social, environmental and technical issues likely to affect the longer-term viability of developed solutions. They can frame the ongoing evaluation of a humanitarian engineering intervention from its early stages and detect changes in energy and flood response capabilities of the end-user communities. However, to allow the continuous mapping of the energy and flood response alterations in multiple communities, the use of a vulnerability and capability mapping process or tool that considers internationally known/accepted metrics for both pre and post-hazard conditions should be considered. This tool is detailed in Paper IV.

2.4 Paper IV: Cross-community Vulnerability and Capability Mapping

> **Aim:** To compile internationally known, comparable, and evidence-informed metrics related to water hazard response capability that can support the development of a community vulnerability and capability mapping tool to support flood management.

This paper (Schismenos et al., 2021a) presents an exploratory investigation of community water hazard vulnerability and capability mapping. For this study, we focused on communities that, based on an assessed aggregate capability level, are more likely to benefit from water hazard risk reduction program engagement and co-development, potentially supported by off-grid renewable energy systems.

To address the interdependency between water hazard impacts and community resilience, we developed a tool that could act as a pre/post measure to assess whether water hazard risk reduction programs have resulted in discernible changes in individual and aggregate measures of water hazard response capabilities.

Our analysis suggests that i) disaster preparedness and response capability, ii) ongoing energy availability, and iii) income (e.g. local community and per person income) are objective, universal and comparable indicators of flood-related vulnerability and capability within a given community. As such, they can provide a useful mapping tool that is easily understood by community actors regarding cross-community comparisons and changes over time (e.g. pre/post project evaluations).

Each metric is both independently and collectively related to community vulnerability:

- Disaster plans, preparedness and capability: Disaster response is effective when there is adequate preparedness and planning (Hashemipour et al., 2017). This includes operational and reliable EWS (Baudoin et al., 2014), and community-level training and educational programs (Keeney, 2004). The availability of such response assets is highly dependent upon funding, governance resources (Sawada and Takasaki, 2017) and energy infrastructure (Phillips, 2019).
- Energy reliability (all conditions): Fekete (2020) indicates that flood hazards can cause multiple, inter-related impacts on community resources, including energy. Power disruptions affect community infrastructure (e.g. power outages in hospitals) and emergency response (e.g. poor fire service and communication due to lack of energy). Hence, reliable power generation/supply, including during extreme weather events can support hazard preparedness and response (Phillips, 2019).
- Income and income generation: Low income levels and poverty are associated with limited availability of hazard preparedness resources (Kooijman-van Dijk, 2012), as well as higher disaster-related loss of proportional gross domestic product and personal income (Sawada and Takasaki, 2017). As such, poverty has been characterised as both a causal factor and outcome of community disaster impacts and losses (Sawada and Takasaki, 2017; Wisner et al., 2004). Conversely, income opportunities typically increase when there is access to reliable energy, particularly in L/LMICs (Kooijman-van Dijk, 2012).

Naylor et al. (2020) argue that "vulnerability is determined by the continuous interaction of multiple exogenous and endogenous stressors, in addition to the interconnectedness of components that interact with them". These stressors inform complex adaptive system approaches for community vulnerability assessment - limited response capacity, power outages, and income loss are among the stressors (Naylor et al., 2020; Sawada and Takasaki, 2017). In our study, community vulnerability is considered a dynamic system. The metrics we suggest are evidence-informed and comparable, albeit stand-alone measures and with limited current evidence regarding their interactions. More sophisticated modelling drawing on a wider range of measures and ascertaining potential interactions will likely provide more accurate determinations of comparative vulnerability in the assessed areas. However, the selected metrics can detect changes in community vulnerability independently (e.g. power outages may affect evacuation), as well as collectively (e.g. power outages and lack of EWS may affect community response).

In this paper, the developed tool was applied in a comparison of three different community examplars with potentially different vulnerability and capability levels (Bluewater, Australia; Aden Governorate, Yemen; and Pheta - Ward 6, Nepal). This assessment indicated that our mapping tool offers a reliable means to evaluate one or more communities in pre and post-hazard phases and can identify communities with potentially greater need for water hazard management resources. Within such programs, it can compile and present clear and accessible information as part of community consultation, support risk assessment and mitigation planning, and can provide a hazard capability change measure in a single community over time (e.g. as a longitudinal or pre/post-intervention measure).

The vulnerability and capability mapping tool can act as a community screening process for humanitarian and development researchers regarding site selection and study development (e.g. such as site selection within our current study). It can potentially be used by humanitarian agencies (e.g. government and non-government authorities) if further developed and tested. It can also act as a supplementary report to other formal assessments to compile complimentary data on the characteristics of communities (e.g., community energy mapping). In addition to consultation with our local research partners, the criteria within the mapping tool were used to identify potential research sites in Nepal and Greece. The study protocol (Paper V) for community engagement at these sites is summarised in the following section.

Paper V: Humanitarian and Development Remote Research: Mixed Methods Approach

Aim: To develop a remote research methodology that can support cross-community humanitarian and development research engagement and participation.

Participatory Action Research approaches are often used in community vulnerability and capability analyses (De Brito et al., 2018; Twigg, 2014). However, such approaches have limitations, particularly where physical access to communities is restricted, such as interaction with remote communities or during crises such as pandemics (e.g. COVID-19). Remote research methods permit research continuity and community access without affecting study participation (Richardson et al., 2021). This approach is appropriate for our study and allowed us to examine how community and professional stakeholders perceive local hazards and response capabilities, priority areas of need and the potential development of resources that could address such needs.

This paper (Schismenos et al., 2021d) details a humanitarian and development research design that addresses restrictions to community research engagement that have occurred due to the current COVID-19 pandemic. We applied the Delphi method (Brent and Kruger, 2009; Dick, 1991) over two rounds of interviews. Delphi provided the broad framework for the data collection process which was augmented in Round Two with two complimentary methods; choice based conjoined analysis (CBCA) (Mansuy et al., 2020; Tanujaya et al., 2020), and strengths, challenges, opportunities, responses and effectiveness analysis (SCORE) (Njoh et al., 2019). Round One aimed to identify community vulnerabilities and capabilities through local stakeholders' perceptions. Round Two was informed by Round One and presented six appropriate options that are acceptable to local communities (market available and evidence informed options, and conceptual systems). In Round Two we used the CBCA and SCORE analyses to evaluate the feasibility of the six options. Lastly, we employed thematic analysis (Castleberry and Nolen, 2018) to derive our primary data from the completed interviews. Figure 7 presents our study design.

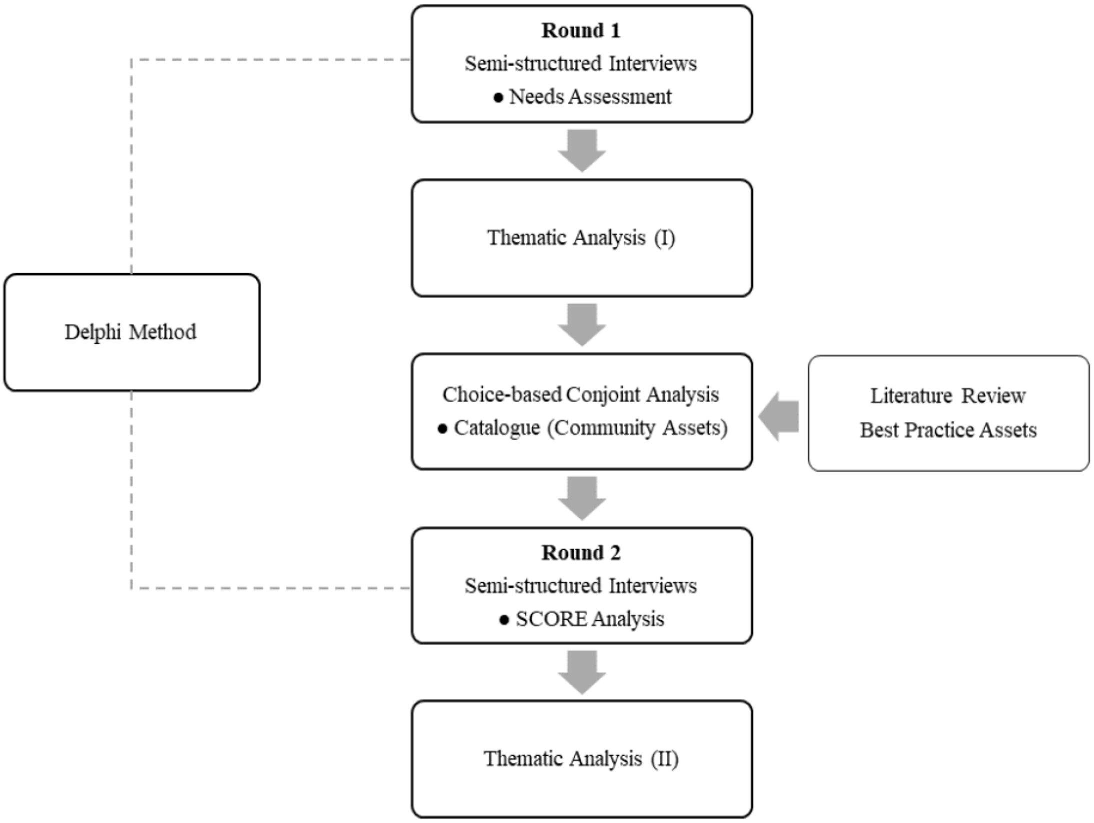


Figure 7. Study design

The overarching methodological framework of this study is based on Participatory Action Research and involved the collection of qualitative data from semi-structured interviews which were examined using thematic analysis. A limited number of frequency counts were derived from both the qualitative data and collected data within the literature and scoping reviews. This latter, generated data, were used to inform study outcomes.

2.6 Paper VI: Report from Dhuskun, Nepal and Aggitis, Greece

> **Aim**: To explore the perceptions of community and professional stakeholders regarding energy availability and flood hazard risks in Dhuskun and Aggitis, and to investigate what options, if any, are feasible and acceptable for further developed in these contexts

This study (Schismenos et al., 2022b) presents findings from our cross-country analysis of off-grid renewable energy generation and flood warning needs in two riparian communities, specifically their appraisals regarding i) market available stand-alone systems (EWS, renewable energy generators), ii) combined systems, and iii) a conceptual hybrid prototype.

The participating communities were:

> Dhuskun village, Tripura Sundari Rural Municipality Ward no.3, Sindhupalchowk District, Bagmati Province, and Sunkoshi River in Nepal; and
>
> Aggitis village, Drama Regional Unit, Eastern Macedonia and Thrace Region, and Aggitis River in Greece.

Both communities have been identified as meeting the study selection criteria – they are vulnerable communities.

The panel of study participants consisted of 16 members (eight for Dhuskun, eight for Aggitis) who represented key community and professional stakeholder groups. All participants had specific knowledge of the selected site and community needs and represented one of the following groups; resident of the selected community; academic with knowledge of selected riparian community; emergency management professional/representative (e.g. civil protection authority, fire/police department); technology experts /entrepreneur. Efforts were made to ensure gender balance and inclusion of members from different age groups and those with disability/mobility issues. Due to COVID-19 and the remote research method used in this study, accessing some groups was difficult. For example, the Aggitis panel did not include a member 65 years or older due to the COVID-19 restrictions in Greece that were effective at the time of data collection (2021). Potential participants in this cohort were found to have little or no computer skills/access and in-person support was not permitted, as was the case in Nepal. However, issues affecting older residents were discussed by Aggitis panel members.

Our partners at Kathmandu University (Nepal) and International Hellenic University (Greece) recommended a list of potential individuals who met our selection criteria and were interested to participate. These candidates had two weeks to consider participation from the time of contact. Those who expressed interest were screened by the primary researcher and one supervisor for suitability and representation. The screening was either online (interview or email) or by phone. If accepted, a consent form was sent to them to sign and return to the primary researcher by email. The interview scripts of the semi-structured interviews for Round 1 and Round 2 are available in Appendices 2a and 2b, respectively.

2.6.1 Round One – Needs Analysis

All panel members in Dhuskun and Aggitis (16/16, eight from each site) indicated that water hazards and lack of continuous energy supply are major concerns for their community. They supported a priority transition to renewable energy sources, including hydropower and solar power, arguing that local experience and site conditions could support such technologies. They also supported the installation of localised EWS, with sirens either as stand-alone systems or combined with SMS alerts as the most preferred warning types.

According to the World Risk Index 2019, Greece’s exposure to natural hazards is ‘very high’, compared to Nepal’s, which is ‘low’, but Greece’s coping and adaptive capacities levels are higher than Nepal’s (Day et al., 2019). These differences in financial resources and preparedness assets underscores why high-income countries are often more resilient to natural extremes (Khan et al., 2022). However, when it comes to flash floods, high-income countries are not always well-prepared, particularly at the local level. In 2021, the record-breaking floods in Germany

(Oltermann, 2021) showed that currently used EWS are not always adequate at the local level, and may not detect the severity, velocity and location of the floods that occur because they are designed to operate for larger scales. Similarly, local communities in Greece, including Aggitis, depend on national EWS for flood warning which are not always effective at a local scale. This was stated by some study participants.

According to study participants in Nepal, Dhuskun's lack of flood EWS is primarily because of the lack of available funds. One participant explained that there is a nearby small hydropower station which uses its own flood EWS and that sometimes local residents receive warnings from it. However, that EWS is designed for the area around the hydropower station and does not provide accurate scanning for the entire community.

Round Two was informed by the Round One analysis and suggested six appropriate options that are acceptable to panel members. These were presented in a 'catalogue'[4] format, as shown in Figure 8.

[4] Option 1 is based on SMART HYDRO (https://www.smart-hydro.de/); Option 2 is based on GPM-250W, Zhejiang G New Energy Technology Co.; Option 3 is based on Telegrafia flood siren system (https://www.telegrafia.eu/en/solution/mass-public-warning/flood-warning-system/); Option 4 is based on LEVELINE-EWS (https://www.aquaread.com/products/water-level/leveline-ews); Option 5 is based on Options 2 and 4; Option 6 is based on Options 1 and 3).

1 HYDRO POWER	2 SOLAR POWER	3 FLOOD SIREN	4 SMS ALERTS	5 SOLAR + SMS	6 HYDRO + SIREN (SINGLE SYSTEM)
UNIT QUANTITY: **1**	UNIT QUANTITY: **20**	UNIT QUANTITY: **1**	UNIT QUANTITY: **1**	UNIT QUANTITY: **21**	UNIT QUANTITY: **1**
GENERATES: **5000 W**	GENERATES: **5000 W**			GENERATES: **5000 W**	GENERATES: **5000 W**
POWERS: **80 HOUSES**	POWERS: **90 HOUSES**			POWERS: **80 HOUSES**	POWERS: **70 HOUSES**
		WARNING RANGE: **1.5 KM**			WARNING RANGE: **1.5 KM**
			NOTIFICATION:**PHONE, EMAIL**	NOTIFICATION:**PHONE, EMAIL**	
NEEDS: **1.1 M WATER DEPTH, AND BATTERY**	NEEDS: **SUNLIGHT FOR AT LEAST 6 HOURS PER DAY**	NEEDS: **POWER SOURCE, AND BATTERY RECHARGE**	NEEDS: **POWER SOURCE, AND BATTERY RECHARGE**	NEEDS: **SUNLIGHT FOR AT LEAST 6 HOURS PER DAY**	NEEDS: **1.1 M WATER DEPTH, AND BATTERY**
LOCATION: **RIVER**	LOCATION: **ROOFS**	LOCATION: **RIVER**	LOCATION: **RIVER**	LOCATION:**ROOFS+RIVER**	LOCATION: **RIVER**
MAINTENANCE:**3 MONTHLY**	MAINTENANCE: **ANNUALLY**	MAINTENANCE: **ANNUALLY**	MAINTENANCE: **ANNUALLY**	MAINTENANCE: **ANNUALLY**	MAINTENANCE:**3 MONTHLY**
EST.COST($): **14,000**	EST.COST($): **10,000**	EST.COST($): **6,000**	EST.COST($): **2,500**	EST.COST($): **12,500**	EST.COST($): **20,000**

- *Photos of actual products (1: SMART HYDRO; 2: GPM-250W; 3: TELEGRAFIA EARLY FLOOD WARNING SYSTEM; 4: LEVELINE EWS; 5: photos of 2 and 4; 6: photos of 1 and 3.*
- *Power per house is for general use only (50W/house) including powering lights, recharging phones and other small devices. All other devices (e.g. refrigerator, air condition) are not considered.*
- *Power loss due to distance and other conditions is estimated to be between 500W and 1000W. This value may differ in actual site conditions.*
- *Estimated cost is in US$ and does not include construction works, licenses, unknown taxes and other non-primary devices/services/works that may vary per community.*

Figure 8. Catalogue of six community assets and their attributes

2.6.2 Round Two – Preferred Option and Rationale

The majority of panel members (10/16) preferred the hybrid prototype (Option 6) as an appropriate community asset for their community. The primary reason for this is that it integrated two required services (reliable energy in the form of hydropower and flood siren warning) as a stand-alone system, and was seen as a more efficient means to deliver these due to the riparian resources that were available (i.e. water flow supporting continuous generation). The combination of solar energy panels and flood alert SMS (Option 5) was the second most preferred option (5/16) as it provided free energy from local site conditions (sunlight) and convenience of receiving warning information (via SMS). An asset that offered a single service (i.e. Option 1 - small-scale hydropower system) was selected by one panel member mainly due to its low cost and the available riparian resources.

The remote research approach was viewed positively by all panel members (16/16) who found that it was convenient and did not restrict their feedback. Table 3 (Appendix 1c) summarises perceptions of major hazard threats, priority developments for resilience and existing assets (Round One), and preferred assets and related developments (Round Two) in an aggregated form (Schismenos et al., 2022b).

The data confirmed that both Dhuskun and Aggitis are prone to water-based disasters and in need of more reliable energy sources. Most panel members (15/16) preferred options with multiple services including energy generation and flood warning, compared to well-established but mono-functional systems (1/16). The combination of hydropower and siren offered the most attractive option and was endorsed by twice as many participants as the next preferred combination (solar and SMS). Integrating these services into a single unit was seen to offer efficiency gains while also supporting greater community input and control as a co-developed asset. Table 4 (Appendix 1d) details the themes and sub-themes that were drawn from the analysis of participant responses.

This remote research approach employed in this study could be utilised in other humanitarian engineering research where in-situ engagement is not feasible or where the travel and logistics costs of a study may be prohibitive. The next stage of this study could involve the co-design, co-development and testing of the hybrid prototype in the participating, or other, communities.

3. CONCLUSIONS

Water-based disasters are the most frequent type of natural hazards affecting human settlements and impact the greatest number people through direct losses and dislocation. Their consequences are more intense in L/LMICs where insufficient infrastructure, poor governance, and lack of emergency services are more common. Remote, riparian communities are particularly vulnerable as they often face the dual-dilemma of insufficient energy and flood response capability; factors that also constrain their climate adaptation. Renewable energy and EWS can provide much-needed assets and capabilities for vulnerable communities as presented in our technical analysis. However, our literature review indicated that their success is grounded in sustained collaboration between local and professional stakeholders, including early engagement regarding priority needs, appropriate design and sustainability tailored to the local context and its resources. The absence of such engagement and stakeholder ‘ownership’ was found to be common in systems that either failed to deploy or did not meet lifespan estimates.

The findings from our literature review posed key questions for our enquiry regarding community priority needs and capabilities in our focal areas, specifically i) how to reliably identify vulnerable communities, ii) what are effective, evidence-informed approaches to engage community participants and ensure a diversity of views, and iii) what are suitable research methods to consult such communities, particularly in the context of pandemic restrictions. Our vulnerability and capability mapping tool was based on objective and universal criteria for the identification of vulnerable communities, their needs and cross-community comparisons. The subsequent analysis of the community engagement literature highlighted the importance of understanding the community as a dynamic ‘system’ with a range of different stakeholder groups, some of which risk being under-represented in research enquiries (e.g. women, older adults, individuals with disabilities or mobility issues). Deliberative approaches are therefore needed to ensure access and equity in their representation and expression of views, particularly as such groups may experience higher risk during floods. Lastly, literature findings also guided the development of our study protocol and its focus on a stepped, Delphi approach to develop community consensus regarding needs and assets/options for further development.

The final paper presented the culmination of the preparatory work detailed above, as development support of our community surveys. Its findings provide new information regarding preferred solutions and asset combinations, which support the following determinations:

i. The remote research approach for Participatory Action Research was an acceptable and legitimate engagement approach to all study participants, involved no discernible loss of information and offered advantages in convenience and time/cost savings. Our approach, including iterative, consensus-building via the Delphi method, can support humanitarian and development research continuity and efficiency, particularly where direct community access is costly and/or disrupted.

ii. Sufficient and reliable energy and flood response capabilities were reported as high priorities for both the Dhuskun and Aggitis communities, even when compared to other immediate concerns, such as COVID-19 and longer-term issues such as population decline and community ageing.

iii. Dual-function resources (energy and flood warning) to address priority concerns were preferred over mono-function systems (i.e. single energy or flood warning). A hybrid unit comprised of hydropower generation and audible flood warning (siren) was perceived as the most suitable option for Dhuskun and Aggitis by study participants, compared to other market available, single or multi-functional systems. The primary reason for this was the perceived ready integration of these systems and the value of their respective functions.

3.1 Recommendation

The combination of energy and flood warning functions under one system is technically feasible, preferred by community members and can satisfy multiple community needs under both normal and extreme conditions. This community selection represents an innovative combination of energy and hazard response capabilities in remote communities. Moreover, it promises a practical integration of the United Nations Agenda 2030 for Sustainable Development and the Sendai Framework for Disaster Risk Reduction. Further consultation with community members could consider progressing this research program to co-design/co-development and community site testing of a working prototype, including assessment its of its outputs, their perceived value and longer-term sustainability in community settings.

3.2 Limitations and Strengths

This study has several limitations and some notable strengths. A full account of the limitations of sub-studies supporting our main enquiry are presented in Papers I-IV, with the key limitations of the primary study (Paper VI) detailed below.

A possible limitation of our community enquiry is that it primarily focused on energy and flood resilience issues in vulnerable communities. Participants were asked about wider issues impacting the community, such that the relative strength of concerns and needs related to energy and flood risk could be ascertained. However, participant awareness of the study's focus on energy and flood issues potentially affected reporting of concerns in other areas. Similarly, while the range of available options and combinations in the Round Two Delphi interviews was drawn from both participant suggestions (Round One) and market available best practice (technical review), the catalogue selections were necessarily limited and other, unappraised solutions/combinations could potentially offer equivalent or superior options for end-users in such communities.

The Dhuksun and Aggitis communities have some local experience with hydropower and this familiarity may have influenced their preference for this option. However, participants from both communities are also familiar with local solar energy installations so a bias based on mode familiarity appears unlikely. These factors would need to be taken into consideration in generalising these findings to other vulnerable communities.

While the sample size (eight participants from Dhuskun and eight participants from Aggitis) was similar to comparable Delphi-based studies, larger samples may have increased the reliability of the findings and the representation of key groups, including those with known higher risk during floods (e.g. participants with physical or intellect disabilities, or restricted mobility).

In the context of the current study, all participants stated that the online interview mode was acceptable and an ‘easy’ process. However, it is possible that some participants may have preferred the experience of face-to-face interviews with the primary researcher, had that option been available. Other issues such as poor internet or technological access could also affect acceptability and preferences regarding interview mode.

The study has notable strengths and innovation. It examines, for the first time, high and low-income community perceptions regarding energy and flood resilience, their intersect, and local solutions appropriate to their context. The effective use of remote research highlights that this method is appropriate, does not impede the capture of information, and supports research continuity and community participation in the context of pandemic restrictions. The acceptability and low reported burden of this approach may make it suitable and time/cost efficient for other humanitarian and development studies, as well as community participants in such research. This could include cross-community and even international research panels collaborating in research and development areas of mutual need.

3.3 Future Directions

A key finding of the study was the interest of both community panels to develop renewable energy in the form of hydropower and to integrate this with flood detection/warning capabilities. As such, the next logical step of this study is to proceed with the development of a hybrid prototype. This could be done in collaboration with Dhuskun and Aggitis residents, due to our existing partnership and project familiarity. Researchers from Western Sydney University, Kathmandu University, and International Hellenic University could collaborate with local actors in the two communities to design, develop and test the prototype in local sites. Such progression of the study is consistent with HCD principles and would see the research relationship progress from the needs-focused consultation of the current study, to active co-design/co-development. Full community management and leadership of co-developed assets would be the ultimate objective. While the prototype may vary in design due to environmental variants, the concept is the same and presented in Figure 9. Our developed vulnerability and capability mapping would allow us to detect any changes in pre and post-installation stages. Future steps could involve engaging communities in other countries (e.g. Brazil and Guatemala where community representatives have expressed interest in joining in the study). Research initiatives could also be developed for other disaster types (e.g. wildfires, earthquakes), integrating sensors with a range of renewable energy types to support local response capabilities. Future research could consider inclusion of both online and face-to-face interview modes. This would permit a direct comparison regarding mode preference and potential implications for future research program deployment and time/monetary costs. However, this is subject to the requirements and circumstances of future studies.

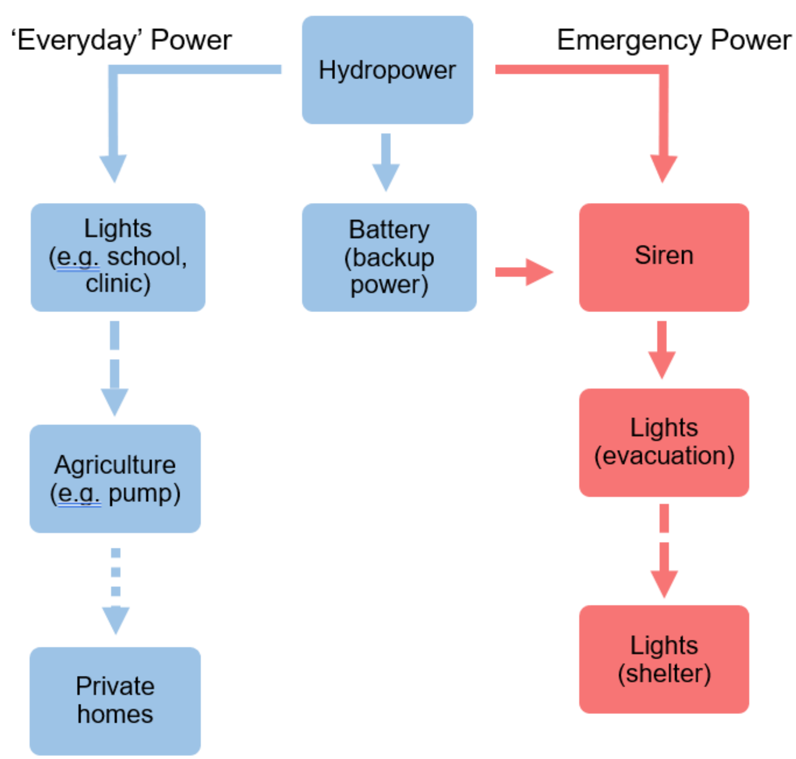


Figure 9. Concept of the hybrid prototype

3.4 Professional Development Outcomes of Candidature

As a doctoral candidate, the current series of publications have allowed me to explore the applications of renewable energy in community disaster resilience and sustainable development. It also helped me to understand how professionals and non-experts perceive the innovative nexus of renewable energy generation and flood warning.

Since the beginning of my candidature, I have learnt from the process of completing study analyses that combine elements, methods and approaches used in Social Sciences, Engineering, Environmental Studies, Psychology, and Project/Product Management. I have also gained knowledge in conducting cross-cultural Participatory Action Research in a remote manner combining mixed techniques.

I was fortunate to be supervised by distinguished academics from three different universities, and to interact with remarkable colleagues at Western Sydney University. I was supported and advised by all community members (partners) at the two sites and drew on their experience and wisdom.

This resulted in a number of achievements including:

- Two research innovation awards (university level and nationwide)
- 27 published articles or chapters in peer-reviewed journals, conference proceedings and reports by international organisations (e.g. the United Nations Office for Disaster Risk Reduction, and Integrated Research on Disaster Risk Programme)
- Keynote speaking at the Challenges and Opportunities for Cooperation - Integrated Research on Disaster Risk 2021 International Conference, by the International Council for Science, International Social Science Council, and United Nations Office for Disaster Risk Reduction
- Five articles in news media, including The Conversation and The Greek Herald
- Two interviews on television

These achievements would not have been possible without the continuous support from my supervisors, the School of Social Sciences Associate Dean, Higher Degree Research, friends, and colleagues at Western Sydney University.

REFERENCES

Adams, R. J., Smart, P., & Huff, A. S. (2017). Shades of grey: guidelines for working with the grey literature in systematic reviews for management and organizational studies. *International Journal of Management Reviews*, *19*(4), 432-454. https://doi.org/10.1111/ijmr.12102

Ahlborg, H., & Hammar, L. (2014). Drivers and barriers to rural electrification in Tanzania and Mozambique–grid-extension, off-grid, and renewable energy technologies. *Renewable Energy*, *61*, 117-124. https://doi.org/10.1016/j.renene.2012.09.057

Alcántara-Ayala, I., & Oliver-Smith, A. (2019). Early warning systems: lost in translation or late by definition? A FORIN approach. *International Journal of Disaster Risk Science*, *10*(3), 317-331. https://doi.org/10.1007/s13753-019-00231-3

Alfieri, L., Salamon, P., Pappenberger, F., Wetterhall, F., & Thielen, J. (2012). Operational early warning systems for water-related hazards in Europe. *Environmental Science & Policy*, *21*, 35-49. https://doi.org/10.1016/j.envsci.2012.01.008

Anderson, N. S. (1988). User centered system design: new perspectives on human-computer interaction. *The American Journal of Psychology*, *101*(1), 148-151. https://doi.org/10.2307/1422802

Aqueduct. (n.d.). *Overall Water Risk*. https://www.wri.org/applications/aqueduct/water-risk-atlas/#/?advanced=false&basemap=hydro&indicator=w_awr_def_tot_cat&lat=30&lng=-80&mapMode=view&month=1&opacity=0.5&ponderation=DEF&predefined=false&projection=absolute&scenario=optimistic&scope=baseline&timeScale=annual&year=baseline&zoom=3 (accessed 25 April 2021)

Arksey, H., & O'Malley, L. (2005). Scoping studies: towards a methodological framework. *International Journal of Social Research Methodology*, *8*(1), 19-32. https://doi.org/10.1080/1364557032000119616

Arnaiz, M., Cochrane, T. A., Hastie, R., & Bellen, C. (2018). Micro-hydropower impact on communities' livelihood analysed with the capability approach. *Energy for Sustainable Development*, *45*, 206-210. https://doi.org/10.1016/j.esd.2018.07.003

Arnold, R. D., & Wade, J. P. (2015). A definition of systems thinking: a systems approach. *Procedia Computer Science*, *44*(2015), 669-678. https://doi.org/10.1016/j.procs.2015.03.050

Azid, S., Sharma, B., Raghuwaiya, K., Chand, A., Prasad, S., & Jacquier, A. (2015). SMS based flood monitoring and early warning system. *ARPN Journal of Engineering and Applied Sciences*, 10(15), 6387-6391. ISSN: 1819-6608

Bahill, A. T., & Gissing, B. (1998). Re-evaluating systems engineering concepts using systems thinking. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)*, *28*(4), 516-527. https://doi.org/10.1109/5326.725338

Basher, R. (2006). Global early warning systems for natural hazards: systematic and people-centred. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*. *364*(1845), 2167-2182. https://doi.org/10.1098/rsta.2006.1819

Baudoin, M. A., Henly-Shepard, S., Fernando, N., & Sitati, A. (2014). Early warning systems and livelihood resilience: exploring opportunities for community participation. *UNU-EHS Working Paper Series*, (1). https://collections.unu.edu/view/UNU:3174#viewMetadata

Baudoin, M. A., Henly-Shepard, S., Fernando, N., Sitati, A., & Zommers, Z. (2016). From top-down to "community-centric" approaches to early warning systems: exploring pathways to improve disaster risk reduction through community participation. *International Journal of Disaster Risk Science*, *7*(2), 163-174. https://doi.org/10.1007/s13753-016-0085-6

Bauer, A. M., & Brown, A. (2014). Quantitative assessment of appropriate technology. *Procedia Engineering*, *78*, 345-358. https://doi.org/10.1016/j.proeng.2014.07.076

Bauer, P., Thorpe, A., & Brunet, G. (2015). The quiet revolution of numerical weather prediction. *Nature*, *525*(7567), 47-55. https://doi.org/10.1038/nature14956

Bergold, J., & Thomas, S. (2012). Participatory research methods: A methodological approach in motion. *Historical Social Research/Historische Sozialforschung*, 191-222. http://www.jstor.org/stable/41756482

Brent, A. C., & Kruger, W. J. (2009). Systems analyses and the sustainable transfer of renewable energy technologies: a focus on remote areas of Africa. *Renewable Energy*, *34*(7), 1774-1781. https://doi.org/10.1016/j.renene.2008.10.012

Canlas, I.P., & Karpudewan, M. (2020). Blending the principles of participatory action research approach and elements of grounded theory in a disaster risk reduction education case study. *International Journal of Qualitative Methods*, *19*, 1609406920958964. https://doi.org/10.1177/1609406920958964

Castleberry, A., & Nolen, A. (2018). Thematic analysis of qualitative research data: is it as easy as it sounds?. *Currents in Pharmacy Teaching and Learning*, *10*(6), 807-815. https://doi.org/10.1016/j.cptl.2018.03.019

Centre for Research on the Epidemiology of Disasters. (2020). *Human cost of disasters: an overview of the last 20 years*. https://www.emdat.be/publications

Chiumento, A., Machin, L., Rahman, A., & Frith, L. (2018). Online interviewing with interpreters in humanitarian contexts. *International Journal of Qualitative Studies on Health and Well-being*, *13*(1), 1444887. https://doi.org/10.1080/17482631.2018.1444887

Day, S., Forster, T., Himmelsbach, J., Korte, L., Mucke, P., Radtke, K., Theilbörger, P., Weller, D. (2019) World Risk Report 2019 -Focus: Water supply. *Bündnis Entwicklung Hilft and Ruhr University Bochum—Institute for International Law of Peace and Armed Conflict (IFHV)*. ISBN 978-3-946785-08-8

De Brito, M. M., Evers, M., & Almoradie, A. D. S. (2018). Participatory flood vulnerability assessment: a multi-criteria approach. *Hydrology and Earth System Sciences*, *22*(1), 373-390. https://doi.org/10.5194/hess-22-373-2018

De Oliveira, B. (2023). Participatory Action Research as a Research Approach: Advantages, Limitations and Criticisms. *Qualitative Research Journal*. https://doi.org/10.1108/QRJ-08-2022-0101

Denzin, N. K. (1978). *The logic of naturalistic inquiry in NK Denzin* (Ed.) Sociological Methods: a sourcebook. ISBN: 0070163669 9780070163669

Dick, R. (1991). *Helping groups to be effective: skills, processes & concepts for group facilitation*. Interchange. ISBN: 978-1-875260-09-6

Douvinet, J., Serra-Llobet, A., Bopp, E., & Kondolf, G. M. (2021). Are sirens effective tools to alert the population in France?. *Natural Hazards and Earth System Sciences*, *21*(10), 2899-2920. https://doi.org/10.5194/nhess-21-2899-2021

Downey, G. (2005). Are engineers losing control of technology?: from 'problem solving' to 'problem definition and solution' in engineering education. *Chemical Engineering Research and Design*, *83*(6), 583-595. https://doi.org/10.1205/cherd.05095

Duque, E., Fonseca, G., Vieira, H., Gontijo, G., & Ishitani, L. (2019). A systematic literature review on user centered design and participatory design with older people. *Proceedings of the 18th Brazilian symposium on human factors in computing systems* (1-11). https://doi.org/10.1145/3357155.3358471

Energy Poverty Action Initiative - World Economic Forum. (n.d.). *World Economic Forum*. http://www.weforum.org/pdf/ip/energy/EPA.pdf (accessed 10 April 2022)

Engineers Without Borders. (n.d). *Human-Centred Engineering –Collaborative Styles*. https://ewb.app.box.com/s/vjgi9z1exbqydpg0q9z9c007sbo7m8vy (accessed 15 April 2022)

Fekete, A. (2020). Critical infrastructure cascading effects. Disaster resilience assessment for floods affecting city of Cologne and Rhein-Erft-Kreis. *Journal of Flood Risk Management*, *13*(2), e312600. https://doi.org/10.1111/jfr3.12600

Fernhaber, S.A., Wada, T., Napier, P., & Suttles, S. (2019). Engaging diverse community stakeholders to co-create solutions in food deserts: A design-thinking approach. *Journal of Public Affairs*, *19*(3), e1874. https://doi.org/10.1002/pa.1874

Foster, K. R. (2010). Telehealth in sub-Saharan Africa: lessons for humanitarian engineering. *IEEE Technology and Society Magazine*, *29*(1), 42-49. https://doi.org/10.1109/MTS.2010.935977

Frank, M. (2002). What is "engineering systems thinking"?. *Kybernetes*. 31(9/10), 1350-1360. https://doi.org/10.1108/03684920210443554

Gautam, D. K., & Phaiju, A. G. (2013). Community based approach to flood early warning in West Rapti River Basin of Nepal. *Journal of Integrated Disaster Risk Management*, *3*(1), 155-169. http://dx.doi.org/10.5595/idrim.2013.0060

Georgeou, N., & Hawksley, C. (Eds.) (2020). Enhancing research impact in international development: a practical guide for practitioners and researchers. *Deakin, A.C.T.: Research for Development Impact Network*. https://rdinetwork.org.au/resources/enhancing-research-impact-in-international-development-a-practical-guide-for-practitioners-and-researchers/

Gielen, D. (2012). Renewable Energy Technologies: cost analysis series. *International Renewable Energy Agency*. *1*(3/5), 1-44. https://www.globalccsinstitute.com/archive/hub/publications/138178/hydropower.pdf

Gosink, J., Lucena, J., & Moskal, B. (2003). *Humanitarian engineering at the Colorado School of Mines: an example of multidisciplinary engineering.* Paper presented at 2003 Annual Conference, Nashville, Tennessee. https://peer.asee.org/11871

Gurung, A., Bryceson, I., Joo, J. H., & Oh, S. E. (2011). Socio-economic impacts of a micro-hydropower plant on rural livelihoods. *Scientific Research and Essays*, *6*(19), 3964-3972. https://doi.org/10.5897/SRE10.766

Hall, B.L. (1981). Participatory research, popular knowledge and power: A personal reflection. *Convergence*, *14*(3), 6.

Haidar, A. M., Senan, M. F., Noman, A., & Radman, T. (2012). Utilization of pico hydro generation in domestic and commercial loads. *Renewable and Sustainable energy reviews*, *16*(1), 518-524. https://doi.org/10.1016/j.rser.2011.08.017

Hallegatte, S. (2012). A cost effective solution to reduce disaster losses in developing countries: hydro-meteorological services, early warning, and evacuation. *World Bank Policy Research Working Paper No. 6058*. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2051341

Hallegatte, S., Vogt-Schilb, A., Rozenberg, J., Bangalore, M., & Beaudet, C. (2020). From poverty to disaster and back: a review of the literature. *Economics of Disasters and Climate Change*, *4*(1), 223-247. https://doi.org/10.1007/s41885-020-00060-5

Hashemipour, M., Stuban, S. M., & Dever, J. R. (2017). A community-based disaster coordination framework for effective disaster preparedness and response. *Australian Journal of Emergency Management, The*, *32*(2), 41-46. ISSN:1324-1540

Hill, S., & Miles, E. (2012). What do students understand by the term 'humanitarian engineering'. *Innovation, Practice and Research in Engineering Education*, 1-11

Hook, J. N., Davis, D. E., Owen, J., Worthington Jr, E. L., & Utsey, S. O. (2013). Cultural humility: measuring openness to culturally diverse clients. *Journal of Counseling Psychology*, *60*(3), 353. https://psycnet.apa.org/doi/10.1037/a0032595

Howells, M., Rogner, H. H., Mentis, D., & Broad, O. (2017). Energy access and electricity planning. *The World Bank*. http://documents.worldbank.org/curated/en/628541494925426928/Energy-access-and-electricity-planning

Ikejemba, E. C., Mpuan, P. B., Schuur, P. C., & Van Hillegersberg, J. (2017). The empirical reality & sustainable management failures of renewable energy projects in Sub-Saharan Africa (part 1 of 2). *Renewable Energy, 102*, 234-240. https://doi.org/10.1016/j.renene.2016.10.037

Ilskog, E., & Kjellström, B. (2008). And then they lived sustainably ever after? - assessment of rural electrification cases by means of indicators. *Energy Policy*, *36*(7), 2674-2684. https://doi.org/10.1016/j.enpol.2008.03.022

International Energy Agency. (n.d.). *SDG7: Data and Projections*. https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity%0Ahttps://www.iea.org/reports/sdg7-data-and-projections (accessed 01 May 2021).

International Federation of Red Cross and Red Crescent Societies. (2007). *The Johns Hopkins and Red Cross Red Crescent Public Health Guide in Emergencies*. https://reliefweb.int/sites/reliefweb.int/files/resources/Forward.pdf

International Renewable Energy Agency. (2019). *Off-grid renewable energy solutions to expand electricity access: an opportunity not to be missed*. ISBN 978-92-9260-101-0. https://www.irena.org/publications/2019/Jan/Off-grid-renewable-energy-solutions-to-expand-electricity-to-access-An-opportunity-not-to-be-missed

Intrieri, E., Gigli, G., Mugnai, F., Fanti, R., & Casagli, N. (2012). Design and implementation of a landslide early warning system. *Engineering Geology, 147*: 124-136. https://doi.org/10.1016/j.enggeo.2012.07.017

Ioannidou, C., & O'Hanley, J. R. (2018). Eco-friendly location of small hydropower. *European Journal of Operational Research*, *264*(3), 907-918. https://doi.org/10.1016/j.ejor.2016.06.067

Jacobson, D., & Mustafa, N. (2019). Social identity map: A reflexivity tool for practicing explicit positionality in critical qualitative research. *International Journal of Qualitative Methods, 18*, 1609406919870075. https://doi.org/10.1177/1609406919870075

Jessel, S., Sawyer, S., & Hernández, D. (2019). Energy, poverty, and health in climate change: a comprehensive review of an emerging literature. *Frontiers in Public Health*, 357. https://doi.org/10.3389/fpubh.2019.00357

Jobert, A., Laborgne, P., & Mimler, S. (2007). Local acceptance of wind energy: factors of success identified in French and German case studies. *Energy Policy, 35*(5), 2751-2760. https://doi.org/10.1016/j.enpol.2006.12.005

Johnson, K., Hadjerioua, B., & Martinez, R. U. (2015). Small hydropower in the United States. *ORNL/TM-2015/326, Oak Ridge, TN: Oak Ridge National Laboratory*. https://info.ornl.gov/sites/publications/files/Pub56556.pdf

Kamperman Sanders, A., Falcão, T., Haider, A., Jambeck, J., LaPointe, C., Vickers, C., & Ziebarth, N. (2018). *World Economic and Social Survey 2018: Frontier Technologies for Sustainable Development*. ISBN: 978-92-1047-224-1; 978-92-1109-179-3

Keeney, G. B. (2004). Disaster preparedness: what do we do now?. *Journal of Midwifery & Women's Health*, *49*(4), 2-6. https://doi.org/10.1016/j.jmwh.2004.05.003

Kelly-Richards, S., Silber-Coats, N., Crootof, A., Tecklin, D., & Bauer, C. (2017). Governing the transition to renewable energy: a review of impacts and policy issues in the small hydropower boom. *Energy Policy, 101*, 251-264. https://doi.org/10.1016/j.enpol.2016.11.035

Khan, M.T.I., Anwar, S., & Batool, Z. (2022). The role of infrastructure, socio-economic development, and food security to mitigate the loss of natural disasters. *Environmental Science and Pollution Research*, *29*(35), 52412-52437. https://doi.org/10.1007/s11356-022-19293-w

Kim, N. (2012). How much more exposed are the poor to natural disasters? Global and regional measurement. *Disasters*, *36*(2), 195-211. https://doi.org/10.1111/j.1467-7717.2011.01258.x

Kirubi, C., Jacobson, A., Kammen, D .M., & Mills, A. (2009). Community-based electric micro-grids can contribute to rural development: evidence from Kenya. *World Development*, *37*(7), 1208-1221. https://doi.org/10.1016/j.worlddev.2008.11.005

Kooijman-van Dijk, A. L. (2012). The role of energy in creating opportunities for income generation in the Indian Himalayas. *Energy Policy*, *41*, 529-536. https://doi.org/10.1016/j.enpol.2011.11.013

Lee, H. R., Šabanović, S., Chang, W. L., Nagata, S., Piatt, J., Bennett, C., & Hakken, D. (2017). Steps toward participatory design of social robots: mutual learning with older adults with depression. *Proceedings of the 2017 ACM/IEEE international conference on human-robot interaction* (244-253). https://doi.org/10.1145/2909824.3020237

Lee, J. (2015). Q&A on disaster risk reduction: if not risk-informed, not sustainable development. *United Nations Foundation*. https://unfoundation.org/blog/post/qa-if-it-is-not-risk-informed-it-is-not-sustainable-development/ (accessed 10 April 2022)

Ma, M. Small hydroelectric dams increase globally with little research, regulations. (2018). *University of Washington News*. https://www.washington.edu/news/2018/01/22/small-hydroelectric-dams-increase-globally-with-little-research-regulations/ (accessed 20 February 2023)

Mackenzie, J., Tan, P.L., Hoverman, S., & Baldwin, C. (2012). The value and limitations of participatory action research methodology. *Journal of Hydrology*, *474*, 11-21. https://doi.org/10.1016/j.jhydrol.2012.09.008

Mansuy, J., Verlinde, S., & Macharis, C. (2020). Understanding preferences for EEE collection services: a choice-based conjoint analysis. *Resources, Conservation and Recycling*, *161*, 104899. https://doi.org/10.1016/j.resconrec.2020.104899

May, N. (2022). Floods and livestock losses leave NSW and Queensland farmers reeling from third disaster in three years. *The Guardian*. https://www.theguardian.com/australia-news/2022/mar/02/floods-and-livestock-losses-leave-nsw-and-queensland-farmers-reeling-from-third-disaster-in-three-years (accessed 01 May 2022)

Mazzurco, A., & Jesiek, B. K. (2017). Five guiding principles to enhance community participation in humanitarian engineering projects. *Journal of Humanitarian Engineering*, *5*(2). https://doi.org/10.36479/jhe.v5i2.80

Meadows, D. H. (2008). *Thinking in systems: a primer*. Chelsea Green Publishing. ISBN: 978-1-84407-726-7

Mosel, I., & Levine, S. (2014). Remaking the case for linking relief, rehabilitation and development: how LRRD can become a practically useful concept for assistance in difficult places. *London: Humanitarian Policy Group, the Overseas Development Institute.* https://cdn.odi.org/media/documents/8882.pdf

Nancy Carter, R. N., Bryant-Lukosius, D., & Alba DiCenso, R. N. (2014). The use of triangulation in qualitative research. *Oncology Nursing Forum*, *41*(5), 545. https://www.proquest.com/openview/1904d067b227719a39567bba50c56328/1?pq-origsite=gscholar&cbl=37213

Naylor, A., Ford, J., Pearce, T., & Van Alstine, J. (2020). Conceptualizing climate vulnerability in complex adaptive systems. *One Earth*, *2*(5), 444-454. https://doi.org/10.1016/j.oneear.2020.04.011

Nerini, F. F., Howells, M., Bazilian, M., & Gomez, M. F. (2014). Rural electrification options in the Brazilian Amazon: a multi-criteria analysis. *Energy for Sustainable Development*, *20*, 36-48. https://doi.org/10.1016/j.esd.2014.02.005

News Agencies. (2020). Afghanistan flooding: dozens dead, hundreds of homes destroyed. *Al Jazeera*. https://www.aljazeera.com/news/2020/8/26/afghanistan-flooding-dozens-dead-hundreds-of-homes-destroyed (accessed 10 March 2022)

Ngowi, J. M., Bångens, L., & Ahlgren, E. O. (2019). Benefits and challenges to productive use of off-grid rural electrification: The case of mini-hydropower in Bulongwa-Tanzania. *Energy for Sustainable Development*, *53*, 97-103. https://doi.org/10.1016/j.esd.2019.10.001

Njoh, A. J. (2016). *Tradition, culture and development in Africa: historical lessons for modern development planning*. Routledge. https://doi.org/10.4324/9781315235868

Nilsson, L., Madon, T., & Sastry, S. S. (2014). Toward a new field of development engineering: linking technology design to the demands of the poor. *Procedia Engineering*, *78,* 3-9. https://doi.org/10.1016/j.proeng.2014.07.032

Oltermann, P. (2021). German flood alert system criticised for 'monumental failure'. *The Guardian.* https://www.theguardian.com/world/2021/jul/19/german-villages-could-be-left-with-no-drinking-water-after-floods (accessed 10 March 2022)

Ostadtaghizadeh, A., Ardalan, A., Paton, D., Jabbari, H., & Khankeh, H. R. (2015). Community disaster resilience: a systematic review on assessment models and tools. *PLoS Currents*, *7*. https://dx.doi.org/10.1371%2Fcurrents.dis.f224ef8efbdfcf1d508dd0de4d8210ed

Owens, B. P., & Hekman, D. R. (2016). How does leader humility influence team performance? Exploring the mechanisms of contagion and collective promotion focus. *Academy of Management Journal*, *59*(3), 1088-1111. https://doi.org/10.5465/amj.2013.0660

Pearson, L., & Pelling, M. (2015). The UN Sendai framework for disaster risk reduction 2015–2030: negotiation process and prospects for science and practice. *Journal of Extreme Events*, *2*(1): 1571001. https://doi.org/10.1142/S2345737615710013

Phillips, C. (2017). Combining energy efficiency and disaster mitigation efforts in residential properties. *Office of Policy Development and Research*. https://www.huduser.gov/portal/periodicals/em/spring17/highlight2.html (accessed 12 December 2021)

Quansah, D. A., Adaramola, M. S., & Mensah, L. D. (2016). Solar photovoltaics in sub-Saharan Africa–addressing barriers, unlocking potential. *Energy Procedia*, *106*, 97-110. https://doi.org/10.1016/j.egypro.2016.12.108

Richardson, J., Godfrey, B., & Walklate, S. (2021). Rapid, remote and responsive research during COVID-19. *Methodological Innovations*, *14*(1), 20597991211008581. https://doi.org/10.1177%2F20597991211008581

Sanders, E. (2006). Scaffolds for building everyday creativity. In J. Frascara (Ed.), *Design for effective communications: Creating contexts for clarity and meaning* (pp. 2–17). New York, NY: Allworth Press.

Sanders, E.B.N., & Stappers, P.J. (2008). Co-creation and the new landscapes of design. *Co-design*, *4*(1), 5-18. https://doi.org/10.1080/15710880701875068

Sawada, Y., & Takasaki, Y. (2017). Natural disaster, poverty, and development: an introduction. *World Development*, *94*, 2-15. https://doi.org/10.1016/j.worlddev.2016.12.035

Schismenos, S., Emmanouloudis, D., Stevens, G. J., & Eslamian, S. (2022a). Torrential and flash flood warning: general overview and uses of localized hydropower. In S. Eslamian and F.A. Eslamian (Eds), *Flood Handbook: Impacts and Management*. Routledge. https://doi.org/10.1201/9780429463327

Schismenos, S., Stevens, G. J., Emmanouloudis, D., Georgeou, N., Shrestha, S., & Chalaris, M. (2020). Humanitarian engineering and vulnerable communities: hydropower applications in localised flood response and sustainable development. *International Journal of Sustainable Energy*, *39*(10), 941-950. https://doi.org/10.1080/14786451.2020.1779274

Schismenos, S., Stevens, G. J., Emmanouloudis, D., Georgeou, N., Shrestha, S., & Chalaris, M. (2021a). Humanitarian engineering at the sustainability-development nexus: mapping vulnerability and capability factors for communities at risk of water-based disasters. *Sustainability Science*, *16*(4), 1185-1199. https://doi.org/10.1007/s11625-020-00890-y

Schismenos, S., Stevens, G. J., Emmanouloudis, D., Georgeou, N., Shrestha, S., & Katopodes, N. D. (2021b). Using off-grid hydropower for community-led flood resilience: an integrated systems approach. *International Journal of Sustainable Energy*, 1-15. https://doi.org/10.1080/14786451.2021.1961773

Schismenos, S., Stevens, G., Emmanouloudis, D., Georgeou, N., Shrestha, S., Katopodes, N., & Wali, N. (2021c). Humanitarian engineering for renewable energy and flood early warning in remote communities: a scoping review of enabling factors and sustainability. *Journal of Sustainable Development of Energy, Water and Environment Systems*, *10*(3), 1090406. https://doi.org/10.13044/j.sdewes.d9.0406

Schismenos, S., Stevens, G. J., Georgeou, N., Emmanouloudis, D., Shrestha, S., & Thapa, B. S. (2021d). Humanitarian and developmental research engagement during COVID-19. *Social Science Protocols*, *4*, 1-14. https://doi.org/10.7565/ssp.v4.6487

Schismenos, S., Stevens, G. J., Georgeou, N., Emmanouloudis, D., Shrestha, S., Thapa, B. S., & Gurung, S. (2022b). Flood and renewable energy humanitarian engineering research: lessons from Aggitis, Greece and Dhuskun, Nepal. *Geosciences*, *12*(2), 71. https://doi.org/10.3390/geosciences12020071

Schöne, T., Pandoe, W., Mudita, I., Roemer, S., Illigner, J., Zech, C., & Galas, R. (2011). GPS water level measurements for Indonesia's tsunami early warning system. *Natural Hazards and Earth System Sciences (NHESS)*, *11*(3): 741-749. https://doi.org/10.5194/nhess-11-741-2011

Sheroubi, A., & Potvin, G. (2018). Humanitarian engineering: a new interdisciplinary course on the application of engineering skills to local and global humanitarian challenges. *Proceedings of the Canadian Engineering Education Association (CEEA)*. https://doi.org/10.24908/pceea.v0i0.12963

Shrestha Pradhan, N. (2020). What is CBFEWS?. *International Centre for Integrated Mountain Development*. https://www.icimod.org/mountain/cbfews

Springett, J., Atkey, K., Kongats, K., Zulla, R., & Wilkins, E. (2016, May). Conceptualizing quality in participatory health research: A phenomenographic inquiry. In *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research*, 17(2), 27). http://nbn-resolving.de/urn:nbn:de:0114-fqs1602274

Stepien, M., Keller, I., Takki, M., & Caldeira, S. (2022). European public health best practice portal-process and criteria for best practice assessment. *Archives of Public Health*, *80*(1), 1-8. https://doi.org/10.1186/s13690-022-00892-5

Stewart, F., Holdstock, D., & Jarquin, A. (2002). Root causes of violent conflict in developing countriesCommentary: Conflict—from causes to prevention?. *BMJ*, *324*(7333), 342-345. https://doi.org/10.1136/bmj.324.7333.342

Sufri, S., Dwirahmadi, F., Phung, D., & Rutherford, S. (2020). A systematic review of community engagement (CE) in disaster early warning systems (EWSs). *Progress in Disaster Science*, *5*, 100058. https://doi.org/10.1016/j.pdisas.2019.100058

Tanujaya, R. R., Lee, C. Y., Woo, J., Huh, S. Y., & Lee, M. K. (2020). Quantifying public preferences for community-based renewable energy projects in South Korea. *Energies*, *13*(9), 2384. https://doi.org/10.3390/en13092384

Tapp, H., White, L., Steuerwald, M., & Dulin, M. (2013). Use of community-based participatory research in primary care to improve healthcare outcomes and disparities in care. *Journal of Comparative Effectiveness Research*, *2*(4), 405-419. https://doi.org/10.2217/cer.13.45

Thomas, E. (2019). Toward a new field of global engineering. *Sustainability*, *11*(14), 3789. https://doi.org/10.3390/su11143789

Twigg, J. (2004). *Disaster risk reduction: mitigation and preparedness in development and emergency programming*. Overseas Development Institute (ODI). http://lib.riskreductionafrica.org/bitstream/handle/123456789/1453/good%20practice%20review%20disaster%20risk%20reduction%20number%209%20march%20200.pdf?sequence=1

Twigg, J. (2014). Attitude before method: disability in vulnerability and capacity assessment. *Disasters*, *38*(3), 465-482. https://doi.org/10.1111/disa.12066

United Nations. (2016). *Transforming our world: the 2030 agenda for sustainable development*. https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf (accessed 15 January 2021)

United Nations Department of Economic and Social Affairs. (2022). 2022 *Energy Statistics Pocketbook*. https://unstats.un.org/unsd/energystats/pubs/pocketbook/

United Nations Framework Convention on Climate Change. (2020). *Community-based flood early-warning system - India*. https://unfccc.int/climate-action/momentum-for-change/information-and-communications-technology-solutions/community-based-flood-early-warning-system-india

United Nations International Strategy for Disaster Reduction. (2009). 2*009 UNISDR Terminology on Disaster Risk Reduction*. https://www.unisdr.org/files/7817_UNISDRTerminologyEnglish.pdf

United Nations Office for Disaster Risk Reduction. (2005). Hyogo Framework for action 2005–2015: building the resilience of nations and communities to disasters. *World Conference on Disaster Reduction, Kobe, Hyogo, Japan* van Stam, G. (2013). Inclusive community engagement in social innovation, case Africa. In *Fifth International Conference on eInfrastructure and eServices for Developing Countries (Africomm 2013), Blantyre, Malawi*

Vollman, A.R., & Jackson, S. F. (2020). *Canadian community as partner: Theory & multidisciplinary practice*. Lippincott Williams & Wilkins. ISBN: 1975141377

Wahlstrom, M., & Guha-Sapir, D. (2015). The human cost of weather related disasters 1995–2015. *United Nations International Strategy for Disaster Reduction (UNISDR).* https://www.unisdr.org/files/46796_cop21weatherdisastersreport2015.pdf

Waidyanatha, N. (2010). Towards a typology of integrated functional early warning systems. *International Journal of Critical Infrastructures*. *6*(1), 31. https://www.inderscienceonline.com/doi/abs/10.1504/IJCIS.2010.029575

Williamson, S. J., Lubitz, W. D., Williams, A. A., Booker, J. D., & Butchers, J. P. (2019). Challenges facing the implementation of pico-hydropower technologies. *Journal of Sustainability Research*, *4*(3). https://doi.org/10.20900/jsr20200003

Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (2014). *At risk: natural hazards, people's vulnerability and disasters*. Routledge. https://doi.org/10.4324/9780203714775

World Bank. (2022). *World Bank Country and Lending Groups*. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups

World Energy Council. (2016). *World Energy Resources 2016.* https://www.worldenergy.org/assets/images/imported/2016/10/World-Energy-Resources-Full-report-2016.10.03.pdf

BIBLIOGRAPHY

Acharya, P., Papadakis, A., & Shaikh, M. N. (2016). Modelling and design of a 3 kW permanent magnet synchronous generator suitable for variable speed small wind turbines. *MATEC Web of Conferences*, *55*, 04001. https://doi.org/10.1051/matecconf/20165504001

Adams, R. J., Smart, P., & Huff, A. S. (2017). Shades of grey: guidelines for working with the grey literature in systematic reviews for management and organizational studies. *International Journal of Management Reviews*, *19*(4), 432-454. https://doi.org/10.1111/ijmr.12102

Ahadzie, D. K., & Proverbs, D. G. (2011). Emerging issues in the management of floods in Ghana. *International Journal of Safety and Security Engineering*, *1*(2), 182-192. https://doi.org/10.2495/SAFE-V1-N2-182-192

Ahlborg, H., & Hammar, L. (2014). Drivers and barriers to rural electrification in Tanzania and Mozambique–grid-extension, off-grid, and renewable energy technologies. *Renewable Energy*, *61*, 117-124. https://doi.org/10.1016/j.renene.2012.09.057

Aien, M., & Mahdavi, O. (2020). On the way of policy making to reduce the reliance of fossil fuels: case study of Iran. *Sustainability*, *12*(24), 10606. https://doi.org/10.3390/su122410606

Alam, F., Alam, Q., Reza, S., Khurshid-ul-Alam, S. M., Saleque, K., & Chowdhury, H. (2017). A review of hydropower projects in Nepal. *Energy Procedia*, *110*, 581-585. https://doi.org/10.1016/j.egypro.2017.03.188

Alcántara-Ayala, I., & Oliver-Smith, A. (2019). Early warning systems: lost in translation or late by definition? A FORIN approach. *International Journal of Disaster Risk Science*, *10*(3), 317-331. https://doi.org/10.1007/s13753-019-00231-3

Alfieri, L., Salamon, P., Pappenberger, F., Wetterhall, F., & Thielen, J. (2012). Operational early warning systems for water-related hazards in Europe. *Environmental Science & Policy*, *21*, 35-49. https://doi.org/10.1016/j.envsci.2012.01.008

Anderson, N. S. (1988). User centered system design: new perspectives on human-computer interaction. *The American Journal of Psychology*, *101*(1), 148-151. https://doi.org/10.2307/1422802

Aqueduct. (n.d.). *Overall Water Risk*. https://www.wri.org/applications/aqueduct/water-risk-atlas/#/?advanced=false&basemap=hydro&indicator=w_awr_def_tot_cat&lat=30&lng=-80&mapMode=view&month=1&opacity=0.5&ponderation=DEF&predefined=false&projection=absolute&scenario=optimistic&scope=baseline&timeScale=annual&year=baseline&zoom=3 (accessed 25 April 2021)

Archer, E. R. (2003). Identifying underserved end-user groups in the provision of climate information. *Bulletin of the American Meteorological Society*, *84*(11), 1525-1532. https://doi.org/10.1175/BAMS-84-11-1525

Arksey, H., & O'Malley, L. (2005). Scoping studies: towards a methodological framework. *International Journal of Social Research Methodology*, *8*(1), 19-32. https://doi.org/10.1080/1364557032000119616

Armah, F. A., Yawson, D. O., Yengoh, G. T., Odoi, J. O., & Afrifa, E. K. (2010). Impact of floods on livelihoods and vulnerability of natural resource dependent communities in Northern Ghana. *Water*, *2*(2), 120-139. https://doi.org/10.3390/w2020120

Arnaiz, M., Cochrane, T. A., Hastie, R., & Bellen, C. (2018). Micro-hydropower impact on communities' livelihood analysed with the capability approach. *Energy for Sustainable Development*, *45*, 206-210. https://doi.org/10.1016/j.esd.2018.07.003

Arnold, R. D., & Wade, J. P. (2015). A definition of systems thinking: a systems approach. *Procedia Computer Science*, *44*(2015), 669-678. https://doi.org/10.1016/j.procs.2015.03.050

Asjes, K. (2014). The hidden benefits of remote research. *uxBOOTH*. https://www.uxbooth.com/articles/hidden-benefits-remote-research/ (accessed 12 September 2021)

Azid, S., Sharma, B., Raghuwaiya, K., Chand, A., Prasad, S., & Jacquier, A. (2015). SMS based flood monitoring and early warning system. *ARPN Journal of Engineering and Applied Sciences*, 10(15), 6387-6391. ISSN: 1819-6608

Bahill, A. T., & Gissing, B. (1997). No matter what the application, it is still systems engineering. *INCOSE International Symposium*, *7*(1), 348-355. https://doi.org/10.1002/j.2334-5837.1997.tb02192.x

Bahill, A. T., & Gissing, B. (1998). Re-evaluating systems engineering concepts using systems thinking. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)*, *28*(4), 516-527. https://doi.org/10.1109/5326.725338

Barbour, R. S. (2001). Checklists for improving rigour in qualitative research: a case of the tail wagging the dog?. *BMJ*, *322*(7294), 1115-1117. https://doi.org/10.1136/bmj.322.7294.1115

Basher, R. (2006). Global early warning systems for natural hazards: systematic and people-centred. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*. *364*(1845), 2167-2182. https://doi.org/10.1098/rsta.2006.1819

Baudoin, M. A., Henly-Shepard, S., Fernando, N., & Sitati, A. (2014). Early warning systems and livelihood resilience: exploring opportunities for community participation. *UNU-EHS Working Paper Series*, (1). https://collections.unu.edu/view/UNU:3174#viewMetadata

Baudoin, M. A., Henly-Shepard, S., Fernando, N., Sitati, A., & Zommers, Z. (2016). From top-down to “community-centric” approaches to early warning systems: exploring pathways to improve disaster risk reduction through community participation. *International Journal of Disaster Risk Science*, *7*(2), 163-174. https://doi.org/10.1007/s13753-016-0085-6

Baudoin, M. A., & Wolde-Georgis, T. (2015). Disaster risk reduction efforts in the greater horn of Africa. *International Journal of Disaster Risk Science*, *6*(1), 49-61. https://doi.org/10.1007/s13753-015-0041-x

Bauer, A. M., & Brown, A. (2014). Quantitative assessment of appropriate technology. *Procedia Engineering*, *78*, 345-358. https://doi.org/10.1016/j.proeng.2014.07.076

Bauer, P., Thorpe, A., & Brunet, G. (2015). The quiet revolution of numerical weather prediction. *Nature*, *525*(7567), 47-55. https://doi.org/10.1038/nature14956

Baurzhan, S., & Jenkins, G. P. (2016). Off-grid solar PV: Is it an affordable or appropriate solution for rural electrification in Sub-Saharan African countries?. *Renewable and Sustainable Energy Reviews*, *60*, 1405-1418. https://doi.org/10.1016/j.rser.2016.03.016

Benson, C., Twigg, J., & Rossetto, T. (2007). *Tools for mainstreaming disaster risk reduction: guidance notes for development organisations*. ProVention Consortium. https://www.preventionweb.net/files/1066_toolsformainstreamingDRR.pdf

Berends, L., & Johnston, J. (2005). Using multiple coders to enhance qualitative analysis: the case of interviews with consumers of drug treatment. *Addiction Research & Theory*, *13*(4), 373-381. https://doi.org/10.1080/16066350500102237

Bergold, J., & Thomas, S. (2012). Participatory research methods: A methodological approach in motion. *Historical Social Research/Historische Sozialforschung*, 191-222. http://www.jstor.org/stable/41756482

Bhattacharyya, S. C. (2013). Financing energy access and off-grid electrification: a review of status, options and challenges. *Renewable and Sustainable Energy Reviews*, *20*, 462-472. https://doi.org/10.1016/j.rser.2012.12.008

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77-101. https://doi.org/10.1191/1478088706qp063oa

Brent, A. C., & Kruger, W. J. (2009). Systems analyses and the sustainable transfer of renewable energy technologies: a focus on remote areas of Africa. *Renewable Energy*, *34*(7), 1774-1781. https://doi.org/10.1016/j.renene.2008.10.012

Burnham, M. G. (2009). The ‘systems approach’ to human problems: how humanitarian engineering can help. *2009 IEEE International Symposium on Technology and Society* (1-10). https://doi.org/10.1109/ISTAS.2009.5155899

Butchers, J., Williamson, S., Booker, J., Tran, A., Karki, P. B., & Gautam, B. (2020). Understanding sustainable operation of micro-hydropower: a field study in Nepal. *Energy for Sustainable Development*, *57*, 12-21. https://doi.org/10.1016/j.esd.2020.04.007

Caniato, M., Carliez, D., & Thulstrup, A. (2017). Challenges and opportunities of new energy schemes for food security in humanitarian contexts: a selective review. *Sustainable Energy Technologies and Assessments*, *22*, 208-219. https://doi.org/10.1016/j.seta.2017.02.006

Canlas, I.P., & Karpudewan, M. (2020). Blending the principles of participatory action research approach and elements of grounded theory in a disaster risk reduction education case study. *International Journal of Qualitative Methods*, *19*, 1609406920958964. https://doi.org/10.1177/1609406920958964

Cantrill, J. A., Sibbald, B., & Buetow, S. (1996). The Delphi and nominal group techniques in health services research. *International Journal of Pharmacy Practice*, *4*(2), 67-74. https://doi.org/10.1111/j.2042-7174.1996.tb00844.x

Castleberry, A., & Nolen, A. (2018). Thematic analysis of qualitative research data: is it as easy as it sounds?. *Currents in Pharmacy Teaching and Learning*, *10*(6), 807-815. https://doi.org/10.1016/j.cptl.2018.03.019

Centre for Research on the Epidemiology of Disasters. (2020). *Human cost of disasters: an overview of the last 20 years*. https://www.emdat.be/publications

Chiumento, A., Machin, L., Rahman, A., & Frith, L. (2018). Online interviewing with interpreters in humanitarian contexts. *International Journal of Qualitative Studies on Health and Well-being*, *13*(1), 1444887. https://doi.org/10.1080/17482631.2018.1444887

Cirella, G. T., Semenzin, E., Critto, A., & Marcomini, A. (2014). Natural hazard risk assessment and management methodologies review: Europe. *Sustainable Cities and Military Installations* (329-358). https://doi.org/10.1007/978-94-007-7161-1_16

Collingridge, D. (2021). Validating a questionnaire. *METHODSPACE*. https://www.methodspace.com/blog/validating-a-questionnaire (accessed 23 August 2021)

Cools, J., Innocenti, D., & O'Brien, S. (2016). Lessons from flood early warning systems. *Environmental Science & Policy*, *58*, 117-122. https://doi.org/10.1016/j.envsci.2016.01.006

Crossland, A. F., Anuta, O. H., & Wade, N. S. (2015). A socio-technical approach to increasing the battery lifetime of off-grid photovoltaic systems applied to a case study in Rwanda. *Renewable Energy*, *83*, 30-40. https://doi.org/10.1016/j.renene.2015.04.020

Day, S., Forster, T., Himmelsbach, J., Korte, L., Mucke, P., Radtke, K., Theilbörger, P., Weller, D. (2019) World Risk Report 2019 -Focus: Water supply. *Bündnis Entwicklung Hilft and Ruhr University Bochum—Institute for International Law of Peace and Armed Conflict (IFHV)*. ISBN 978-3-946785-08-8

D'Cunha, S. D. (2017). How off-grid renewable energy came to the rescue in India's flood zones. *Forbes*. https://www.forbes.com/sites/suparnadutt/2017/09/15/how-off-grid-renewable-energy-came-to-the-rescue-in-indias-floodzones/?sh=6df386fabc49 (accessed 27 January 2022)

De Brito, M. M., Evers, M., & Almoradie, A. D. S. (2018). Participatory flood vulnerability assessment: a multi-criteria approach. *Hydrology and Earth System Sciences*, *22*(1), 373-390. https://doi.org/10.5194/hess-22-373-2018

De Oliveira, B. (2023). Participatory Action Research as a Research Approach: Advantages, Limitations and Criticisms. *Qualitative Research Journal*. https://doi.org/10.1108/QRJ-08-2022-0101

Deichmann, U., Meisner, C., Murray, S., & Wheeler, D. (2011). The economics of renewable energy expansion in rural Sub-Saharan Africa. *Energy Policy*, *39*(1), 215-227. https://doi.org/10.1016/j.enpol.2010.09.034

Denzin, N. K. (1978). *The logic of naturalistic inquiry in NK Denzin* (Ed.) Sociological Methods: A sourcebook. ISBN: 0070163669 9780070163669

Devine-Wright, P. (2005). Local aspects of UK renewable energy development: exploring public beliefs and policy implications. *Local Environment*, *10*(1), 57-69. https://doi.org/10.1080/1354983042000309315

Di Baldassarre, G., Montanari, A., Lins, H., Koutsoyiannis, D., Brandimarte, L., & Blöschl, G. (2010). Flood fatalities in Africa: from diagnosis to mitigation. *Geophysical Research Letters*, *37*(22). https://doi.org/10.1029/2010GL045467

Dick, R. (1991). *Helping groups to be effective: skills, processes & concepts for group facilitation*. Interchange. ISBN: 978-1-875260-09-6

Dincer, I. (1999). Environmental impacts of energy. *Energy Policy*, *27*(14), 845-854. https://doi.org/10.1016/S0301-4215(99)00068-3

Douvinet, J., Serra-Llobet, A., Bopp, E., & Kondolf, G. M. (2021). Are sirens effective tools to alert the population in France?. *Natural Hazards and Earth System Sciences*, *21*(10), 2899-2920. https://doi.org/10.5194/nhess-21-2899-2021

Downey, G. (2005). Are engineers losing control of technology?: from 'problem solving' to 'problem definition and solution' in engineering education. *Chemical Engineering Research and Design*, *83*(6), 583-595. https://doi.org/10.1205/cherd.05095

Duque, E., Fonseca, G., Vieira, H., Gontijo, G., & Ishitani, L. (2019). A systematic literature review on user centered design and participatory design with older people. *Proceedings of the 18th Brazilian symposium on human factors in computing systems* (1-11). https://doi.org/10.1145/3357155.3358471

Elalem, S., & Pal, I. (2015). Mapping the vulnerability hotspots over Hindu-Kush Himalaya region to flooding disasters. *Weather and Climate Extremes*, *8*, 46-58. https://doi.org/10.1016/j.wace.2014.12.001

Energy Poverty Action Initiative - World Economic Forum. (n.d.). *World Economic Forum*. http://www.weforum.org/pdf/ip/energy/EPA.pdf (accessed 10 April 2022)

Engineers Without Borders. (n.d). *Human-Centred Engineering –Collaborative Styles*. https://ewb.app.box.com/s/vjgi9z1exbqydpg0q9z9c007sbo7m8vy (accessed 15 April 2022)

Federal Emergency Management Agency. (2008). *Using the hazard mitigation plan to prepare successful mitigation projects.* https://www.hsdl.org/?abstract&did=28466 (accessed 15 January 2021)

Fekete, A. (2020). Critical infrastructure cascading effects. Disaster resilience assessment for floods affecting city of Cologne and Rhein-Erft-Kreis. *Journal of Flood Risk Management*, *13*(2), e312600. https://doi.org/10.1111/jfr3.12600

Fernhaber, S.A., Wada, T., Napier, P., & Suttles, S. (2019). Engaging diverse community stakeholders to co-create solutions in food deserts: A design-thinking approach. *Journal of Public Affairs*, *19*(3), e1874. https://doi.org/10.1002/pa.1874

Foster, K. R. (2010). Telehealth in sub-Saharan Africa: lessons for humanitarian engineering. *IEEE Technology and Society Magazine*, *29*(1), 42-49. https://doi.org/10.1109/MTS.2010.935977

Frame, D., Tembo, K., Dolan, M. J., Strachan, S. M., & Ault, G. W. (2011). A community based approach for sustainable off-grid PV systems in developing countries. *2011 IEEE Power and Energy Society General Meeting* (1-7). https://doi.org/10.1109/PES.2011.6039593

Frank, M. (2002). What is "engineering systems thinking"?. *Kybernetes*. 31(9/10), 1350-1360. https://doi.org/10.1108/03684920210443554

Garniati, L., Owen, A., Kruijsen, J., Ishadamy, Y., & Wibisono, I. (2014). Interface between appropriate technology and sustainable energy policy in vulnerable societies. *Sustainable Cities and Society*, *12*, 9-15. https://doi.org/10.1016/j.scs.2013.10.003

Gautam, D. K., & Phaiju, A. G. (2013). Community based approach to flood early warning in West Rapti River Basin of Nepal. *Journal of Integrated Disaster Risk Management*, *3*(1), 155-169. http://dx.doi.org/10.5595/idrim.2013.0060

Georgeou, N., & Hawksley, C. (Eds.) (2020). Enhancing research impact in international development: a practical guide for practitioners and researchers. *Deakin, A.C.T.: Research for Development Impact Network*. https://rdinetwork.org.au/resources/enhancing-research-impact-in-international-development-a-practical-guide-for-practitioners-and-researchers/

Gielen, D. (2012). Renewable energy technologies: cost analysis series. *International Renewable Energy Agency*. *1*(3/5), 1-44. https://www.globalccsinstitute.com/archive/hub/publications/138178/hydropower.pdf

González, A. M., Sandoval, H., Acosta, P., & Henao, F. (2016). On the acceptance and sustainability of renewable energy projects - a systems thinking perspective. *Sustainability*, *8*(11), 1171. https://doi.org/10.3390/su8111171

Gosink, J., Lucena, J., & Moskal, B. (2003). *Humanitarian engineering at the Colorado School of Mines: an example of multidisciplinary engineering*. Paper presented at 2003 Annual Conference, Nashville, Tennessee. https://peer.asee.org/11871

Grisham, T. (2009). The Delphi technique: a method for testing complex and multifaceted topics. *International Journal of Managing Projects in Business*, *2*(1), 112-130. https://doi.org/10.1108/17538370910930545

Gupta, A. K., & Nair, S. S. (2010). Flood risk and context of land-uses: Chennai city case. *Journal of Geography and Regional Planning*, *3*(12), 365-372. https://doi.org/10.5897/JGRP.9000057

Gurung, A., Bryceson, I., Joo, J. H., & Oh, S. E. (2011). Socio-economic impacts of a micro-hydropower plant on rural livelihoods. *Scientific Research and Essays*, *6*(19), 3964-3972. https://doi.org/10.5897/SRE10.766

Hall, B.L. (1981). Participatory research, popular knowledge and power: A personal reflection. *Convergence*, *14*(3), 6.

Haidar, A. M., Senan, M. F., Noman, A., & Radman, T. (2012). Utilization of pico hydro generation in domestic and commercial loads. *Renewable and Sustainable energy reviews*, *16*(1), 518-524. https://doi.org/10.1016/j.rser.2011.08.017

Hallegatte, S. (2012). A cost effective solution to reduce disaster losses in developing countries: hydro-meteorological services, early warning, and evacuation. *World Bank Policy Research Working Paper No. 6058*. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2051341

Hallegatte, S., Vogt-Schilb, A., Rozenberg, J., Bangalore, M., & Beaudet, C. (2020). From poverty to disaster and back: a review of the literature. *Economics of Disasters and Climate Change*, *4*(1), 223-247. https://doi.org/10.1007/s41885-020-00060-5

Hashemipour, M., Stuban, S. M., & Dever, J. R. (2017). A community-based disaster coordination framework for effective disaster preparedness and response. *Australian Journal of Emergency Management, The*, *32*(2), 41-46. ISSN:1324-1540

Hill, S., & Miles, E. (2012). What do students understand by the term 'humanitarian engineering'. *Innovation, Practice and Research in Engineering Education*, 1-11

Hindmarsh, R., & Matthews, C. (2008). Deliberative speak at the turbine face: community engagement, wind farms, and renewable energy transitions, in Australia. *Journal of Environmental Policy & Planning*, *10*(3), 217-232. https://doi.org/10.1080/15239080802242662

Hinton, A., Ortbal, K., & Mehta, K. (2014). The praxis of grassroots diplomacy for social entrepreneurship. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, *9*(2), 116-134. https://doi.org/10.24908/ijsle.v9i2.5454

Hitzeroth, M., & Megerle, A. (2013). Renewable energy projects: acceptance risks and their management. *Renewable and Sustainable Energy Reviews*, *27*, 576-584. https://doi.org/10.1016/j.rser.2013.07.022

Hong, G. W., & Abe, N. (2012). Sustainability assessment of renewable energy projects for off-grid rural electrification: The Pangan-an Island case in the Philippines. *Renewable and Sustainable Energy Reviews*, *16*(1), 54-64. https://doi.org/10.1016/j.rser.2011.07.136

Honma, T. (2017). Advancing alternative pathways to science: community partnership, do-it-yourself (DIY)/do-it-together (DIT) collaboration, and STEM learning "from below". *Transformations*, *27*(1), 41-50. https://doi.org/10.5325/trajincschped.27.1.0041

Hook, J. N., Davis, D. E., Owen, J., Worthington Jr, E. L., & Utsey, S. O. (2013). Cultural humility: measuring openness to culturally diverse clients. *Journal of Counseling Psychology*, *60*(3), 353. https://psycnet.apa.org/doi/10.1037/a0032595

Howells, M., Rogner, H. H., Mentis, D., & Broad, O. (2017). Energy access and electricity planning. *The World Bank*. http://documents.worldbank.org/curated/en/628541494925426928/Energy-access-and-electricity-planning

Huijts, N. M., Molin, E. J., & Steg, L. (2012). Psychological factors influencing sustainable energy technology acceptance: a review-based comprehensive framework. *Renewable and Sustainable Energy Reviews*, *16*(1), 525-531. https://doi.org/10.1016/j.rser.2011.08.018

Ikejemba, E. C., Mpuan, P. B., Schuur, P. C., & Van Hillegersberg, J. (2017). The empirical reality & sustainable management failures of renewable energy projects in Sub-Saharan Africa (part 1 of 2). *Renewable Energy*, *102*, 234-240. https://doi.org/10.1016/j.renene.2016.10.037

Ilskog, E. (2008). Indicators for assessment of rural electrification - an approach for the comparison of apples and pears. *Energy Policy*, *36*(7), 2665-2673. https://doi.org/10.1016/j.enpol.2008.03.023

Ilskog, E., & Kjellström, B. (2008). And then they lived sustainably ever after? - assessment of rural electrification cases by means of indicators. *Energy Policy*, *36*(7), 2674-2684. https://doi.org/10.1016/j.enpol.2008.03.022

International Energy Agency. (n.d.). *SDG7: Data and Projections*. https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity%0Ahttps://www.iea.org/reports/sdg7-data-and-projections (accessed 01 May 2021)

International Federation of Red Cross and Red Crescent Societies. (2007). *The Johns Hopkins and Red Cross Red Crescent Public Health Guide in Emergencies*. https://reliefweb.int/sites/reliefweb.int/files/resources/Forward.pdf

International Renewable Energy Agency. (2019). *Off-grid renewable energy solutions to expand electricity access: An opportunity not to be missed*, ISBN 978-92-9260-101-0. https://www.irena.org/publications/2019/Jan/Off-grid-renewable-energy-solutions-to-expand-electricity-to-access-An-opportunity-not-to-be-missed

Intrieri, E., Gigli, G., Mugnai, F., Fanti, R., & Casagli, N. (2012). Design and implementation of a landslide early warning system. *Engineering Geology, 147*, 124-136. https://doi.org/10.1016/j.enggeo.2012.07.017

Ioannidou, C., & O'Hanley, J. R. (2018). Eco-friendly location of small hydropower. *European Journal of Operational Research, 264*(3), 907-918. https://doi.org/10.1016/j.ejor.2016.06.067

Jacobson, D., & Mustafa, N. (2019). Social identity map: A reflexivity tool for practicing explicit positionality in critical qualitative research. *International Journal of Qualitative Methods, 18*, 1609406919870075. https://doi.org/10.1177/1609406919870075

Jha, A. K., Bloch, R., & Lamond, J. (2012). *Cities and flooding: a guide to integrated urban flood risk management for the 21st century*. World Bank Publications. https://doi.org/10.1596/978-0-8213-8866-2

Jessel, S., Sawyer, S., & Hernández, D. (2019). Energy, poverty, and health in climate change: a comprehensive review of an emerging literature. *Frontiers in Public Health*, 357. https://doi.org/10.3389/fpubh.2019.00357

Jobert, A., Laborgne, P., & Mimler, S. (2007). Local acceptance of wind energy: factors of success identified in French and German case studies. *Energy Policy*, *35*(5), 2751-2760. https://doi.org/10.1016/j.enpol.2006.12.005

Johnson, K., Hadjerioua, B., & Martinez, R. U. (2015). Small hydropower in the United States. *ORNL/TM-2015/326, Oak Ridge, TN: Oak Ridge National Laboratory*. https://info.ornl.gov/sites/publications/files/Pub56556.pdf

Kamperman Sanders, A., Falcão, T., Haider, A., Jambeck, J., LaPointe, C., Vickers, C., & Ziebarth, N. (2018). *World Economic and Social Survey 2018: Frontier Technologies for Sustainable Development*. ISBN: 978-92-1047-224-1; 978-92-1109-179-3

Keeney, G. B. (2004). Disaster preparedness: what do we do now?. *Journal of Midwifery & Women's Health*, *49*(4), 2-6. https://doi.org/10.1016/j.jmwh.2004.05.003

Kelly-Richards, S., Silber-Coats, N., Crootof, A., Tecklin, D., & Bauer, C. (2017). Governing the transition to renewable energy: a review of impacts and policy issues in the small hydropower boom. *Energy Policy*, *101*, 251-264. https://doi.org/10.1016/j.enpol.2016.11.035

Kenfack, J., Bossou, O. V., Voufo, J., & Djom, S. (2014). Addressing the current remote area electrification problems with solar and microhydro systems in Central Africa. *Renewable Energy*, *67*, 10-19. https://doi.org/10.1016/j.renene.2013.11.044

Khan, M.T.I., Anwar, S., & Batool, Z. (2022). The role of infrastructure, socio-economic development, and food security to mitigate the loss of natural disasters. *Environmental Science and Pollution Research*, *29*(35), 52412-52437. https://doi.org/10.1007/s11356-022-19293-w

Kim, N. (2012). How much more exposed are the poor to natural disasters? Global and regional measurement. *Disasters*, *36*(2), 195-211. https://doi.org/10.1111/j.1467-7717.2011.01258.x

Kirubi, C., Jacobson, A., Kammen, D .M., & Mills, A. (2009). Community-based electric micro-grids can contribute to rural development: evidence from Kenya. *World Development*, *37*(7), 1208-1221. https://doi.org/10.1016/j.worlddev.2008.11.005

Kooijman-van Dijk, A. L. (2012). The role of energy in creating opportunities for income generation in the Indian Himalayas. *Energy Policy*, *41*, 529-536. https://doi.org/10.1016/j.enpol.2011.11.013

Kotzee, I., & Reyers, B. (2016). Piloting a social-ecological index for measuring flood resilience: a composite index approach. *Ecological Indicators*, *60*, 45-53. https://doi.org/10.1016/j.ecolind.2015.06.018

Kumar, V., Cheng, S. Y. C., & Singh, A. K. (2016). Impact of flood on rural population and strategies for mitigation: a case study of Darbhanga district, Bihar state, India. *Contemporary Rural Social Work Journal*, *8*(1), 5. https://digitalcommons.murraystate.edu/crsw/vol8/iss1/5

Lebeau, K., Van Mierlo, J., Lebeau, P., Mairesse, O., & Macharis, C. (2012). A choice-based conjoint analysis on the market potential of PHEVs and BEVs in Flanders. *World Electric Vehicle Journal*, *5*(4), 871-880. https://doi.org/10.3390/wevj5040871

Lebel, P., Lebel, L., Singphonphrai, D., Duangsuwan, C., & Zhou, Y. (2019). Making space for women: civil society organizations, gender and hydropower development in the Mekong region. *International Journal of Water Resources Development*, *35*(2), 305-325. https://doi.org/10.1080/07900627.2018.1425133

Lee, H. R., Šabanović, S., Chang, W. L., Nagata, S., Piatt, J., Bennett, C., & Hakken, D. (2017). Steps toward participatory design of social robots: mutual learning with older adults with depression. *Proceedings of the 2017 ACM/IEEE international conference on human-robot interaction* (244-253). https://doi.org/10.1145/2909824.3020237

Lee, J. (2015). Q&A on disaster risk reduction: if not risk-informed, not sustainable development. *United Nations Foundation*. https://unfoundation.org/blog/post/qa-if-it-is-not-risk-informed-it-is-not-sustainable-development/ (accessed 10 April 2022)

Li, X. (2005). Diversification and localization of energy systems for sustainable development and energy security. *Energy Policy*, *33*(17), 2237-2243. https://doi.org/10.1016/j.enpol.2004.05.002

Ma, M. Small hydroelectric dams increase globally with little research, regulations. (2018). *University of Washington News*. https://www.washington.edu/news/2018/01/22/small-hydroelectric-dams-increase-globally-with-little-research-regulations/ (accessed 20 February 2023)

Mackenzie, J., Tan, P.L., Hoverman, S., & Baldwin, C. (2012). The value and limitations of participatory action research methodology. *Journal of Hydrology*, *474*, 11-21. https://doi.org/10.1016/j.jhydrol.2012.09.008

Maguire, B., & Hagan, P. (2007). Disasters and communities: understanding social resilience. *Australian Journal of Emergency Management, The*, *22*(2), 16-20. ISSN:1324-1540

Mangham, L. J., Hanson, K., & McPake, B. (2009). How to do (or not to do)… Designing a discrete choice experiment for application in a low-income country. *Health Policy and Planning*, *24*(2), 151-158. https://doi.org/10.1093/heapol/czn047

Mansuy, J., Verlinde, S., & Macharis, C. (2020). Understanding preferences for EEE collection services: a choice-based conjoint analysis. *Resources, Conservation and Recycling*, *161*, 104899. https://doi.org/10.1016/j.resconrec.2020.104899

May, N. (2022). Floods and livestock losses leave NSW and Queensland farmers reeling from third disaster in three years. *The Guardian*. https://www.theguardian.com/australia-news/2022/mar/02/floods-and-livestock-losses-leave-nsw-and-queensland-farmers-reeling-from-third-disaster-in-three-years (accessed 01 May 2022)

Mazzurco, A., & Jesiek, B. K. (2017). Five guiding principles to enhance community participation in humanitarian engineering projects. *Journal of Humanitarian Engineering*, *5*(2). https://doi.org/10.36479/jhe.v5i2.80

Meadows, D. H. (2008). *Thinking in systems: a primer*. Chelsea Green Publishing. ISBN: 978-1-84407-726-7

Mercer, J., Kelman, I., Taranis, L., & Suchet-Pearson, S. (2010). Framework for integrating indigenous and scientific knowledge for disaster risk reduction. *Disasters*, *34*(1), 214-239. https://doi.org/10.1111/j.1467-7717.2009.01126.x

Meyer, V., Kuhlicke, C., Luther, J., Fuchs, S., Priest, S., Dorner, W., Serrhini, K., Pardoe, J., McCarthy, S., Seidel, J., Palka, G., Unnerstall, H., Viavattene, C., & Scheuer, S. (2012). Recommendations for the user-specific enhancement of flood maps. *Natural Hazards and Earth System Sciences*, *12*(5), 1701-1716. https://doi.org/10.5194/nhess-12-1701-2012

Mohammed, Y. S., Mustafa, M. W., & Bashir, N. (2013). Status of renewable energy consumption and developmental challenges in Sub-Sahara Africa. *Renewable and Sustainable Energy Reviews*, *27*, 453-463. https://doi.org/10.1016/j.rser.2013.06.044

Monyei, C. G., Adewumi, A. O., & Jenkins, K. E. H. (2018). Energy (in) justice in off-grid rural electrification policy: South Africa in focus. *Energy Research & Social Science*, *44*, 152-171. https://doi.org/10.1016/j.erss.2018.05.002

Morrow, B. H. (1999). Identifying and mapping community vulnerability. *Disasters*, *23*(1), 1-18. https://doi.org/10.1111/1467-7717.00102

Mosel, I., & Levine, S. (2014). Remaking the case for linking relief, rehabilitation and development: how LRRD can become a practically useful concept for assistance in difficult places. *London: Humanitarian Policy Group, the Overseas Development Institute.* https://cdn.odi.org/media/documents/8882.pdf

Mullen, P. M. (2003). Delphi: myths and reality. *Journal of Health Organization and Management. 17*(1), 37-32. https://doi.org/10.1108/14777260310469319

Murray, V., & Ebi, K. L. (2012). IPCC special report on managing the risks of extreme events and disasters to advance climate change adaptation (SREX). *Journal of Epidemiology and Community Health*, *66*(9), 759-760. http://dx.doi.org/10.1136/jech-2012-201045

Mutezo, G., & Mulopo, J. (2021). A review of Africa's transition from fossil fuels to renewable energy using circular economy principles. *Renewable and Sustainable Energy Reviews*, *137*, 110609. https://doi.org/10.1016/j.rser.2020.110609

Nancy Carter, R. N., Bryant-Lukosius, D., & Alba DiCenso, R. N. (2014). The use of triangulation in qualitative research. *Oncology Nursing Forum*, *41*(5), 545. https://www.proquest.com/openview/1904d067b227719a39567bba50c56328/1?pq-origsite=gscholar&cbl=37213

Naylor, A., Ford, J., Pearce, T., & Van Alstine, J. (2020). Conceptualizing climate vulnerability in complex adaptive systems. *One Earth*, *2*(5), 444-454. https://doi.org/10.1016/j.oneear.2020.04.011

Nerini, F. F., Howells, M., Bazilian, M., & Gomez, M. F. (2014). Rural electrification options in the Brazilian Amazon: a multi-criteria analysis. *Energy for Sustainable Development*, *20*, 36-48. https://doi.org/10.1016/j.esd.2014.02.005

News Agencies. (2020). Afghanistan flooding: dozens dead, hundreds of homes destroyed. *Al Jazeera*. https://www.aljazeera.com/news/2020/8/26/afghanistan-flooding-dozens-dead-hundreds-of-homes-destroyed (accessed 10 March 2022)

Nfah, E. M., & Ngundam, J. M. (2012). Identification of stakeholders for sustainable renewable energy applications in Cameroon. *Renewable and Sustainable Energy Reviews*, *16*(7), 4661-4666. https://doi.org/10.1016/j.rser.2012.05.019

Ngowi, J. M., Bångens, L., & Ahlgren, E. O. (2019). Benefits and challenges to productive use of off-grid rural electrification: the case of mini-hydropower in Bulongwa-Tanzania. *Energy for Sustainable Development*, *53*, 97-103. https://doi.org/10.1016/j.esd.2019.10.001

Njogu, H. W. (2021). Effects of floods on infrastructure users in Kenya. *Journal of Flood Risk Management*, *14*(4), e12746. https://doi.org/10.1111/jfr3.12746

Njoh, A. J. (2016). *Tradition, culture and development in Africa: Historical lessons for modern development planning*. Routledge. https://doi.org/10.4324/9781315235868

Njoh, A. J., Etta, S., Ngyah-Etchutambe, I. B., Enomah, L. E., Tabrey, H. T., & Essia, U. (2019). Opportunities and challenges to rural renewable energy projects in Africa: lessons from the Esaghem village, Cameroon solar electrification project. *Renewable Energy*, *131*, 1013-1021. https://doi.org/10.1016/j.renene.2018.07.092

Nilsson, L., Madon, T., & Sastry, S. S. (2014). Toward a new field of development engineering: linking technology design to the demands of the poor. *Procedia Engineering*, *78,* 3-9. https://doi.org/10.1016/j.proeng.2014.07.032

Norén, V., Hedelin, B., Nyberg, L., & Bishop, K. (2016). Flood risk assessment–practices in flood prone Swedish municipalities. *International Journal of Disaster Risk Reduction*, *18*, 206-217. https://doi.org/10.1016/j.ijdrr.2016.07.003

Novel, J. P., Dimadi, A., Zervopoulou, A., & Bakalowicz, M. (2007). The Aggitis karst system, Eastern Macedonia, Greece: Hydrologic functioning and development of the karst structure. *Journal of Hydrology*, *334*(3-4), 477-492. https://doi.org/10.1016/j.jhydrol.2006.10.029

Nyiwul, L. (2017). Economic performance, environmental concerns, and renewable energy consumption: drivers of renewable energy development in Sub-Sahara Africa. *Clean Technologies and Environmental Policy*, *19*(2), 437-450. https://doi.org/10.1007/s10098-016-1229-5

Oltermann, P. (2021). German flood alert system criticised for 'monumental failure'. *The Guardian.* https://www.theguardian.com/world/2021/jul/19/german-villages-could-be-left-with-no-drinking-water-after-floods (accessed 10 March 2022)

Omeje, K. (2006). The rentier state: oil-related legislation and conflict in the Niger Delta, Nigeria: analysis. *Conflict, Security & Development*, *6*(2), 211-230. https://doi.org/10.1080/14678800600739259

Ostadtaghizadeh, A., Ardalan, A., Paton, D., Jabbari, H., & Khankeh, H. R. (2015). Community disaster resilience: a systematic review on assessment models and tools. *PLoS Currents*, *7*. https://dx.doi.org/10.1371%2Fcurrents.dis.f224ef8efbdfcf1d508dd0de4d8210ed

Owens, B. P., & Hekman, D. R. (2016). How does leader humility influence team performance? Exploring the mechanisms of contagion and collective promotion focus. *Academy of Management Journal*, *59*(3), 1088-1111. https://doi.org/10.5465/amj.2013.0660

Pearson, L., & Pelling, M. (2015). The UN Sendai framework for disaster risk reduction 2015–2030: negotiation process and prospects for science and practice. *Journal of Extreme Events*, *2*(1): 1571001. https://doi.org/10.1142/S2345737615710013

Peek, L. (2008). Children and disasters: understanding vulnerability, developing capacities, and promoting resilience - An introduction. *Children Youth and Environments*, *18*(1), 1-29. https://www.jstor.org/stable/10.7721/chilyoutenvi.18.1.0001

Pennos, C., Lauritzen, S. E., Pechlivanidou, S., & Sotiriadis, Y. (2016). Geomorphic constrains on the evolution of the Aggitis River Basin Northern Greece (a preliminary report). *Bulletin of the Geological Society of Greece*, *50*(1), 365-373. https://doi.org/10.12681/bgsg.11737

Phillips, C. (2017). Combining energy efficiency and disaster mitigation efforts in residential properties. *Office of Policy Development and Research*. https://www.huduser.gov/portal/periodicals/em/spring17/highlight2.html (accessed 12 December 2021)

Powell, J. H., Hammond, M., Chen, A., & Mustafee, N. (2018). Human agency in disaster planning: a systems approach. *Risk Analysis*, *38*(7), 1422-1443. https://doi.org/10.1111/risa.12958

Quansah, D. A., Adaramola, M. S., & Mensah, L. D. (2016). Solar photovoltaics in sub-Saharan Africa–addressing barriers, unlocking potential. *Energy Procedia*, *106*, 97-110. https://doi.org/10.1016/j.egypro.2016.12.108

Rabetanetiarimanana, J. C. I., Radanielina, M. H., & Rakotondramiarana, H. T. (2018). PV-hybrid off-grid and mini-grid systems for rural electrification in Sub-Saharan Africa. *Smart Grid and Renewable Energy*, *9*(10), 171. http://www.scirp.org/journal/PaperInformation.aspx?PaperID=87888&#abstract

Rehman, J., Sohaib, O., Asif, M., & Pradhan, B. (2019). Applying systems thinking to flood disaster management for a sustainable development. *International Journal of Disaster Risk Reduction*, *36*, 101101. https://doi.org/10.1016/j.ijdrr.2019.101101

Richardson, J., Godfrey, B., & Walklate, S. (2021). Rapid, remote and responsive research during COVID-19. *Methodological Innovations*, *14*(1), 20597991211008581. https://doi.org/10.1177%2F20597991211008581

Ross, M. L. (2015). What have we learned about the resource curse?. *Annual Review of Political Science*, *18*, 239-259. https://doi.org/10.1146/annurev-polisci-052213-040359

Samarakoon, S. (2020). The troubled path to ending darkness: energy injustice encounters in Malawi's off-grid solar market. *Energy Research & Social Science*, *69*, 101712. https://doi.org/10.1016/j.erss.2020.101712

Sachdev, H. S., Akella, A. K., & Kumar, N. (2015). Analysis and evaluation of small hydropower plants: a bibliographical survey. *Renewable and Sustainable Energy Reviews*, *51*, 1013-1022. https://doi.org/10.1016/j.rser.2015.06.065

Sanders, E. (2006). Scaffolds for building everyday creativity. In J. Frascara (Ed.), *Design for effective communications: Creating contexts for clarity and meaning* (pp. 2–17). New York, NY: Allworth Press.

Sanders, E.B.N., & Stappers, P.J. (2008). Co-creation and the new landscapes of design. *Co-design*, *4*(1), 5-18. https://doi.org/10.1080/15710880701875068

Sangroula, D. P. (2009). Hydropower development and its sustainability with respect to sedimentation in Nepal. *Journal of the Institute of Engineering*, *7*(1), 56-64. https://doi.org/10.3126/jie.v7i1.2063

Sawada, Y., & Takasaki, Y. (2017). Natural disaster, poverty, and development: an introduction. *World Development*, *94*, 2-15. https://doi.org/10.1016/j.worlddev.2016.12.035

Schismenos, S., Emmanouloudis, D., Stevens, G. J., & Eslamian, S. (2022a). Torrential and flash flood warning: general overview and uses of localized hydropower. In S. Eslamian and F.A. Eslamian (Eds), *Flood Handbook: Impacts and Management*. Routledge. https://doi.org/10.1201/9780429463327

Schismenos, S., Stevens, G. J., Emmanouloudis, D., Georgeou, N., Shrestha, S., & Chalaris, M. (2020). Humanitarian engineering and vulnerable communities: hydropower applications in localised flood response and sustainable development. *International Journal of Sustainable Energy*, *39*(10), 941-950. https://doi.org/10.1080/14786451.2020.1779274

Schismenos, S., Stevens, G. J., Emmanouloudis, D., Georgeou, N., Shrestha, S., & Chalaris, M. (2021a). Humanitarian engineering at the sustainability-development nexus: mapping vulnerability and capability factors for communities at risk of water-based disasters. *Sustainability Science*, *16*(4), 1185-1199. https://doi.org/10.1007/s11625-020-00890-y

Schismenos, S., Stevens, G. J., Emmanouloudis, D., Georgeou, N., Shrestha, S., & Katopodes, N. D. (2021b). Using off-grid hydropower for community-led flood resilience: an integrated systems approach. *International Journal of Sustainable Energy*, 1-15. https://doi.org/10.1080/14786451.2021.1961773

Schismenos, S., Stevens, G., Emmanouloudis, D., Georgeou, N., Shrestha, S., Katopodes, N., & Wali, N. (2021c). Humanitarian engineering for renewable energy and flood early warning in remote communities: a scoping review of enabling factors and sustainability. *Journal of Sustainable Development of Energy, Water and Environment Systems*, *10*(3), 1090406. https://doi.org/10.13044/j.sdewes.d9.0406

Schismenos, S., Stevens, G. J., Georgeou, N., Emmanouloudis, D., Shrestha, S., & Thapa, B. S. (2021d). Humanitarian and developmental research engagement during COVID-19. *Social Science Protocols*, *4*, 1-14. https://doi.org/10.7565/ssp.v4.6487

Schismenos, S., Stevens, G. J., Georgeou, N., Emmanouloudis, D., Shrestha, S., Thapa, B. S., & Gurung, S. (2022b). Flood and renewable energy humanitarian engineering research: lessons from Aggitis, Greece and Dhuskun, Nepal. *Geosciences*, *12*(2), 71. https://doi.org/10.3390/geosciences12020071

Schöne, T., Pandoe, W., Mudita, I., Roemer, S., Illigner, J., Zech, C., & Galas, R. (2011). GPS water level measurements for Indonesia's tsunami early warning system. *Natural Hazards and Earth System Sciences (NHESS)*, *11*(3): 741-749. https://doi.org/10.5194/nhess-11-741-2011

Sharma, R. H., & Awal, R. (2013). Hydropower development in Nepal. *Renewable and Sustainable Energy Reviews*, *21*, 684-693. https://doi.org/10.1016/j.rser.2013.01.013

Sheroubi, A., & Potvin, G. (2018). Humanitarian engineering: a new interdisciplinary course on the application of engineering skills to local and global humanitarian challenges. *Proceedings of the Canadian Engineering Education Association (CEEA)*. https://doi.org/10.24908/pceea.v0i0.12963

Shoaib, A., & Ariaratnam, S. (2016). A study of socioeconomic impacts of renewable energy projects in Afghanistan. *Procedia Engineering*, *145*, 995-1003. https://doi.org/10.1016/j.proeng.2016.04.129

Shrestha Pradhan, N. (2020). What is CBFEWS?. *International Centre for Integrated Mountain Development*. https://www.icimod.org/mountain/cbfews

Sianipar, C. P., Yudoko, G., & Adhiutama, A. (2014). Technological solution for vulnerable communities: reverse engineering below the radar. *Advanced Science Letters*, *20*(10-11), 2282-2286. https://doi.org/10.1166/asl.2014.5726

Sianipar, C. P. M., Yudoko, G., Adhiutama, A., & Dowaki, K. (2013). Community empowerment through appropriate technology: sustaining the sustainable development. *Procedia Environmental Sciences*, *17*, 1007-1016. https://doi.org/10.1016/j.proenv.2013.02.120

Simpson, N. P., Rabenold, C. J., Sowman, M., & Shearing, C. D. (2021). Adoption rationales and effects of off-grid renewable energy access for African youth: a case study from Tanzania. *Renewable and Sustainable Energy Reviews*, *141*, 110793. https://doi.org/10.1016/j.rser.2021.110793

Smith, A., Bates, P. D., Wing, O., Sampson, C., Quinn, N., & Neal, J. (2019). New estimates of flood exposure in developing countries using high-resolution population data. *Nature Communications*, *10*(1), 1-7. https://doi.org/10.1038/s41467-019-09282-y

Sovacool, B. K., D'Agostino, A. L., & Bambawale, M. J. (2011). The socio-technical barriers to solar home systems (SHS) in Papua New Guinea: "Choosing pigs, prostitutes, and poker chips over panels". *Energy Policy*, *39*(3), 1532-1542. https://doi.org/10.1016/j.enpol.2010.12.027

Springett, J., Atkey, K., Kongats, K., Zulla, R., & Wilkins, E. (2016, May). Conceptualizing quality in participatory health research: A phenomenographic inquiry. In *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research*, 17(2), 27). http://nbn-resolving.de/urn:nbn:de:0114-fqs1602274

Stewart, F., Holdstock, D., & Jarquin, A. (2002). Root causes of violent conflict in developing countries commentary: conflict—from causes to prevention?. *BMJ*, *324*(7333), 342-345. https://doi.org/10.1136/bmj.324.7333.342

Stepien, M., Keller, I., Takki, M., & Caldeira, S. (2022). European public health best practice portal-process and criteria for best practice assessment. *Archives of Public Health*, *80*(1), 1-8. https://doi.org/10.1186/s13690-022-00892-5

Stigka, E. K., Paravantis, J. A., & Mihalakakou, G. K. (2014). Social acceptance of renewable energy sources: a review of contingent valuation applications. *Renewable and Sustainable Energy Reviews*, *32*, 100-106. https://doi.org/10.1016/j.rser.2013.12.026

Strömberg, D. (2007). Natural disasters, economic development, and humanitarian aid. *Journal of Economic Perspectives*, *21*(3), 199-222. https://doi.org/10.1257/jep.21.3.199

Sufri, S., Dwirahmadi, F., Phung, D., & Rutherford, S. (2020). A systematic review of community engagement (CE) in disaster early warning systems (EWSs). *Progress in Disaster Science*, *5*, 100058. https://doi.org/10.1016/j.pdisas.2019.100058

Tanujaya, R. R., Lee, C. Y., Woo, J., Huh, S. Y., & Lee, M. K. (2020). Quantifying public preferences for community-based renewable energy projects in South Korea. *Energies*, *13*(9), 2384. https://doi.org/10.3390/en13092384

Tapp, H., White, L., Steuerwald, M., & Dulin, M. (2013). Use of community-based participatory research in primary care to improve healthcare outcomes and disparities in care. *Journal of Comparative Effectiveness Research*, *2*(4), 405-419. https://doi.org/10.2217/cer.13.45

Terrapon-Pfaff, J., Dienst, C., König, J., & Ortiz, W. (2014). How effective are small-scale energy interventions in developing countries? Results from a post-evaluation on project-level. *Applied Energy*, *135*, 809-814. https://doi.org/10.1016/j.apenergy.2014.05.032

Thomas, E. (2019). Toward a new field of global engineering. *Sustainability*, *11*(14), 3789. https://doi.org/10.3390/su11143789

Troncoso, K., Castillo, A., Masera, O., & Merino, L. (2007). Social perceptions about a technological innovation for fuelwood cooking: case study in rural Mexico. *Energy Policy*, *35*(5), 2799-2810. https://doi.org/10.1016/j.enpol.2006.12.011

Twigg, J. (2004). *Disaster risk reduction: mitigation and preparedness in development and emergency programming*. Overseas Development Institute (ODI). http://lib.riskreductionafrica.org/bitstream/handle/123456789/1453/good%20practice%20review%20disaster%20risk%20reduction%20number%209%20march%20200.pdf?sequence=1

Twigg, J. (2014). Attitude before method: disability in vulnerability and capacity assessment. *Disasters*, *38*(3), 465-482. https://doi.org/10.1111/disa.12066

United Nations. (2016). *Transforming our world: The 2030 agenda for sustainable development*. https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf (accessed 15 January 2021)

United Nations Department of Economic and Social Affairs. (2022). 2022 *Energy Statistics Pocketbook*. https://unstats.un.org/unsd/energystats/pubs/pocketbook/

United Nations Framework Convention on Climate Change. (2020). *Community-based flood early-warning system - India*. https://unfccc.int/climate-action/momentum-for-change/information-and-communications-technology-solutions/community-based-flood-early-warning-system-india

United Nations International Strategy for Disaster Reduction. (2009). 2*009 UNISDR Terminology on Disaster Risk Reduction*. https://www.unisdr.org/files/7817_UNISDRTerminologyEnglish.pdf

United Nations Office for Disaster Risk Reduction. (2005). Hyogo Framework for action 2005–2015: building the resilience of nations and communities to disasters. *World Conference on Disaster Reduction, Kobe, Hyogo, Japan*

Vaidya, R. (2012). Water and hydropower in the green economy and sustainable development of the Hindu Kush-Himalayan region. *Hydro Nepal: Journal of Water, Energy and Environment*, *10*, 11-19. https://doi.org/10.3126/hn.v10i0.7097

Van Dijk, J. A. (1990). Delphi questionnaires versus individual and group interviews: a comparison case. *Technological Forecasting and Social Change*, *37*(3), 293-304. https://doi.org/10.1016/0040-1625(90)90029-U

van Stam, G. (2013). Inclusive community engagement in social innovation, case Africa. In *Fifth International Conference on eInfrastructure and eServices for Developing Countries (Africomm 2013), Blantyre, Malawi*

Vollman, A.R., & Jackson, S. F. (2020). *Canadian community as partner: Theory & multidisciplinary practice*. Lippincott Williams & Wilkins. ISBN: 1975141377

Wahlstrom, M., & Guha-Sapir, D. (2015). The human cost of weather related disasters 1995–2015. *United Nations International Strategy for Disaster Reduction (UNISDR).* https://www.unisdr.org/files/46796_cop21weatherdisastersreport2015.pdf

Waidyanatha, N. (2010). Towards a typology of integrated functional early warning systems. *International Journal of Critical Infrastructures*. *6*(1), 31. https://www.inderscienceonline.com/doi/abs/10.1504/IJCIS.2010.029575

Williamson, S. J., Lubitz, W. D., Williams, A. A., Booker, J. D., & Butchers, J. P. (2019). Challenges facing the implementation of pico-hydropower technologies. *Journal of Sustainability Research*, *4*(3). https://doi.org/10.20900/jsr20200003

Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (2014). *At risk: natural hazards, people's vulnerability and disasters*. Routledge. https://doi.org/10.4324/9780203714775

World Bank. (2022). *World Bank Country and Lending Groups*. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups

World Energy Council. (2016). *World Energy Resources 2016.* https://www.worldenergy.org/assets/images/imported/2016/10/World-Energy-Resources-Full-report-2016.10.03.pdf

Younger, J. S., Booth, D. J., Parry, D. E., & Kurniawan, K. (2018). Sustainable humanitarian engineering in practice–the East Bali poverty project. *Proceedings of the Institution of Civil Engineers-Municipal Engineer, 171*(2), 67-77. https://doi.org/10.1680/jmuen.16.00034

Zhang, X., & Kumar, A. (2011). Evaluating renewable energy-based rural electrification program in western China: emerging problems and possible scenarios. *Renewable and Sustainable Energy Reviews*, *15*(1), 773-779. https://doi.org/10.1016/j.rser.2010.08.023

Zoellner, J., Schweizer-Ries, P., & Wemheuer, C. (2008). Public acceptance of renewable energies: results from case studies in Germany. *Energy Policy*, *36*(11), 4136-4141. https://doi.org/10.1016/j.enpol.2008.06.026

COMPLETE LIST OF PUBLICATIONS DURING CANDIDATURE

Journal Articles

Georgeou, N., Schismenos, S., Wali, N., Mackay, K., & Moraitakis, E. (2022). COVID-19 and 'ageing well' for the older migrants and refugees in rural Australia: the case of Bhutanese elders in Albury, New South Wales. 2022. *Quality in Ageing and Older Adults.* https://doi.org/10.1108/QAOA-09-2021-0068

Schismenos, S., Stevens, G. J., Georgeou, N., Emmanouloudis, D., Shrestha, S., Thapa, B. S., & Gurung, S. (2022). Flood and renewable energy humanitarian engineering research: lessons from Aggitis, Greece and Dhuskun, Nepal. *Geosciences*, *12*(2), 71. https://doi.org/10.3390/geosciences12020071

Schismenos, S., Emmanouloudis, D., Stevens, G. J., Katopodes, N. D., & Melesse, A. M. (2022). Soil governance in Greece: a Snapshot. *Soil Security*. 100035 https://doi.org/10.1016/j.soisec.2022.100035

Schismenos, S., Stevens, G. J., Georgeou, N., Emmanouloudis, D., Shrestha, S., & Thapa, B. S. (2021). Humanitarian and developmental research engagement during COVID-19. *Social Science Protocols, 4,* 1-14. https://doi.org/10.7565/ssp.v4.6487

Georgeou, N., Schismenos, S., Wali, N., Mackay, K., & Moraitakis, E. (2021). A scoping review of ageing experiences among culturally and linguistically diverse people in Australia: towards better ageing policy and cultural well-being for migrant and refugee adults. *The Gerontologist*. https://doi.org/10.1093/geront/gnab191

Schismenos, S., Stevens, G., Emmanouloudis, D., Georgeou, N., Shrestha, S., Katopodes, N., & Wali, N. (2021). Humanitarian engineering for renewable energy and flood early warning in remote communities: a scoping review of enabling factors and sustainability. *Journal of Sustainable Development of Energy, Water and Environment Systems*, *10*(3), 1090406. https://doi.org/10.13044/j.sdewes.d9.0406

Stevens, G. J., Bienz, T., Wali, N., Condie, J., & Schismenos, S. (2021). Online university education is the new normal: but is face-to-face better?. *Interactive Technology and Smart Education, 18*(3), 278-297. https://doi.org/10.1108/ITSE-08-2020-0181

Schismenos, S., Stevens, G. J., Emmanouloudis, D., Georgeou, N., Shrestha, S., & Katopodes, N. D. (2021). Using off-grid hydropower for community-led flood resilience: an integrated systems approach. *International Journal of Sustainable Energy*, 1-15. https://doi.org/10.1080/14786451.2021.1961773

Schismenos, S., Chalaris, M., & Stevens, G. J. (2021). Battery hazards and safety: a scoping review for lead acid and silver-zinc batteries. *Safety Science*, 140, 105290 https://doi.org/10.1016/j.ssci.2021.105290

Schismenos, S., Buhler, C., Gurung, S., Wali, N., Ball C., Gannon, S., Stevens, G. J., Horsfall, D., & Georgeou N. (2021). 'Side by side' for COVID recovery: de-stigmatising ageing and re-integrating elders as valued contributors to society. *Royal Commission into Aged Care Quality and Safety.* https://agedcare.royalcommission.gov.au/media/30059

Schismenos, S., Stevens, G. J., Emmanouloudis, D., Georgeou, N., Shrestha, S., & Chalaris, M. (2021). Humanitarian engineering at the sustainability-development nexus: mapping vulnerability and capability factors for communities at risk of water-based disasters. *Sustainability Science*, *16*(4), 1185-1199. https://doi.org/10.1007/s11625-020-00890-y

Schismenos, S., Smith, A. A., Stevens, G. J., & Emmanouloudis, D. (2020). Failure to lead on COVID-19: what went wrong with the United States?. *International Journal of Public Leadership, 17*(1), 39-53. https://doi.org/10.1108/IJPL-08-2020-0079

Schismenos, S., Stevens, G. J., Emmanouloudis, D., Georgeou, N., Shrestha, S., & Chalaris, M. (2020). Humanitarian engineering and vulnerable communities: hydropower applications in localised flood response and sustainable development. *International Journal of Sustainable Energy*, *39*(10), 941-950. https://doi.org/10.1080/14786451.2020.1779274

Bienz, T., Schismenos, S., Stevens, G., & Georgeou, N. (2020). New analysis tools and leadership model for a modern UN to the United Nations Secretary-General. *Journal of Science & Policy Governance, 16*(2). https://doi.org/10.38126/JSPG160202

Book Chapters

Schismenos, S., Emmanouloudis, D., Stevens, G. J., & Eslamian, S. (2022). Torrential and flash flood warning: general overview and uses of localized hydropower. S. Eslamian and F.A. Eslamian (Eds) *Flood Handbook: Impacts and Management* (Milton Park: Routledge). eBook ISBN: 978042946332. https://doi.org/10.1201/9780429463327

Castaneda, A., Calderón, A., Emmanouloudis, D., & Schismenos, S. (2020). Mitigación de la vulnerabilidad, medida por el Índice de Riesgo Climático en la Región Centroamericana (desafíos y oportunidades) [Vulnerability Mitigation, measured by the Climate Risk Index in the Central American Region (Challenges and Opportunities). *La Integración Centroamericana y la Globalización Mundial*. Secretaria General del SICA (SG-SICA), Secretaria de Integración Económica Centroamericana (SIECA), and Banco Centroamericano de Integración Económica (BCIE), pp. 96-107.

Bienz, T., Stevens, G. J., & Schismenos, S. (2020). Sans-papiers in Switzerland under COVID-19. N. Georgeou, and C. Hawksley (Eds) *State Responses to COVID-19: a global snapshot at 1 June 2020* (Parramatta, NSW: Humanitarian and Development Research Initiative, Western Sydney University), pp 96-97. https://doi.org/10.26183/5ed5a2079cabd

Schismenos, S., Gkiatas, A., Stevens, G. J., Bienz, T., & Smith, A. A. (2020). "Bend it like Greece": a success story for flattening the COVID-19 curve. N. Georgeou, and C. Hawksley (Eds) *State Responses to COVID-19: a global snapshot at 1 June 2020* (Parramatta, NSW: Humanitarian and Development Research Initiative, Western Sydney University), pp 101-102. https://doi.org/10.26183/5ed5a2079cabd

Stevens, G. J., Schismenos, S., Bienz, T., Smith, A. A., & Gkiatas, A. (2020). Frontline heroes left behind: American healthcare workers during the era of COVID-19. N. Georgeou, and C. Hawksley (Eds) *State Responses to COVID-19: a global snapshot at 1 June 2020* (Parramatta, NSW: Humanitarian and Development Research Initiative, Western Sydney University), pp 132-133. https://doi.org/10.26183/5ed5a2079cabd

Schismenos, S., Stevens, G., Georgeou, N., Emmanouloudis, D., Smith, A., & Wali, N. (2019). localized disaster management and community development in Western Africa: challenges and opportunities in Nigeria, United Nations Major Group of Children and Youth, Youth Science Policy Interface Publication (Ed.) *2nd Special Edition: Disaster Risk Reduction: Moving Forward, Thinking Ahead*, pp. 12-16. https://www.preventionweb.net/publications/view/68036

Smith, A., Schismenos, S., Stevens, G., Hutton, L., Chalaris, M., & Emmanouloudis, D. (2019). Understanding large-scale fire events: megafires in Attica, Greece and California, USA, United Nations Major Group of Children and Youth, Youth Science Policy Interface Publication (Ed.) *2nd Special Edition: Disaster Risk Reduction: Moving Forward, Thinking Ahead*, pp. 29-34. https://www.preventionweb.net/publications/view/68036

Schismenos, S., Stevens, G., Emmanouloudis, D., Georgeou, N., Chalaris, M., & Smith, A. (2019). Local disaster vulnerability analysis: an approach to identify communities, United Nations Major Group of Children and Youth, Youth Science Policy Interface Publication (Ed.) *2nd Special Edition: Disaster Risk Reduction: Moving Forward, Thinking Ahead*, pp. 49-54. https://www.preventionweb.net/publications/view/68036

Bienz, T., Schismenos, S., Stevens, G., Tran, C., & Georgeou, N. (2019). Incubators as a potential tool for employment creation: a focus on Sub-Saharan Africa, Kim, J.J., and Halbert, A. (Eds.) *The Next Generation of Work: Pathways to Sustainable Economies and Decent Jobs for All by 2030*, (New York, USA: United Nations Major Group of Children and Youth), pp. 100-104. https://pathways2030.org/

Karma, S., Schismenos, S., Emmanouloudis, D., & Chalaris, M. (2019). Challenges and lessons learned from past major environmental disasters due to technological or wildland urban interface fire incidents. *United Nations Global Assessment Report on Disaster Risk Reduction 2019 (GAR19) Contributing Paper, United Nations Office for Disaster Risk Reduction.* https://www.preventionweb.net/publications/view/66718

The Conversation

Stevens, J. G., Taylor, M., & Schismenos, S. (2021). Why do people try to drive through floodwater or leave it too late to flee? Psychology offers some answers. *The Conversation*. https://theconversation.com/why-do-people-try-to-drive-through-floodwater-or-leave-it-too-late-to-flee-psychology-offers-some-answers-157577

Schismenos, S., Stevens, J. G., and Georgeou, N. (2021). It’s 2am, you’re sleeping, and a flash flood hits your home. without a warning system, what do you do?, *The Conversation*. https://theconversation.com/its-2am-youre-sleeping-and-a-flash-flood-hits-your-home-without-a-warning-system-what-do-you-do-154805

Appendices

1a. Table 1. Evaluation criteria for off-grid renewable energy systems and early warning systems

Criteria	Description	Off-grid renewable energy systems	Early warning systems
Disaster-resilience	Durability against floating debris, logs and products of weather extremes (e.g. hail).	√	√
Low maintenance	Requires minimal repairs over time.	√	√
Portability	Easily carried, transferred, installed, uninstalled and reinstalled by a small number of individuals.	√	√
Readily sourced Materials	Made with materials easily sourced locally (e.g. recycled and natural materials).	√	√
Durability (time)	Unit lasts for relatively long periods under any atmospheric conditions.	√	√
Affordability	Can be purchased/maintained by low-income end-users.	√	√
Autonomy	Not dependent on other external systems and/or services (e.g. internet, telecommunication antennas).	√	√
Workability	Continuous operation under any atmospheric condition (operates 24/7).	√	√
Do-it-yourself/easy-to-deploy-and-operate (DIY/EDO)	Can be assembled, dismantled, rebuilt, deployed and operated by end-users with limited experience or technical knowledge.	√	√
Minor environmental impacts	No/Minor impacts caused on local ecosystems.	√	√
Minor impacts (other)	No/Minor impacts caused on the local populations and surroundings.	√	√
Safety	No/Minor impacts on human health and well-being.	√	√
Adaptability	Can be installed and operate in sites of different hydrogeomorphological conditions (e.g. water depth, width, flow). No/Minor operational impacts due to atmospheric changes.	√	√
Energy needs	Requires minimum or no power to operate.	√	√
Large range and population reach	Can reach a relatively wide radius of space and large group of people, including those with vision and hearing impairments (local level scale).	-	√
Power range	Can cover some basic energy needs under any conditions.	√	-

1b. Table 2. Appropriate technology and systems evaluation tool

FAILURE IDENTIFIED CASE STUDIES		DIMENSIONS OF SYSTEM SUSTAINABILITY INDICATORS OF TECHNOLOGY 'APPROPRIATENESS'		SUCCESS IDENTIFIED CASE STUDIES
-	Institutional	Autonomy (Community Self-Sufficiency)	Institutional	-
-	Institutional	Co-Creation (Local and Professional Stakeholders)	Institutional	-
-	Institutional	Community Input (Engagement)	Institutional	-
-	Institutional	Community Controlled (Managed, Owned)	Institutional	-
-	Institutional	Legal and Regulatory	Institutional	-
-	Institutional	Support (Technical, Administrative, Financing)	Institutional	-
-	Environmental	Habitat Neutral	Environmental	-
-	Environmental	Low Emergy	Environmental	-
-	Environmental	Low Emissions	Environmental	-
-	Environmental	Renewable Energy	Environmental	-
-	Environmental	Renewable Resources Availability	Environmental	-
-	Environmental	Scaled for Conditions (Resources, Weather, Land)	Environmental	-
-	Environmental	Waste Utilisation and Reduction	Environmental	-
-	Social / Ethical	Acceptability	Social / Ethical	-
-	Social / Ethical	Aesthetics	Social / Ethical	-
-	Social / Ethical	Ease of Use	Social / Ethical	-
-	Social / Ethical	Gender Appropriate (e.g. women in staff/management)	Social / Ethical	-
-	Social / Ethical	Indigenous Techniques	Social / Ethical	-
-	Social / Ethical	Knowledge, Skills, Feedback	Social / Ethical	-
-	Social / Ethical	Social Entrepreneurialism	Social / Ethical	-
-	Social / Ethical	Socio-Cultural -incl. health, education, harmony, etc.	Social / Ethical	-
-	Economic	Affordability	Economic	-
-	Economic	Income Generating	Economic	-
-	Economic	Job Creating	Economic	-
-	Economic	Money Saving	Economic	-
-	Economic	Labour Intensive	Economic	-
-	Economic	Resource Efficiency	Economic	-
-	Economic	Selling Appropriate	Economic	-
-	Technical	Adaptability	Technical	-
-	Technical	Constructability and Replicability	Technical	-
-	Technical	Compatibility	Technical	-
-	Technical	Durability (e.g. against time or extremes)	Technical	-
-	Technical	Effectiveness	Technical	-
-	Technical	Energy Efficiency	Technical	-
-	Technical	Low Power	Technical	-
-	Technical	Maintainability	Technical	-
-	Technical	Modification vs Invention	Technical	-
-	Technical	Multi-Purpose	Technical	-
-	Technical	Open Source Manual and Design	Technical	-
-	Technical	Parts and Hardware	Technical	-
-	Technical	Raw Materials Availability	Technical	-
-	Technical	Reliability	Technical	-
-	Technical	Reparability	Technical	-
-	Technical	Reusability	Technical	-
-	Technical	Scalability	Technical	-
-	Technical	Simplicity	Technical	-
-	Technical	System Independence	Technical	-

1c. Table 3. Community perceptions of major hazard threats and priority developments

Theme	Sub-theme	Aggitis	Dhuskun
Round One			
Water hazards	Natural disasters	Floods (storms, snow melt): 8/8 COVID-19 pandemic: 1/8	Floods (monsoons, snow melt): 8/8 Landslides (usually during floods): 8/8 Earthquakes: 1/8 COVID-19 pandemic: 1/8
	Flood warning: (i) current systems	No local warning system: 8/8 Flood SMS alert (not real time – does not support evacuation, esp. flash floods): 2/8	No local warning system: 8/8 Flood SMS alert (messages delayed and/or mobile service unavailable – does not assist response): 3/8 Flood siren at nearby hydropower plant (plant specific warning, only partial community coverage): 1/8
	(ii) needs/preferred functions	Combination (siren and SMS alert): 5/8 Flood siren (wide range, loud): 2/8 Combination (siren, SMS alert, lights): 1/8 Hydrometric station: 1/8	Siren (real time warning, wide range, warns at night): 6/8 Combination (siren and SMS alert): 2/8
	Flood evacuation: (i) training/experience	No training/drills: 7/8; self-taught (online): 1/8 No personal evacuation: 8/8	No training: 7/8; participated in evacuation drills: 1/8 Evacuation due to floods and/or landslides: 8/8
	(ii) personal emergency devices - most used or priority need	Mobile phones (contact others, news update): 8/8 Lights: 5/8 Oxygen tanks (priority need for older adults): 8/8	Mobile phones (contact others, news update): 8/8 Lights 5/8 Power banks: 1/8
Community vulnerabilities	Population and infrastructure	Ageing population (younger adults move to cities, low-birth rate): 8/8	Poor roads, education, drinking water supply: 1/8
	Energy supply (extreme conditions)	Unreliable (old infrastructure): 8/8	Unreliable (seasonal impacts, unexpected power outages common): 8/8
Community cohesion	Help one another	Support each other (assist older adults): 8/8	Strong bonds between members (small community is an asset): 8/8
Reliable energy	Energy supply (normal conditions)	Reliable - normal conditions (meets daily needs): 8/8	Reliable - normal conditions: 6/8
	Renewable energy (i) existing assets	Site appropriateness (water and sunlight): 8/8 Technology acceptance (privately-owned local hydro and solar): 8/8	Site appropriateness (water and sunlight): 8/8 Technology acceptance (hydro for community use and solar for private/government use): 8/8
	(ii) asset types needed	Local hydro (community use): 8/8 Solar (individual use supported/upscaled): 7/8 Combination (hydro and solar): 2/8 Wind energy: 2/8	Small hydro (higher output): 8/8 Solar (community access): 3/8 Combination (hydro and solar): 2/8 Wind energy: 1/8
Round Two			
Preferred community asset		**Option 6** (hydro and siren hybrid): 5/8 Option 5 (solar and SMS alert combination): 3/8	**Option 6** (hydro and siren hybrid): 5/8 Option 5 (solar and SMS alert combination): 2/8 Option 1 (hydro): 1/8
Multiple services	Combining proven functions	Integrated hydro and siren: 5/5 Combined solar and SMS alert: 3/3	Integrated hydro and siren: 5/5 Combined solar and SMS alert: 2/3
	Site appropriateness	Sufficient riparian resources (water flow): 2/5 Sufficient sunlight throughout the year: 2/3	Sufficient riparian resources (water flow, depth): 3/5 & 1/1 Sufficient sunlight throughout the year: 1/2
Development benefits	Stakeholder participation	Collaboration (community stakeholders and government – funding/management): 8/8	Collaboration (community stakeholder, including public-private partnerships): 8/8
	Economic growth	Employment opportunities: 5/5 & 2/3 Tourism increase: 3/5 & 1/3 Exemplar community (role model for other flood-prone communities): 1/5	Employment opportunities: 4/5 & 1/1
Risks and solutions	Post-installation risks	No major risks: 4/5 & 2/3 Aesthetic risks ("ugly" – natural beauty, traditional buildings): 1/5 & 1/3	No risks: 3/5, 2/2 & 1/1
	Issues and management (i) technical	Insufficient energy output [install more units]: 4/5 Lack of energy storage [include batteries]: 4/5 Vulnerable in flood conditions [analysis to find optimal hydro locations]: 2/5 River depth limitation - summer [determine best locations]: 2/5 Insufficient sunlight – cloudy/winter [large capacity batteries]: 3/3 Siren warning coverage insufficient [install more units and/or combine with SMS alert]: 3/5 SMS warning unreliable [augment with siren]: 2/3 No funds [funding via stakeholder participation]: 3/5 & 3/3	No major issues: 4/5 & 2/2 Vulnerable in flood conditions [analysis to find optimal hydro locations]: 2/5 & 1/1 Insufficient sunlight – cloudy/winter [large capacity batteries]: 1/2 Siren warning coverage insufficient [install more units]: 2/5 SMS warning unreliable [augment with siren]: 1/2

(ii) resources	No human resources for installation and maintenance [works complete via stakeholder participation]: 2/5 & 2/3 Aesthetic risks [community acceptance via broad stakeholder participation]: 2/5	
Remote research	Satisfied with remote approach: 8/8	Satisfied with remote approach: 8/8 Approach was innovative and comfortable:1/8

Notes: Fractions in Round One refer to participants from Aggitis (up to 8/8) and Dhuskun (up to 8/8). Fractions in Round Two refer to: (a) participants from Aggitis (up to 8/8) and Dhuskun (up to 8/8); (b) participants who selected Option 6 – hydro and siren hybrid from Aggitis (up to 5/5) and Dhuskun (up to 5/5); (c) participants who selected Option 5 – solar and SMS alert combination from Aggitis (up to 3/3) and Dhuskun (up to 2/2); and (d) a participant who selected Option 1 – hydropower generator from Dhuskun (1/1).

1d. Table 4. Themes and sub-themes – definitions, exemplars and frequency

THEMES	SUB-THEMES	DEFINITION	FREQUENCY	EXAMPLE	REASON EXAMPLE FITS SUB-THEME
ROUND ONE					
1. WATER HAZARDS					
	a. Natural disasters	Perception that floods and landslides are the most serious threats for their community	16/16	(Male, 30 - Dhuskun): "... I worked in a rescue (team) after a landslide where about twenty to twenty-five people died."	Personal experience on human loss that shows how lethal landslides can be
	b. Flood warning: (i) current systems	Current status of localised early warning systems	16/16	(Female, 49 - Aggitis): "Nothing! We have absolutely nothing (no early warning systems)!"	An 'emotional' belief showing the lack of early warning systems in their community
	(ii) needs/preferred functions	Preferred warning type for floods	8/16	(Male, 21 – Dhuskun): "I think the siren is good. Because the siren is something that, if it is pressed once, everyone finds out. And if it is pressed three or four times, the whole society will know. The message system (flood SMS alerts), people don't always get [...]. If the sirens are played three or four times, then people will know, they will know the river is coming."	Belief that community is familiar with siren warning (how people are alerted)
	c. Flood evacuation: (i) training/experience	Current status of community flood evacuation programs	14/16	(Female, 30 – Dhuskun): "Up till now, no (I haven't received any flood evacuation training)."	A response showing lack of flood evacuation training
	(ii) personal emergency devices - most used or priority need	Preferred emergency device to use during extremes	16/16	(Female, 52 – Aggitis): "We definitely need a mobile phone. I consider it to be a very important device, first of all so that we can notify people about the power outage and to communicate with each other, but also if there is a need to call the Fire Department or for an ambulance in case a sick person needs help, that is why the mobile phone is such an important device."	Belief that mobile phones are the most important personal emergency devices during floods
2. COMMUNITY VULNERABILITIES					
	a. Population and infrastructure	Perception that Aggitis community is 'dying' because most permanent residents are older adults	8/16 (8/8 Aggitis)	(Male, 36 – Aggitis): "[...] the community is made up mostly of people over the age of sixty-five... seventy...who are retired or nearing retirement age. The younger generation chooses not to live in Aggitis, but in a bigger city and to have a house there, so to live both in	Belief that Aggitis population is ageing and that younger adults are leaving the community

				Aggitis and in the big city, like I do. Therefore, the community is shrinking."	
	b. Energy supply (extreme conditions)	Status of energy supply during extremes	16/16	(Male, 21 – Dhuskun): "Floods and blackouts come time and again, and because of that, people can't be safe, and they can't protect the things that they work so hard for. They don't know what will happen at what time, they have to remain alert, and know when to run."	Perception that floods and power outages are frequent and usually come 'together'
3. COMMUNITY COHESION					
	a. Help one another	Perception that community members help each other in times of emergency	16/16	(Male, 70 – Dhuskun): "In Nepal, and in Sunkoshi (Dhuskun) community, people tie up in such a way that if one knows about it, they will warn other people. One thing. And second thing is, who is living in which house, because everyone knows everyone's name. That is what I noticed. So, if and when time permits, time permits, those who can hear, they will ask other people and inform them."	Belief that community members are a 'homogenous' and caring population
4. RELIABLE ENERGY					
	a. Energy supply (normal conditions)	Perception that the current energy supply and infrastructure are reliable and satisfy 'everyday' energy needs	14/16	(Male, 25 - Aggitis): "The electric power supply in the community is good and stable when there are no problems due to the weather."	Belief that the energy supply and infrastructure are 'good enough' under normal conditions
	b. Renewable energy (i) existing assets	Perception that local communities can support renewable energy systems due to site characteristics (e.g. water, sunlight)	16/16	(Male, 25 – Aggitis): "If I had to choose one of the renewable energy sources for my community, I would choose small hydroelectric systems [...] and solar energy, because these are the two (renewable) energy sources which are the most suitable to be used in this specific area."	Perception that small-scale hydropower and solar panels are suitable for their community
	(ii) asset types needed	Perception that hydropower is the most suitable renewably energy type	16/16	(Male, 21 – Dhuskun): I think hydropower is good. Because if hydropower is in one's area, everyone will also get jobs and will not face issues because of that, and because of hydropower, the village's ecological system...there will be nature...all of this will be studied before construction is started. So, because of that, if we have hydropower, it will be better, and will be something we don't ever have to worry about. I think.	Belief as to why hydropower is the most suitable renewable energy source for their community

ROUND TWO					
5. MULTIPLE SERVICES					
	a. Combining proven functions	Perception as to why energy generation and flood warning are preferred	15/16	(Female, 45 – Aggitis): "I think it is the most beneficial option (Option 6) because it can make use of the water (river) that exists in Aggitis, so that we can have electricity at any time, especially in case of floods, that usually happen simultaneously with a power outage. We can also use the system with the sirens to alert everyone. "	Belief as to why combined services are the most attractive attributes
	b. Site appropriateness	Perception as to why the selected option is suitable for their community	16/16	(Male, 30 – Dhuskun): "There is hydropower here already…and it's mainly about the safety of people. So, in that regard, I think the best would be sirens, in an area where there is flood and landslide. I think these are absolutely needed for safety. So, hydropower and siren. Hydropower we need anyway, and the siren too."	Belief that the hydropower-siren hybrid (Option 6) is suitable for the community
6. DEVELOPMENT BENEFITS					
	a. Stakeholder participation	Perception as to why stakeholder synergy is important	16/16	(Female, 45 – Aggitis): "A combination of these people (professional and non-professional stakeholders who are familiar with the community) and organisations could be involved in order to study the area, install the system and manage the project. They can be found in the wider area, within the competent bodies (authorities and organisations). Initially, the competent municipality in collaboration with the local district (authorities) could do research regarding the financing of this program, or set up an auction so the project can be completed by private companies. That is, I think the ideal would be for all the (competent) bodies to work together, because I do not think that the municipality alone has the know-how to do such a thing."	Belief that different stakeholders are needed to support the selected option (installation, maintenance, funding, etc.)
	b. Economic growth	Perception of community benefits after system installation	16/16	(Female, 52 – Aggitis): "Of course (there are additional benefits)! The cave (of Aggitis) could be developed (more) in terms of tourism by being constantly illuminated by the solar energy	Belief that the selected option could increase tourism potential in the area

				that will be collected, i.e. there can be lighting for the entire surrounding area along the riverbed and not only in the cave. An increase in traffic and revenue in the area of the cave will be able to attract more investments, especially since its lighting would be feasible for very low costs."	
7. RISKS AND SOLUTIONS					
	a. Post-installation risks	Perception regarding any risks to their community and local sites	14/16	(Male, 25 – Aggitis): "I do not believe that there will be problems (risks), only benefits to the community"	Belief that the selected option will have no risks after installation
	b. Issues and management (i) technical	Perceptions as to how the selected option can be optimised	8/18	(Female, 36 – Aggitis): "There are now sirens that can be combined with safety lights [...]. Sirens that could be combined with sending a text message or an email, which would not be difficult to do [..]. Whenever someone who might be away from the sirens (out of range) or for example someone who sleeps with earplugs, probably would not be able to hear the siren but maybe they could see the notification alert, if their mobile phone was vibrating."	Belief that the selected option can use combined warning types (sirens and SMS alerts) to increase warning reliability
	(ii) resources	Perception regarding the current community capacity (funding and human resources)	8/16 (8/8 Aggitis)	(Male, 31 – Aggitis: "I believe that the community being this small does not have the resources that are needed, but neither has the (necessary) human resources, because most of the residents are old. It (the community) could obtain the (necessary) resources from the municipality, the district, the state (government) or from European funds ... anything (really)."	Belief that their community will need support from the state and other agencies to install and maintain the selected option

2a. Interview Script - Round 1

Electrical power is considered as sufficient when it satisfies the daily energy needs of its users. It is reliable when it is not unexpectedly interrupted (for example, via frequent blackouts). 1) Given the statements above, how would you describe the electrical power supply in your community, and why? *PROMPT1 if needed: Does it satisfy your daily energy needs?* *PROMPT2 if needed: Is it reliable?*
2) What do you think are the most important problems of the current electrical power supply in your community, and why?
3) What can you tell us about your electrical power supply and needs during severe storms or floods? *PROMPT1 if needed: Do you have frequent blackouts and if yes, is this a problem to you?* *PROMPT2 if needed: Which of your electrical devices would you most need to use during storms and floods?*
Electrical power can come through mains power sources such as gas or coal-fired power stations, and sources of renewable energy that come from the wind, sun and water, which are commonly known as wind energy, solar and hydropower. 4) If you could choose any electrical power source (or sources) which would you prefer for your community, and why? PROMPT if needed: What features make it suitable?
5) Would you consider renewable energy systems as a priority solution for your community and why?
6) Is there anything else about the supply of electrical power in your community you think is worth mentioning?
Now I will ask some questions about floods and flood warnings. As you know, a severe flood might cover roads and enter people's houses. 7) Could you tell me about any severe floods that have occurred in your community? PROMPT if needed: Do floods occur frequently in your community?
Warning systems for floods can include things like flashing lights, sirens, SMS text messages, warnings on radio/TV and flood markers which show high water levels. 8) Does your community have any of these (or other) flood warning systems, and what do you like or not like about this system? *PROMPT1 if needed: Do you think this system works well, and why?* *PROMPT2 if needed: Do people get enough warning time?*
9) If you could choose any flood warning type (or types) which would you prefer for your community and why? *PROMPT1 if needed: Let me remind you that warning systems for floods can include mechanisms like flashing lights, sirens, SMS text messages, warnings on radio/TV and flood markers.* *PROMPT2 if needed: What features make it suitable?*
10) Would you consider flood early warning systems as a priority for dealing with floods in your community, and why?
11) Is there anything else about flood warnings in your community you think is worth mentioning?

In this interview, we have discussed issues about having reliable electrical power supply and warning systems for floods.

12) Are these the biggest problems in your community or are there other things that are more important to deal with?

PROMPT if needed: What do you think of the biggest needs for the community right now?

2b. Interview Script - Round 2

Now I am going to ask some questions about the options I've just presented. 1) If these were the only options for your community, which one would you prefer?
2) Why do you think this option is the most useful for your community? *PROMPT1 if needed: What particular aspects make it suitable (i.e. its attributes or the way the community will use it)?*
3) What disadvantages might there be for the option you suggested? *PROMPT1 if needed: What particular aspects might make it unsuitable (i.e. its attributes or the way the community will use it)?*
4) What solutions can you think of to overcome these disadvantages? *PROMPT1 if needed: Can you think of any changes with this option that would make it better, like its features or the way it's used- if yes which?*
5) Do you think there could be any particular risks or problems for your community if you install this option? *PROMPT1 if needed:* Could this option have a negative effect on people in the community or the environment?
6) Apart from its main benefits *[state benefit of selected option],* would such an option have other positive effects in your community? *PROMPT1 if needed: What other specific benefits could it bring?*
7) If this option was installed would your community have enough resources (e.g. manpower or money) to 'run' it for 10 years? If yes, what resources does your community have for this, if not what would you need?
8) Who would be the best people or groups to install and 'run' this option (for example, individual community members, Village Development Committee, whole community, local government, banks, private sector, NGOs or others)? *PROMPT1 if needed: W*hy these /this combination? *PROMPT 2 if needed:* What skills/strengths do they have?
9) Would you be interested to take part in 'running' this option (for example, monitor the system or help with maintenance)? If yes why so, if not why not? *PROMPT 1 if yes: If this was a volunteer (unpaid) role, would you still like to take part?*
10) Would you be willing to have some free training for this? If yes why so? If not why not?
11) Is there anything else about the option you suggested that you want to mention?
(ask if they don't pick hybrid/combo option) 12) In order to both generate power and have flood warnings would it be better to have two separate systems like option 5, or a single system, like option 6, and why?
13) Would you like to mention anything else?

14) The interviews took place online, was the online process easy for you?
PROMPT 1 if yes: Was the catalogue information clear to you?
PROMPT 2 if yes: Were you able to say everything you wanted to?
PROMPT 3 if yes: Is there anything we could do to improve these online interviews?

AUSTRALIAN HIGHER EDUCATION GRADUATION STATEMENT

Water-based disasters are increasing worldwide. This affects small communities with limited resources, including energy availability and flood hazard resilience. Humanitarian engineering interventions for localised sustainable development and disaster resilience could support such populations. This thesis collects information from both professionals and non-experts in two flood-prone communities in Nepal and Greece to understand what options are perceived as reliable, realistic and appropriate for local priority needs. The findings indicate that the co-development of a hybrid unit for hydropower generation and outdoor flood early warning is most preferred. This unit could find applications as either a main or supplementary system in riparian communities.

Supplementary Materials

Paper II

Journal of Sustainable Development of Energy, Water and Environment Systems

http://www.sdewes.org/jsdewes

Year 2022, Volume 10, Issue 3, 1090406

Review Article

Humanitarian Engineering for Renewable Energy and Flood Early Warning in Remote Communities: A Scoping Review of Enabling Factors and Sustainability

Spyros Schismenos[1*], Garry J. Stevens[2], Dimitrios Emmanouloudis[3], Nichole Georgeou[4], Surendra Shrestha[5], Nikolaos D. Katopodes[6] and Nidhi Wali[7]

[1]School of Social Sciences, Humanitarian and Development Research Initiative (HADRI), Western Sydney University, Sydney, Australia;
UNESCO Chair on Conservation and Ecotourism of Riparian and Deltaic Ecosystems, International Hellenic University, Drama, Greece.
e-mail: s.schismenos@westernsydney.edu.au

[2]School of Social Sciences, Humanitarian and Development Research Initiative (HADRI), Western Sydney University, Sydney, Australia.
e-mail: g.stevens@westernsydney.edu.au

[3]Department of Forestry and Natural Environment, International Hellenic University, Drama, Greece; UNESCO Chair on Conservation and Ecotourism of Riparian and Deltaic Ecosystems, International Hellenic University, Drama, Greece.
e-mail: demmano@teiemt.gr

[4]School of Social Sciences, Humanitarian and Development Research Initiative (HADRI), Western Sydney University, Sydney, Australia.
e-mail: n.georgeou@westernsydney.edu.au

[5]School of Engineering, Western Sydney University, Sydney, Australia.
e-mail: s.shrestha@westernsydney.edu.au

[6]Department of Civil and Environmental Engineering, University of Michigan, Ann Arbor, USA;
UNESCO Chair on Conservation and Ecotourism of Riparian and Deltaic Ecosystems, International Hellenic University, Drama, Greece.
e-mail: ndk@umich.edu

[7]School of Social Sciences, Humanitarian and Development Research Initiative (HADRI), Western Sydney University, Sydney, Australia.
e-mail: n.wali@westernsydney.edu.au

Cite as: Schismenos, S., Stevens, G., Emmanouloudis, D., Georgeou, N., Shrestha, S., Katopodes, N., Wali, N., Humanitarian Engineering for Renewable Energy and Flood Early Warning in Remote Communities: A Scoping Review of Enabling Factors and Sustainability, J.sustain. dev. energy water environ. syst., 10(3), 1090406, 2022, DOI: https://doi.org/10.13044/j.sdewes.d9.0406

ABSTRACT

Small communities in remote, riparian sites often have limited resources, and experience energy insufficiencies and poor disaster resilience to intensifying weather hazards such as rainstorms and floods. Humanitarian engineering interventions for off-grid renewable energy generation and flood response at the local level have the potential to support community hazard management and socio-economic development. This scoping review examines communities in low and lower middle-income countries, and their use of renewable energy and flood warning systems. Its primary focus is vulnerable communities and how they can achieve hazard protection as part of sustainable development initiatives. The findings highlight that it is important to consider institutional, environmental, social/ethical, economic and technical indicators in developing a comprehensive understanding of the success or failure of a given system. The study concludes that an integrated renewable energy and flood warning system may provide an optimal, community-managed approach to address priority needs.

KEYWORDS

Hydropower, Solar energy, Appropriate technology, Developing countries, Hybrid system.

INTRODUCTION

Localised renewable energy is an affordable, clean alternative to fossil fuels that is gaining popularity for use in remote 'off-grid' communities [1-4], particularly in low and lower-middle income countries [5], where reducing costs make it more feasible [4, 6, 7]. To support such communities and their ecosystems, national and international organizations often provide development assistance programs alongside specific forms of humanitarian intervention. Key goals of these programs, respectively, include enhancing community capabilities regarding energy sufficiency [8-10] and disaster risk reduction at the local level [11-13].

Access to resources and knowledge on how to establish, operate, repair and maintain local infrastructure and services increases community self-sufficiency. Frequently however, this is not the case for the remote, riparian communities in low and lower middle-income countries. Assistance provided to these communities is often temporary, or promised longer-term solutions fail over time as they cannot support (or be supported by) end-users in a realistic and sustainable manner. Such communities are often small, agriculture-based monoeconomies with low incomes, power insufficiencies, and increased exposure to extreme weather events due, in part, to limited response capability and technological support [14-16]. In this study, communities with such characteristics are described as vulnerable or remote. Its focus is on their current use of support technologies and potential future development of such assets.

The United Nations 2030 Agenda for Sustainable Development [8] highlights the importance of Sustainable Development Goal 7: Affordable and Clean Energy as essential for socio-economic development and self-sufficiency, as well as for the success of other Goals [17]. Off-grid renewable energy systems (OGRES), such as small-scale hydropower generators and solar panels, offer a range of potential benefits to vulnerable communities, including enhanced disaster response capability when generated power can support flood early-warning systems (EWS) [18]. According to the Sendai Framework for Disaster Risk Reduction, community resilience against natural hazards is an essential element of sustainable development [11]. Successfully combining OGRES and EWS would provide a comprehensive humanitarian engineering solution that accords with the principles of both of these international frameworks [19].

In this study, humanitarian engineering is defined as the technology-focused applications that can support the basic needs (e.g. energy generation, shelter, water sanitation) of an affected population, including preparation for, and response to hazard events [20-22]. Such applications can be either temporary or permanent [23]. Humanitarian engineering is often conceived by aid practitioners and field engineers as providing innovation and 'elegant solutions' to more than one issue simultaneously (e.g. a micro-hydropower system for irrigation may also power public lights and a school facility) [24, 25]. While humanitarian engineering has the potential to provide such multi-faceted solutions in vulnerable communities, a key requirement is that such solutions are sustainable over time and within community resources, especially after the professionals leave or external funding discontinues.

To evaluate sustainability, it is essential to determine the appropriateness of a proposed technology to the community (perceived value and sustained use) and its environmental context (i.e. low and/or positive impact). So-called 'appropriate technology' frameworks consider local characteristics and allow slow adaptations while end-user communities reach and maintain sustainable forms of development [26-29]. Assessments of technology appropriateness for local-level renewable energy systems typically examine technical, economic and social indicators that would support effective use in a specific community [30], [31]. Bauer and Brown [32] developed the 'Appropriate Technology Assessment Tool' which uses 47 indicators to determine technology appropriateness. The tool has a strong evidence base, with its indicators derived from a meta-analysis of 53 articles, books and conference proceedings in appropriate technology. In addition to appropriateness, Ilskog [33] has argued for additional analysis of the sustainability of community-level technology developments across two categories: environmental and institutional. Her proposed method assesses these across 39 indicators, with these articulating closely with the United Nations Millennium Development Goals, and the United Nations Sustainable Development Goals. Importantly, this assessment framework has also demonstrated specific utility in sustainability evaluations of energy-related projects [34]. The frameworks of Bauer and Brown [32] and Ilskog [33] provide comprehensive coverage of the appropriateness and sustainability of community developments which have a technology focus, and both will be used in the evaluation of case studies identified in this review.

This scoping review investigates the uses of OGRES and flood EWS in vulnerable communities, including specific indicators of strengthened or undermined end-user confidence in these systems or their sustainability. While individual case studies have detailed the successes and failures of OGRES or EWS in remote communities, a comparative analysis of these systems following the four-stage framework of Arksey and O'Malley [35] has not previously been conducted. Such an analysis can inform researchers, government authorities, development, and humanitarian agencies, as well as communities themselves, as to the viability and cost-benefit of such systems in these contexts. These data will also inform a wider study at Western Sydney University in Australia which is examining whether community-level renewable energy sources can reliably power flood EWS as a hybrid system. To the authors' knowledge, there has been no such study of combined systems for sustainable development and flood resilience at the local level. While some researchers have examined solar energy use in EWS [36-38], there are no published data regarding other OGRES (i.e. hydropower) powering localised EWS for community response. While the primary focus of this review is the community use and effectiveness of OGRES and EWS as individual 'sub' systems, a secondary focus will be the implications of these findings and potential applications for a future hybrid system. Community-focused features that enhance acceptability and sustainability of the sub-systems among different populations facing similar threats will likely be integral to hybrid systems [39].

METHOD

This article presents a scoping review analysis that follows the four-stage framework of Arksey and O'Malley [35]: (i) identification of research questions, (ii) identification of relevant studies, (iii) selection of studies, and (iv) collation and report of findings. This method has been used by many scholars, and has been adopted for use in a wide range of disciplines [40]; for example water, sanitation and hygiene (WASH) [41], aging studies [42, 43], education [44], and occupational safety [45].

Research questions

The aim of this scoping review is to collect research findings (success cases, lessons and failure factors) related to community-based renewables and flood EWS installed in low and lower middle-income countries. The review was guided by the following questions:

1. What are the elements of successful OGRES and EWS within vulnerable communities experiencing energy insufficiency and/or flood risk?
2. What factors contribute to (or enable/disenable) the successful establishment and ongoing maintenance of such systems in low and lower middle-income countries in order to achieve sustainable development?
3. What features should a hybrid system have in order to be sustainable longer-term?

Search strategy

A range of terms are used in the literature to describe the focus areas highlighted in this article. For example, "renewable energy" is sometimes used interchangeably with terms like "green energy", "clean energy" or "sustainable energy". We conducted our search based on the most commonly used version of these terms. The following string was used for the identification of relevant studies: (“success” OR “lesson” OR “failure”) AND (“renewable energy” OR “flood early warning” OR “technology acceptance” OR “technology transfer”) AND (“developing countr*” OR “low income countr*”)

Identification of studies

ScienceDirect was selected as the primary source for research articles in multi-disciplinary themes (e.g. engineering, energy, environmental, social and sustainability) fields. Google Scholar was also used to broadly search for relative scholarly literature. In addition, the following key academic journals were selected for this search due to their high relevance in their fields:

- Energy for Sustainable Development;
- Engineering Failure Analysis;
- Environmental Science & Policy;
- Journal of Cleaner Production;
- Journal of Rural Studies;
- International Journal of Disaster Risk Reduction;
- Procedia Engineering;
- Progress in Disaster Science;
- Renewable Energy;
- Renewable and Sustainable Energy Reviews.

Lastly, the authors examined so-called ‘grey literature’, which is understood as literature produced and/or delivered by international and multinational organizations and agencies that are not primarily focus on ‘traditional’/academic publishing. The following bodies were searched:

- International Centre for Integrated Mountain Development;
- International Renewable Energy Agency;
- United Nations Framework Convention on Climate Change;
- United Nations University Institute of Environment and Human Security.

Inclusion criteria

Review articles, research articles, case reports and product reviews available in English were included; all other types of publications and languages were excluded. As interest in renewable energy and early warning technologies dates roughly from the beginning the selected period was from January 2000 to December 2020. This is a period that has witnessed a plethora of innovations and optimizations. Furthermore, the Sendai Framework for Disaster Risk Reduction, and the 2030 Agenda for Sustainable Development were also initiated during this period, guiding responses for disaster resilience, environmental protection, humanitarian aid and sustainable development.

Selection of studies

A total of 2,449 studies were identified from ScienceDirect and Google Scholar, with the period of examination lasting up until December 31st, 2020. After journal searching, 325 studies were retrieved. Firstly, titles and abstracts were screened which resulted in 42 studies. Full-text screening of the included studies resulted in nine studies. After bibliographical searching, one study [14] was additionally included. Two other studies [46, 47] were added due their high relevance to the topic and response to research questions; these were found by using the string keywords in the Google search engine. The ‘grey literature’ search resulted in six reports, while full-text screening led to the inclusion of only two reports. The full-text analysis thus resulted in 14 studies for final inclusion. The entire process is visually explained in **Figure 1** and a summary of the studies is provided in **Table A1** in Appendix.

Data analysis

The selected-for-inclusion studies were coded following the 6-step process as detailed by Braun and Clarke (2006) [48]. This process includes: (i) data familiarization by reading and re-reading the studies, (ii) initial codes generation; (iii) codes grouping into relevant themes; (iv) review themes to develop a 'thematic map', (v) themes definition and naming, and (vi) themes narration.

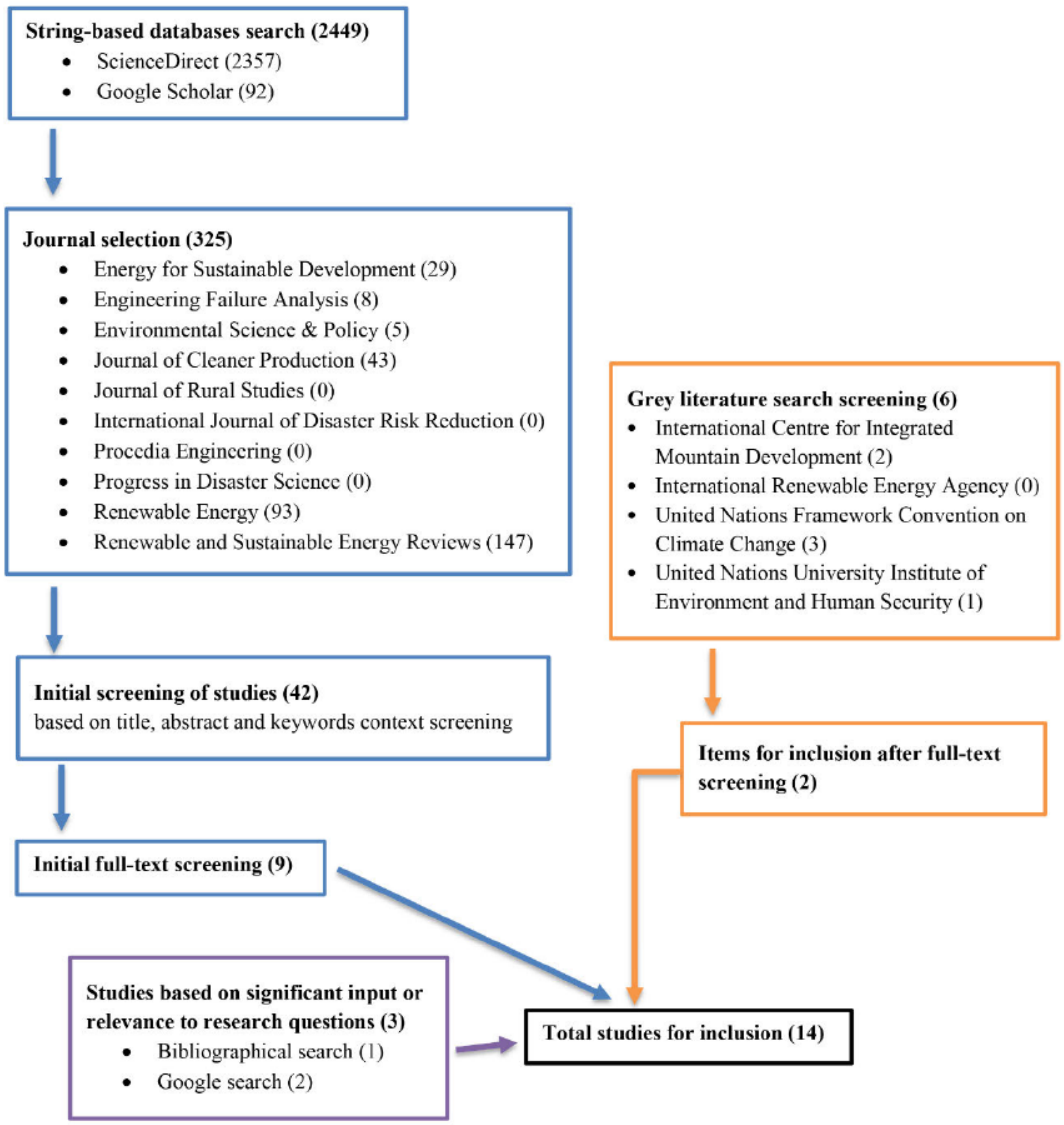


Figure 1. Study selection flow chart

RESULTS

The scoping review led to three major findings:

- Despite the differences in socio-cultural, economic and environmental conditions, many communities have similar needs and lack similar capabilities;
- Many cases shared either the same or similar system failure/success indicators;
- Long-term community engagement and equitable socio-economic benefits delivery were crucial in the success of both systems, while lack of support, technical know-how, funding and system service were major indicators for failure.

Three primary themes were distilled from the findings:

i. Recognition of diversities and similarities in vulnerable communities;
ii. Appropriate technology and sustainability mapping:
iii Enablers for success and failure factors.

Recognition of diversities and similarities in vulnerable communities

The review summarised OGRES case studies (hydro, solar, and wind-power, and mixed projects) from Bolivia, Philippines, Nepal, Rwanda, Ethiopia, Gabon, Ghana, Kenya, Malawi, Mozambique, Nigeria, Tanzania, Cameroon, Central African Republic, Chad, Republic of Congo, Afghanistan, and Papua New Guinea. The EWS case studies (flood or multi-hazard) were located in Kenya, Sri Lanka, Egypt, Mali, Afghanistan, India, Nepal, and Pakistan. The findings indicate that most cases for renewables were located in the African region, while for flood EWS they were located in both African and Asian regions. Another observation from the data in **Table A1** is that some of the OGRES and flood EWS cases were located in the same country (e.g. Kenya, Nepal). This shows that some regions in these countries are in need of both energy and flood resilience aid.

Besides the similarities in the lack of sufficient energy and flood resilience infrastructure, communities demonstrated differences to each other due to their differing needs, capabilities and socio-cultural makeups. For instance, communities in Bolivia used electricity for powering refrigerators, while communities in the Philippines did not. The OGRES in Bolivia and the Philippines increased income and created more jobs but not in Afghanistan. In Mali, neighboured communities and different groups were in conflict with each other due to water scarcity, however, in Hindu Kush Himalaya, communities worked well together to face floods.

Appropriate technology and sustainability mapping

The complimentary assessment frameworks [32, 33] described in Introduction are suitable to combined use to support a comprehensive review of the identified studies. **Table A2** in Appendix summarises the findings and classifies the cases based on information of failure or success outcomes. The following session further details the results of **Table A2**.

Enablers for success and failure factors

Table A2 presents important information for the technology appropriateness of both OGRES and EWS installations. Importantly, it frames enablers for successful approaches and problem solving, as well as conditions that lead to failure.

Regarding the institutional indicators, community engagement was perhaps the most important enabler for technology appropriateness as it was highlighted in many OGRES and EWS cases. Ownership and management, as well as autonomy were also important, especially when local stakeholders were involved in system development. None of the reviewed OGRES and EWS were reported to have caused any significant impacts to local ecosystems. Conversely, some OGRES were found to have supported ‘damaged’ ecosystems (e.g. reduced use of firewood). Both types of systems were most successful when adjusted to local environmental conditions (e.g. could operate/multi-function in high and low water levels). In social/ethical matters, post-installation improvements in daily activities, health conditions (e.g. reduced use of kerosene) and services, education, socializing and entertainment were crucial enablers for the success and acceptability of both system types. In the economic realm, the generation of income, creation of new jobs and low installation and maintenance costs were major success indicators. With respect to technical matters, and for both systems types, adaptability, simplicity, effectiveness, multi-purposing capacity, and materials availability were good enablers. Notably, one EWS presented hybrid characteristics (self-powered by solar panels).

In terms of failure factors in institutional matters, issues occurred when the legislation and regulations were not appropriate to such systems development. The lack of support of all kinds was also a significant disenabling factor. With respect to the environment, the systems could not operate well when they were not designed for local site conditions, while for social and ethical issues, the lack of benefits or inequitable delivering, fear of identity loss and conflicts, theft and jealously were serious failure factors. Knowledge, training and ease of use were also important criteria for the success or failure of a system. In terms of economics, the most important factor was the high cost of the systems. Furthermore, marketing strategies in local populations also contributed to the acceptance of or apathy toward systems. Lastly, in technical matters, most failures occurred when the system was not appropriately constructed, vulnerable to extreme weather conditions, energy inefficient, poorly maintained, broken, and complex. These issues were primarily the outcomes of a lack of funding, knowledge and skills and overall support.

DISCUSSION

The findings from this scoping review can help improve humanitarian engineering interventions regarding the appropriateness of OGRES and EWS in remote communities, with the outcome data examining both failure and success factors.

As noted above, OGRES were largely situated in African regions where instability in electrical power provision is common. Africa has the physical characteristics required to develop a range of renewable energy applications and increase energy supply [49-52]. For example, the Sub-Saharan region is one of the least developed regions globally with major electrification problems, so there is great potential for OGRES [16], [53-60]. The local atmospheric and hydrogeomorphological conditions permit both hydro and solar-power installations. However, countries in the Sub-Saharan region often lack resources, infrastructure, political will and funding to establish such systems on a sustainable basis [50, 54], [61-68]. Figure 2 presents the Population without Access to Electricity 2019 Map*, developed by the International Energy Agency – IEA [69]. The map focuses on countries in the 'Global South'.

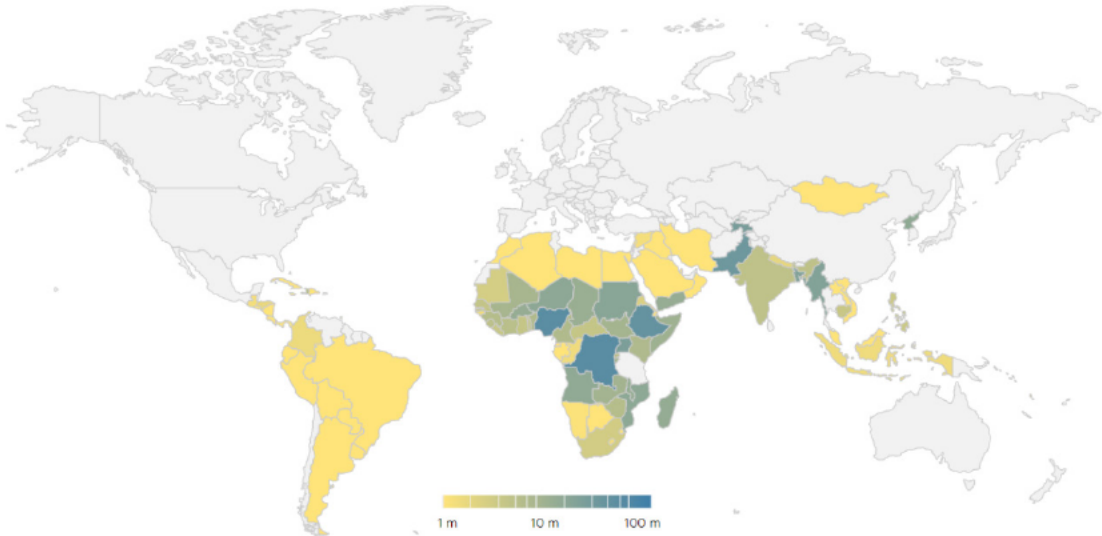


Figure 2. Population without Access to Electricity 2019 Map

Figure 2 illustrates the serious energy insufficiency of Sub-Saharan Africa. It also shows that regions in Asia (primarily Southeast Asia and Hindu Kush Himalayan) and Latin America are also in need of OGRES as their power capacity is not sufficient. Our review findings articulate with this data.

* This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Besides the Sub-Saharan region, the conditions for renewable installations in the other regions are also encouraging. For instance, the hydrogeomorphology of the Hindu Kush Himalayan is appropriate for installing small scale hydropower systems [70-72] - it is riparian and mountainous. Nepal, a country in that region, has high hydropower potential with proven economic feasibility [73-78]. Its annual average water run-off is 225 billion m^3 from more than 6,000 rivers and other stream flows [79]. Therefore, local communities can greatly benefit from localised hydropower compared to other energy sources, such as portable diesel generators and solar energy.

The findings for EWS indicated that African, as well as Asian countries were in need of flood warnings. Both the Sub-Saharan [80-82] and Hindu Kush Himalayan [83-88] regions have experienced increasing vulnerability to the impacts of climate change, particularly floods, due to increased temperatures [89, 90]. Figure 3 presents the Overall Water Risk Map, developed by the World Resource Institute's Aqueduct tool [91]. It presents evidence that Africa, Southeast Asia, Hindu Kush Himalayan and Latin America are at great risk of water-based disasters.

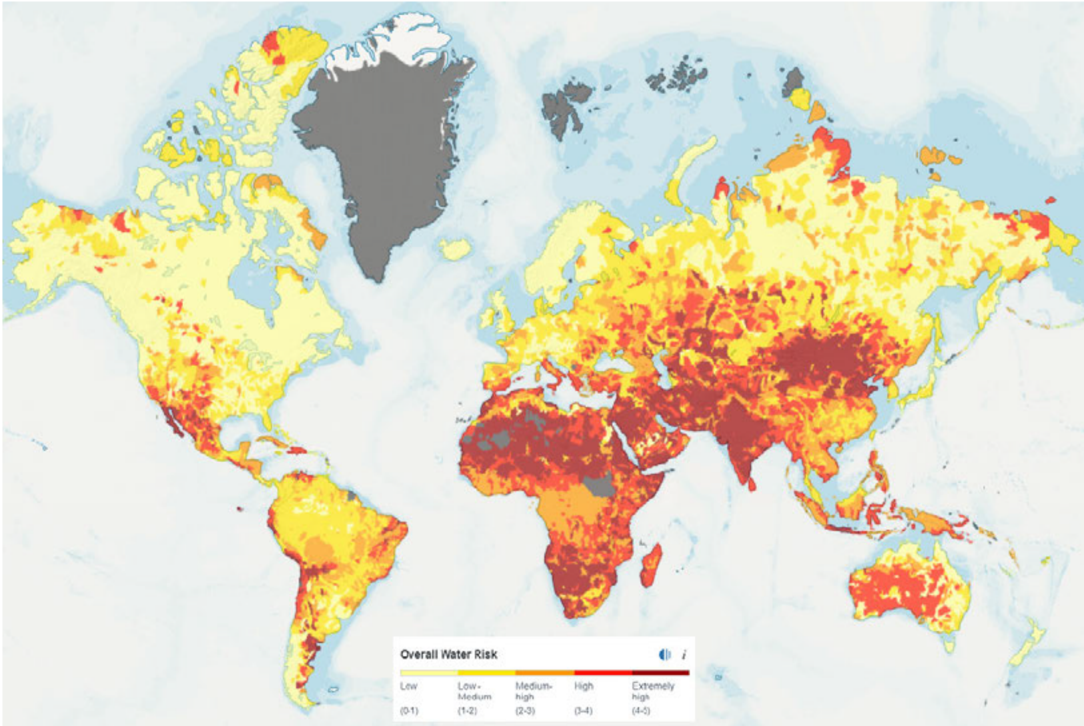


Figure 3. Overall Water Risk Map

However, it should be noted that besides the identified similarities above, differences between communities were obvious and this should be highlighted. Differences in populations exist not only between different countries and regions, but also within the same communities. Therefore, any systems developed for remote communities cannot be considered as a "one size fits all" solution - it must be co-developed with community stakeholders based on their knowledge of local conditions, values and needs, and the available/needed resources to sustain these solutions over time [92, 93].

In addition, the review identified common factors that undermined or strengthened systems' workability and longer-term use by applying the combined appropriate technology and systems evaluation tool. The findings stress the importance of collaboration between end-user communities and professionals, including key interest groups. Equity in resources and benefits, consideration of traditional or local knowledge in the processes, and community-centred management clearly contribute to increase efficiency in similar interventions [93]. A key finding with both EWS and OGRES was that community end-user groups were often minimally involved with system development, deployment and maintenance. This reflected a lack of community-focused development by implementing groups, yet it also shows community perceptions of the insufficient gain derived from them. Further, there is a clear lack of community stewardship over such systems, a critical asset in these contexts if the systems are to be maintained and scaled up over time.

The scoping review highlighted those indicators related to the complexity of the systems and unfamiliarity of end-users in proper installation, repair and maintenance. Automatic, low-tech and user-friendly localised solutions (e.g. portable, plastic, colour warning rain gauges) that correspond to the limited capabilities and resources of vulnerable communities could strengthen the success of future systems. Site-conditional indicators causing dysfunctionality in the system were also identified. As the impacts of climate change can be intense, the development of such units should endure products of extreme weather events (e.g. logs and floating debris). Climate change is contributing to more unstable weather patterns, resulting in more frequent and extreme weather events [94]. This leads to a twofold issue; it is imperative to build stronger systems in order to survive such disasters, but they must also be effective in terms of their maintenance and operations in order to overcome prolonged dry/wet periods so that they can re-focus a community's attention when flood risk returns.

Finally, one flood EWS that was self-powered by mini solar panels was detected in the review [95]. While there was no information about how other EWS were powered, this case study can be considered as a 'proof of concept' hybrid system, where renewable energy is used to power the EWS alone (i.e. system-level power). Solar energy was one of the most common type of OGRES in the reviewed case studies (along with hydropower). Collectively, this evidence suggests that that a 'scaled-up' hybrid system is feasible and could be developed, for example, a set of panels that support 'everyday' energy needs could also power local EWS (for flood and other hazard types).

A potential hybrid system for renewable energy generation and flood-warning detection at the local level could have multiple benefits for vulnerable communities and their ecosystems. It could generate free, clean continuous electricity securing energy availability to local end-users. It could also detect water level changes and inform nearby communities of potential flood development, increasing awareness and response levels. However, the data gathered regarding its constituent systems indicate that a hybrid system would need to address key issues to support successful and sustainable use in these contexts, including:

- The selection of appropriate OGRES type and parts. This should be decided based on local atmospheric and hydrogeomorphological conditions. For instance, solar panels for covering both EWS and community energy needs in mountainous areas, such as the Hindu Kush Himalayan region, may not be an appropriate solution. A key issue is the availability of solar energy equipment in the local area. In the case of malfunction (e.g. a broken solar panel), end-users may not be able to find replacement parts in the local markets or conduct repairs on their own, undermining the long-term feasibility of these systems. In this scenario, small scale hydropower generators may be the optimal solution for remote, riparian communities.
- The selection of appropriate EWS-part type: Due to the differences in response levels between communities, the flood warnings should consist of localised sirens and outdoor lights so as to serve more populations with limited capabilities. These warning devices are widely available, energy-efficient, and easy to repair or replace. Colour code variations (e.g. traffic light colour gauges, emergency lighting or different siren tones depending on flood development stages) could prepare local communities more effectively in case of scheduled or immediate evacuation.

Potential solutions to these issues could be extrapolated from the reviewed data and inform the design and development of this system so as to meet its dual aims: supporting socio-economic development and increasing flood/hazard response capabilities. Drawing on these findings, a hybrid system should combine community-level flood risk education with training planning (e.g.

evacuation drills). This would increase the response efficiency, particularly in remote communities. Based on local environmental conditions (e.g. water flow) the system should be able to generate minimum energy amounts to cover basic energy needs under both normal and extreme conditions. Excess energy could be stored in batteries for later use or delivered to other community needs.

Even when systems are seen by remote communities as providing community benefits, local participation often remains minimal. One solution to this could be a more direct and substantial involvement of communities at the planning and development stages. For example, aid organizations or civil protection authorities could work with local populations to prioritise needs, both power use and hazard management. This was the case with local communities in Nepal [14, 95]. As the system may not be able to satisfy every energy need, consultation about equitable use or common purpose may support harmonious and sustainable maintenance of the system. For example, the system could power a local classroom or public lights. Under normal conditions such lights could provide safety during the night, or increased working or study hours. This could increase income, and consequently community interest and maintenance of the system. During floods, the lights could act as emergency lights (e.g. powering an evacuation route and community hall/shelter). These developed capabilities could be used to increase disaster risk awareness and improve response (e.g. evacuation drills). This may be of particular benefit to the community's planning for, and developing the capabilities of, vulnerable groups such as the elderly and people with mobility issues.

The co-design of such systems between professional and community stakeholders could increase community interest in the longer term. Professional stakeholders should provide information on technical aspects of the system, while community engagement should emphasise traditional know-how, and address potential concerns about changes for the community, and enhance familiarization with the system's functions. In such instances, a system is less likely to be 'foreign' and different community groups are more likely to collaborate to support proper operation. This approach would minimise failures. In order to increase end-users' involvement in pre and post-installation phases, the system could be made of readily available materials (e.g. recycled components or parts that are available in most countries and online) and/or be designed using do-it-yourself (DIY), and easy-to-deploy-and-operate (EDO) techniques [96]. These techniques increase system adaptation through community participation [97]. Such systems are widely known for their ease of assembly, deployment and capacity to be repaired (e.g. home furniture and appliances) without the need of professionals. They also include aspects of leisure, work and education, and are used across a range of fields including engineering, medicine, emergency management, energy and occupational safety [98]. Importantly, some small-scale hydropower and solar energy projects are designed based on these techniques [99].

Such approaches offer advantages to humanitarian engineering while also supporting perceived 'ownership' within beneficiary communities [97], and would include the potential to minimise or eliminate reliance on external technicians and promote community-based skills centred on repair and ongoing maintenance. Community access and oversight of this kind could reduce the risk of technological failures. In order to increase endurance against weather extremes and other environmental impacts, the appropriate location of systems could be determined based on hierarchical flood risk models at the local level. This data could then inform community deliberations as to placement and use, as well as contributing to the resolution of other issues to be factored in regarding site selection.

CONCLUSIONS

This article has critically reviewed cases of communities using OGRES and EWS. It presented existing concepts and emphasised failure and success indicators and their reported sources using a combined tool for appropriate technology and sustainability evaluation. The wider aim of this study was to consider the feasibility of an integrated system supporting both the flood resilience and socio-economic development of remote communities. The study also explored how lacking capabilities in energy generation and flood resilience affect local populations. Vulnerable communities in low and lower-middle income countries are at higher risk, and external assistance is often needed to establish suitable protections. While humanitarian engineering interventions can provide such support, it is common for these interventions to fail over time, often because they are not designed in conjunction with the community, or with specific regard to the community's context and needs.

Recommended features for more appropriate design include: the input of community stakeholders; technology appropriateness for the consideration of local/traditional knowledge in the processes; scaling of community demands based on energy availability; and use of techniques such as the DIY and EDO in assembling and maintaining systems were highlighted.

Further research is needed to better understand how local knowledge can best adapt to these technologies in order to strengthen the feasibility analysis of hybrid systems. Such systems have the potential to support local ecosystems in sustainable ways, as well as provide vital services to remote populations.

Limitations and future work

Future studies could include databases and journals that are not considered in this scoping review. This would allow more comprehensive findings. Follow-up research should also focus on how the COVID-19 pandemic affected the sustainability of OGRES and EWS in remote communities, and how local energy and disaster response needs changed or escalated during the lockdown restrictions.

REFERENCES

1. X. Li, "Diversification and localization of energy systems for sustainable development and energy security," Energy Policy, vol. 33, no. 17, pp. 2237-2243, Nov. 2005, https://doi.org/10.1016/j.enpol.2004.05.002.
2. B. Nagpal, Divyam and Parajuli, Off-grid renewable energy solutions to expand electricity access: An opportunity not to be missed. 2019.
3. M. Aien and O. Mahdavi, "On the Way of Policy Making to Reduce the Reliance of Fossil Fuels: Case Study of Iran," Sustainability, vol. 12, no. 24, p. 10606, Dec. 2020, https://doi.org/10.3390/su122410606.
4. G. Mutezo and J. Mulopo, "A review of Africa's transition from fossil fuels to renewable energy using circular economy principles," Renew. Sustain. Energy Rev., vol. 137, p. 110609, Mar. 2021, https://doi.org/10.1016/j.rser.2020.110609.
5. "List of lower and lower middle-income countries," World Bank Country and Lending Groups. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups [Accessed: Jan. 26, 2021].
6. IRENA, OFF-GRID RENEWABLE ENERGY SOLUTIONS Global and regional status and trends. International Renewable Energy Agency (IRENA), 2018.
7. J. C. I. Rabetanetiarimanana, M. H. Radanielina, and H. T. Rakotondramiarana, "PV-Hybrid Off-Grid and Mini-Grid Systems for Rural Electrification in Sub-Saharan Africa," Smart Grid Renew. Energy, vol. 09, no. 10, pp. 171-185, 2018, https://doi.org/10.4236/sgre.2018.910011.
8. United Nations, "Transforming our world: The 2030 agenda for sustainable development," 2016. https://sustainabledevelopment.un.org/content/documents/21252030 [Accessed: Jan. 15, 2021].
9. G. Lahn and O. Grafham, "Heat, light and power for refugees: saving lives, reducing costs," 2015.
10. M. Caniato, D. Carliez, and A. Thulstrup, "Challenges and opportunities of new energy schemes for food security in humanitarian contexts: A selective review," Sustain. Energy

Technol. Assessments, vol. 22, pp. 208-219, Aug. 2017, https://doi.org/10.1016/j.seta.2017.02.006.

11. L. Pearson and M. Pelling, "The UN Sendai Framework for Disaster Risk Reduction 2015-2030: Negotiation Process and Prospects for Science and Practice," J. Extrem. Events, vol. 02, no. 01, p. 1571001, 2015, https://doi.org/10.1142/s2345737615710013.
12. P. Seck, "Links between natural disasters, humanitarian assistance and disaster risk reduction: A critical perspective," Occas. Pap., vol. 15, 2007.
13. J. Linnerooth-Bayer and S. Hochrainer-Stigler, "Financial instruments for disaster risk management and climate change adaptation," Clim. Change, vol. 133, no. 1, pp. 85-100, Nov. 2015, https://doi.org/10.1007/s10584-013-1035-6.
14. A. Gurung, I. Bryceson, J. H. Joo, and S. E. Oh, "Socio-economic impacts of a micro-hydropower plant on rural livelihoods," Sci. Res. Essays, vol. 6, no. 19, pp. 3964-3972, 2011, https://doi.org/10.5897/sre10.766.
15. M.-A. Baudoin, S. Henly-Shepard, N. Fernando, A. Sitati, and Z. Zommers, "Early warning systems and livelihood resilience: Exploring opportunities for community participation," UNU-EHS Work. Pap. Ser., vol. 1, 2014, [Online]. Available: http://www.munichre-foundation.org/dms/MRS/Documents/Resilience-Academy/2014_resilience_academy_wp1.pdf .
16. K. Simmons, "Sub-Saharan Africa makes progress against poverty but has long way to go," Pew Research Center, 2015. http://www.pewresearch.org/fact-tank/2015/09/24/sub-saharan-africa-makes-progress-against-poverty-but-has-long-way-to-go/ [Accessed: Jan. 16, 2021].
17. M. Howells, H. H. Rogner, D. Mentis, and O. Broad, "Energy Access and Electricity Planning," State Electr. access Rep., p. 16, 2017.
18. C. Phillips, "Combining Energy Efficiency and Disaster Mitigation Efforts in Residential Properties," Office of Policy Development and Research, 2017. https://www.huduser.gov/portal/periodicals/em/spring17/highlight2.html [Accessed: Jan. 16, 2021].
19. S. Schismenos, G. J. Stevens, D. Emmanouloudis, N. Georgeou, S. Shrestha, and M. Chalaris, "Humanitarian engineering and vulnerable communities: hydropower applications in localised flood response and sustainable development," Int. J. Sustain. Energy, vol. 39, no. 10, pp. 941-950, 2020, https://doi.org/10.1080/14786451.2020.1779274.
20. J. Gosink, J. Lucena, and B. Moskal, "Humanitarian engineering at the Colorado school of mines: An example of multidisciplinary engineering," in ASEE Annual Conference Proceedings, 2003, pp. 10161-10175, https://doi.org/10.18260/1-2--11871.
21. S. Hill and E. Miles, "What do students understand by the term 'Humanitarian Engineering'?," 2012.
22. A. Sheroubi and G. Potvin, "Humanitarian Engineering: A New Interdisciplinary Course on the Application of Engineering Skills to Local and Global Humanitarian Challenges," 2018, https://doi.org/10.24908/pceea.v0i0.12963.
23. J. Kellet and K. Peters, "Dare to prepare: taking risk seriously. Summary," pp. 1-18, 2014.
24. A. Mazzurco and B. K. Jesiek, "Five Guiding Principles to Enhance Community Participation in Humanitarian Engineering Projects.," J. Humanit. Eng., vol. 5, no. 2, 2017, https://doi.org/10.36479/jhe.v5i2.80.
25. J. S. Younger, D. J. Booth, D. E. Parry, and K. Kurniawan, "Sustainable humanitarian engineering in practice - The East Bali Poverty Project," Proc. Inst. Civ. Eng. Munic. Eng., vol. 171, no. 2, pp. 67-77, 2018, https://doi.org/10.1680/jmuen.16.00034.
26. C. P. M. Sianipar, G. Yudoko, A. Adhiutama, and K. Dowaki, "Community Empowerment through Appropriate Technology: Sustaining the Sustainable

Development," Procedia Environ. Sci., vol. 17, pp. 1007-1016, 2013, https://doi.org/10.1016/j.proenv.2013.02.120.

27. L. Garniati, A. Owen, J. Kruijsen, Y. Ishadamy, and I. Wibisono, "Interface between appropriate technology and sustainable energy policy in vulnerable societies," Sustain. Cities Soc., vol. 12, pp. 9-15, Jul. 2014, https://doi.org/10.1016/j.scs.2013.10.003.
28. C. P. M. Sianipar, K. Dowaki, and G. Yudoko, "Technological solution for vulnerable communities: How does its approach matter?," IOP Conf. Ser. Mater. Sci. Eng., vol. 58, p. 012022, Jun. 2014, https://doi.org/10.1088/1757-899X/58/1/012022.
29. C. P. M. Sianipar, G. Yudoko, and A. Adhiutama, "Technological Solution for Vulnerable Communities: Reverse Engineering Below the Radar," Adv. Sci. Lett., vol. 20, no. 10, pp. 2282-2286, Oct. 2014, https://doi.org/10.1166/asl.2014.5726.
30. G. W. Hong and N. Abe, "Sustainability assessment of renewable energy projects for off-grid rural electrification: The Pangan-an Island case in the Philippines," Renew. Sustain. Energy Rev., vol. 16, no. 1, pp. 54-64, 2012, https://doi.org/10.1016/j.rser.2011.07.136.
31. J. Terrapon-Pfaff, C. Dienst, J. König, and W. Ortiz, "How effective are small-scale energy interventions in developing countries? Results from a post-evaluation on project-level," Appl. Energy, vol. 135, pp. 809-814, 2014, https://doi.org/10.1016/j.apenergy.2014.05.032.
32. A. M. Bauer and A. Brown, "Quantitative assessment of appropriate technology," Procedia Eng., vol. 78, pp. 345-358, 2014, https://doi.org/10.1016/j.proeng.2014.07.076.
33. E. Ilskog, "Indicators for assessment of rural electrification-An approach for the comparison of apples and pears," Energy Policy, vol. 36, no. 7, pp. 2665-2673, 2008, https://doi.org/10.1016/j.enpol.2008.03.023.
34. E. Ilskog and B. Kjellström, "And then they lived sustainably ever after?-Assessment of rural electrification cases by means of indicators," Energy Policy, vol. 36, no. 7, pp. 2674-2684, 2008, https://doi.org/10.1016/j.enpol.2008.03.022.
35. H. Arksey and L. O'Malley, "Scoping studies: Towards a methodological framework," Int. J. Soc. Res. Methodol. Theory Pract., vol. 8, no. 1, pp. 19-32, 2005, https://doi.org/10.1080/1364557032000119616.
36. T. Schöne et al., "GPS water level measurements for Indonesia's tsunami early warning system," Nat. Hazards Earth Syst. Sci., vol. 11, no. 3, pp. 741-749, 2011, https://doi.org/10.5194/nhess-11-741-2011.
37. E. Intrieri, G. Gigli, F. Mugnai, R. Fanti, and N. Casagli, "Design and implementation of a landslide early warning system," Eng. Geol., vol. 147-148, pp. 124-136, 2012, https://doi.org/10.1016/j.enggeo.2012.07.017.
38. S. Azid, B. Sharma, K. Raghuwaiya, A. Chand, S. Prasad, and A. Jacquier, "SMS based flood monitoring and early warning system," ARPN J. Eng. Appl. Sci., vol. 10, no. 15, pp. 6387-6391, 2015.
39. S. Schismenos, G. J. Stevens, D. Emmanouloudis, N. Georgeou, S. Shrestha, and M. Chalaris, "Humanitarian engineering at the sustainability-development nexus: mapping vulnerability and capability factors for communities at risk of water-based disasters," Sustain. Sci., 2021, https://doi.org/10.1007/s11625-020-00890-y.
40. M. T. Pham, A. Rajić, J. D. Greig, J. M. Sargeant, A. Papadopoulos, and S. A. Mcewen, "A scoping review of scoping reviews: Advancing the approach and enhancing the consistency," Res. Synth. Methods, vol. 5, no. 4, pp. 371-385, 2014, https://doi.org/10.1002/jrsm.1123.
41. N. Wali, N. Georgeou, O. Simmons, M. S. Gautam, and S. Gurung, "Women and WASH in Nepal: a scoping review of existing literature," Water Int., vol. 45, no. 3, pp. 222-245, 2020, https://doi.org/10.1080/02508060.2020.1754564.

42. A. Grenier, S. Hatzifilalithis, D. Laliberte-Rudman, K. Kobayashi, P. Marier, and C. Phillipson, "Precarity and Aging: A Scoping Review," Gerontologist, vol. 60, no. 8, pp. e620-e632, Nov. 2020, https://doi.org/10.1093/geront/gnz135.
43. S. Hausknecht, L.-F. Low, K. O'Loughlin, J. McNab, and L. Clemson, "Older Adults' Self-Perceptions of Aging and Being Older: A Scoping Review," Gerontologist, vol. 60, no. 7, pp. e524-e534, Sep. 2020, https://doi.org/10.1093/geront/gnz153.
44. G. J. Stevens, T. Bienz, N. Wali, J. Condie, and S. Schismenos, "Online university education is the new normal: but is face-to-face better?," Interact. Technol. Smart Educ., vol. ahead-of-p, no. ahead-of-print, Jan. 2021, https://doi.org/10.1108/ITSE-08-2020-0181.
45. S. Schismenos, M. Chalaris, and G. Stevens, "Battery hazards and safety: A scoping review for lead acid and silver-zinc batteries," Saf. Sci., vol. 140, p. 105290, 2021, https://doi.org/10.1016/j.ssci.2021.105290.
46. M. Arnaiz, T. A. Cochrane, R. Hastie, and C. Bellen, "Micro-hydropower impact on communities' livelihood analysed with the capability approach," Energy Sustain. Dev., vol. 45, pp. 206-210, 2018, https://doi.org/10.1016/j.esd.2018.07.003.
47. A. Shoaib and S. Ariaratnam, "A Study of Socioeconomic Impacts of Renewable Energy Projects in Afghanistan," Procedia Eng., vol. 145, pp. 995-1003, 2016, https://doi.org/10.1016/j.proeng.2016.04.129.
48. B. V. and C. V, "Using thematic analysis in psychology.," Qual. Res. Psychol., vol. 3, no. 2, pp. 77-101, 2006.
49. U. Deichmann, C. Meisner, S. Murray, and D. Wheeler, "The economics of renewable energy expansion in rural Sub-Saharan Africa," Energy Policy, vol. 39, no. 1, pp. 215-227, 2011, https://doi.org/10.1016/j.enpol.2010.09.034.
50. H. Ahlborg and L. Hammar, "Drivers and barriers to rural electrification in Tanzania and Mozambique - Grid-extension, off-grid, and renewable energy technologies," Renew. Energy, vol. 61, pp. 117-124, Jan. 2014, https://doi.org/10.1016/j.renene.2012.09.057.
51. N. P. Simpson, C. J. Rabenold, M. Sowman, and C. D. Shearing, "Adoption rationales and effects of off-grid renewable energy access for African youth: A case study from Tanzania," Renew. Sustain. Energy Rev., vol. 141, p. 110793, May 2021, https://doi.org/10.1016/j.rser.2021.110793.
52. J. M. Ngowi, L. Bångens, and E. O. Ahlgren, "Benefits and challenges to productive use of off-grid rural electrification: The case of mini-hydropower in Bulongwa-Tanzania," Energy Sustain. Dev., vol. 53, pp. 97-103, Dec. 2019, https://doi.org/10.1016/j.esd.2019.10.001.
53. M. L. rew, "Towards sustainable financing models for micro-hydro plants in Sub-Saharan African countries: A theoretical review," J. Econ. Int. Financ., vol. 8, no. 3, pp. 19-33, 2016, https://doi.org/10.5897/jeif2016.0750.
54. E. C. X. Ikejemba, P. B. Mpuan, P. C. Schuur, and J. Van Hillegersberg, "The empirical reality & sustainable management failures of renewable energy projects in Sub-Saharan Africa (part 1 of 2)," Renew. Energy, vol. 102, pp. 234-240, 2017, https://doi.org/10.1016/j.renene.2016.10.037.
55. Y. S. Mohammed, M. W. Mustafa, and N. Bashir, "Status of renewable energy consumption and developmental challenges in Sub-Sahara Africa," Renew. Sustain. Energy Rev., vol. 27, pp. 453-463, Nov. 2013, https://doi.org/10.1016/j.rser.2013.06.044.
56. L. Nyiwul, "Economic performance, environmental concerns, and renewable energy consumption: drivers of renewable energy development in Sub-Sahara Africa," Clean Technol. Environ. Policy, vol. 19, no. 2, pp. 437-450, Mar. 2017, https://doi.org/10.1007/s10098-016-1229-5.
57. D. Frame, K. Tembo, M. J. Dolan, S. M. Strachan, and G. W. Ault, "A community based approach for sustainable off-grid PV systems in developing countries," in 2011 IEEE

Power and Energy Society General Meeting, Jul. 2011, pp. 1-7, https://doi.org/10.1109/PES.2011.6039593.

58. B. Pillot, "Off-grid rural electrification planning in Sub-Saharan Africa using renewable energy systems: the case of photovoltaics in the Republic of Djibouti."
59. K. Gebrehiwot, M. A. H. Mondal, C. Ringler, and A. G. Gebremeskel, "Optimization and cost-benefit assessment of hybrid power systems for off-grid rural electrification in Ethiopia," Energy, vol. 177, pp. 234-246, 2019, https://doi.org/10.1016/j.energy.2019.04.095.
60. C. S. Kaunda, C. Z. Kimambo, and T. K. Nielsen, "Potential of Small-Scale Hydropower for Electricity Generation in Sub-Saharan Africa," ISRN Renew. Energy, vol. 2012, pp. 1-15, Aug. 2012, https://doi.org/10.5402/2012/132606.
61. D. A. Quansah, M. S. Adaramola, and L. D. Mensah, "Solar Photovoltaics in Sub-Saharan Africa - Addressing Barriers, Unlocking Potential," Energy Procedia, vol. 106, pp. 97-110, Dec. 2016, https://doi.org/10.1016/j.egypro.2016.12.108.
62. S. C. Bhattacharyya, "Financing energy access and off-grid electrification: A review of status, options and challenges," Renew. Sustain. Energy Rev., vol. 20, pp. 462-472, Apr. 2013, https://doi.org/10.1016/j.rser.2012.12.008.
63. R. Fischer, J. Lopez, and S. Suh, "Barriers and drivers to renewable energy investment in sub-Saharan Africa," J. Environ. Invest., vol. 2, no. 1, pp. 54-80, 2011.
64. H. Louie, G. Goldsmith, P. Dauenhauer, and R. H. Almeida, "Issues and applications of real-time data from off-grid electrical systems," in 2016 IEEE PES PowerAfrica, Jun. 2016, pp. 88-92, https://doi.org/10.1109/PowerAfrica.2016.7556577.
65. E. Quak, "Lighting and Electricity Services for Off-Grid Populations in Sub-Sahara Africa," 2018.
66. C. G. Monyei, A. O. Adewumi, and K. E. H. Jenkins, "Energy (in)justice in off-grid rural electrification policy: South Africa in focus," Energy Res. Soc. Sci., vol. 44, pp. 152-171, Oct. 2018, https://doi.org/10.1016/j.erss.2018.05.002.
67. S. Baurzhan and G. P. Jenkins, "Off-grid solar PV: Is it an affordable or appropriate solution for rural electrification in Sub-Saharan African countries?," Renew. Sustain. Energy Rev., vol. 60, pp. 1405-1418, Jul. 2016, https://doi.org/10.1016/j.rser.2016.03.016.
68. S. Samarakoon, "The troubled path to ending darkness: Energy injustice encounters in Malawi's off-grid solar market," Energy Res. Soc. Sci., vol. 69, p. 101712, Nov. 2020, https://doi.org/10.1016/j.erss.2020.101712.
69. IEA, "SDG7: Data and Projections," SDG7: Data and Projections, 2020. https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity%0Ahttps://www.iea.org/reports/sdg7-data-and-projections [Accessed: May 01, 2021].
70. S. Dhakal et al., "Meeting future energy needs in the Hindu Kush Himalaya," in The Hindu Kush Himalaya Assessment, Springer, 2019, pp. 167-207.
71. A. Hussain et al., "Hydropower development in the Hindu Kush Himalayan region: Issues, policies and opportunities," Renew. Sustain. Energy Rev., vol. 107, pp. 446-461, Jun. 2019, https://doi.org/10.1016/j.rser.2019.03.010.
72. R. Vaidya, "Water and hydropower in the green economy and sustainable development of the Hindu Kush--Himalayan region," J. Int. Assoc. Electr. Gener. Transm. Distrib., vol. 25, no. 2, pp. 21-30, 2012.
73. S. Pokharel, "Promotional issues on alternative energy technologies in Nepal," Energy Policy, vol. 31, no. 4, pp. 307-318, 2003, https://doi.org/10.1016/S0301-4215(02)00043-5.
74. D. Adhikari, "Hydropower development in Nepal," NRB Econ. Rev., vol. 18, pp. 70-94, 2006.

75. F. Alam, Q. Alam, S. Reza, S. M. Khurshid-ul-Alam, K. Saleque, and H. Chowdhury, "A Review of Hydropower Projects in Nepal," Energy Procedia, vol. 110, pp. 581-585, Mar. 2017, https://doi.org/10.1016/j.egypro.2017.03.188.
76. H. Gunatilake, P. Wijayatunga, and D. Roland-Holst, "Hydropower development and economic growth in Nepal," 2020.
77. R. H. Sharma and R. Awal, "Hydropower development in Nepal," Renew. Sustain. Energy Rev., vol. 21, pp. 684-693, May 2013, https://doi.org/10.1016/j.rser.2013.01.013.
78. S. K.C., S. K. Khanal, P. Shrestha, and B. Lamsal, "Current status of renewable energy in Nepal: Opportunities and challenges," Renew. Sustain. Energy Rev., vol. 15, no. 8, pp. 4107-4117, Oct. 2011, https://doi.org/10.1016/j.rser.2011.07.022.
79. D. P. Sangroula, "Hydropower Development and Its Sustainability With Respect to Sedimentation in Nepal," J. Inst. Eng., vol. 7, no. 1, pp. 56-64, 1970, https://doi.org/10.3126/jie.v7i1.2063.
80. F. A. Armah, D. O. Yawson, G. T. Yengoh, J. O. Odoi, and E. K. A. Afrifa, "Impact of Floods on Livelihoods and Vulnerability of Natural Resource Dependent Communities in Northern Ghana," Water, vol. 2, no. 2, pp. 120-139, Apr. 2010, https://doi.org/10.3390/w2020120.
81. D. K. Ahadzie and D. G. Proverbs, "Emerging issues in the management of floods in ghana," Int. J. Saf. Secur. Eng., vol. 1, no. 2, pp. 182-192, Aug. 2011, https://doi.org/10.2495/SAFE-V1-N2-182-192.
82. H. W. Njogu, "Effects of floods on infrastructure users in Kenya," J. Flood Risk Manag., Jul. 2021, https://doi.org/10.1111/jfr3.12746.
83. X. Jianchu, M. Eriksson, J. Ferdinand, and J. Merz, "Managing flash floods and sustainable development in the Himalayas," 2006.
84. H. K. Nibanupudi and M. Khadka, "Gender and Disaster Resilience in the Hindu Kush Himalayan Region," 2015, pp. 233-249.
85. S. Elalem and I. Pal, "Mapping the vulnerability hotspots over Hindu-Kush Himalaya region to flooding disasters," Weather Clim. Extrem., vol. 8, pp. 46-58, Jun. 2015, https://doi.org/10.1016/j.wace.2014.12.001.
86. R. A. Vaidya et al., "Disaster Risk Reduction and Building Resilience in the Hindu Kush Himalaya," in The Hindu Kush Himalaya Assessment, Cham: Springer International Publishing, 2019, pp. 389-419.
87. M. Eriksson, J. Fang, and J. Dekens, "How does climate change affect human health in the Hindu Kush-Himalaya region," in Regional Health Forum, 2008, vol. 12, no. 1, pp. 11-15.
88. Atta-ur-Rahman and R. Shaw, "Floods in the Hindu Kush Region: Causes and Socio-Economic Aspects," 2015, pp. 33-52.
89. L. Zwarts, V. B. Beuering, B. Kone, and E. Wymenga, "The Niger , a lifeline: effective water management in the Upper Niger Basin," Africa (Lond)., no. Ivm, p. 304, 2005.
90. "Community-based flood early-warning system - India, United Nations Framework Convention on Climate Change," United Nations Framework Convention on Climate Change, 2020.
91. Aqueduct, "Overall Water Risk," Water Risk Atlas. https://www.wri.org/applications/aqueduct/water-risk-atlas/#/?advanced=false&basemap=hydro&indicator=w_awr_def_tot_cat&lat=30&lng=-80&mapMode=view&month=1&opacity=0.5&ponderation=DEF&predefined=false&projection=absolute&scenario=optimistic&scope=baseline&timeScale=annual&year=baseline&zoom=3 [Accessed: Apr. 25, 2021].
92. N. Georgeou and C. Hawksley, "Enhancing Research Impact in International Development: A Practical Guide for Practitioners and Researchers," 2020. [Online]. Available: https://rdinetwork.org.au/resources/enhancing-research-impact-in-international-development-a-practical-guide-for-practitioners-and-researchers/ .

93. S. Schismenos, G. J. Stevens, D. Emmanouloudis, N. Georgeou, S. Shrestha, and N. D. Katopodes, "Using off-grid hydropower for community-led flood resilience: an integrated systems approach," Int. J. Sustain. Energy, pp. 1-15, Aug. 2021, https://doi.org/10.1080/14786451.2021.1961773.
94. V. Murray and K. L. Ebi, "IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)," J. Epidemiol. Community Health, vol. 66, no. 9, pp. 759-760, 2012, https://doi.org/10.1136/jech-2012-201045.
95. ICIMOD, "Community-based Flood Early Warning System: The Story from Then to Now," 2018. [Online]. Available: http://www.unisdr.org/2006/ppew/whats-ew/basics-ew.htm .
96. S. Nair et al., "Design of a do-it-yourself (DIY) based solar-powered led lighting system for training and empowering rural youth," 2019, [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85060282798&doi=10.1007%2F978-981-13-5974-3_39&partnerID=40&md5=b5dd5ecc3c08a5c36b579a433f391a9f .
97. T. Honma, "Advancing Alternative Pathways to Science: Community Partnership, Do-It-Yourself (DIY)/Do-It-Together (DIT) Collaboration, and STEM Learning 'from Below,'" Transform. J. Incl. Scholarsh. Pedagog., vol. 27, no. 1, pp. 41-50, 2017, https://doi.org/10.1353/tnf.2017.0004.
98. E. W. Smith, DIY solar projects. How to put the sun to work in your home. 2011.
99. S. Jaglin, "Electricity autonomy and power grids in Africa: From rural experiments to urban hybridizations," in Local Energy Autonomy: Spaces, Scales, Politics, 2019, pp. 291-314.
100. J. Butchers, S. Williamson, J. Booker, A. Tran, P. B. Karki, and B. Gautam, "Understanding sustainable operation of micro-hydropower: a field study in Nepal," Energy Sustain. Dev., vol. 57, pp. 12-21, 2020, https://doi.org/10.1016/j.esd.2020.04.007.
101. A. J. Njoh, S. Etta, I. B. Ngyah-Etchutambe, L. E. D. Enomah, H. T. Tabrey, and U. Essia, "Opportunities and challenges to rural renewable energy projects in Africa: Lessons from the Esaghem Village, Cameroon solar electrification project," Renew. Energy, vol. 131, pp. 1013-1021, 2019, https://doi.org/10.1016/j.renene.2018.07.092.
102. A. F. Crossland, O. H. Anuta, and N. S. Wade, "A socio-technical approach to increasing the battery lifetime of off-grid photovoltaic systems applied to a case study in Rwanda," Renew. Energy, vol. 83, pp. 30-40, 2015, https://doi.org/10.1016/j.renene.2015.04.020.
103. J. Kenfack, O. V. Bossou, J. Voufo, and S. Djom, "Addressing the current remote area electrification problems with solar and microhydro systems in Central Africa," Renew. Energy, vol. 67, pp. 10-19, 2014, https://doi.org/10.1016/j.renene.2013.11.044.
104. E. M. Nfah and J. M. Ngundam, "Identification of stakeholders for sustainable renewable energy applications in Cameroon," Renew. Sustain. Energy Rev., vol. 16, no. 7, pp. 4661-4666, 2012, https://doi.org/10.1016/j.rser.2012.05.019.
105. A. K. Sovacool, A. L. D'Agostino, and M. Jain Bambawale, "The socio-technical barriers to Solar Home Systems (SHS) in Papua New Guinea: 'Choosing pigs, prostitutes, and poker chips over panels,'" Energy Policy, vol. 39, no. 3, pp. 1532-1542, 2011, https://doi.org/10.1016/j.enpol.2010.12.027.
106. J. Cools, D. Innocenti, and S. O'Brien, "Lessons from flood early warning systems," Environ. Sci. Policy, vol. 58, pp. 117-122, 2016, https://doi.org/10.1016/j.envsci.2016.01.006.

Paper submitted: 05.05.2021
Paper revised: 11.08.2021
Paper accepted: 18.08.2021

APPENDIX

Table A1. Summary of case studies

Author/s (year)	Methodology	System type	Region(s), site(s) and/or population(s)	Findings	
				Failure and Issue indicators	Success indicators
Butchers *et al.* (2020) [100]	Mixed methods - maintenance assessment, and interviews with managers, operators and consumers	Micro-hydropower systems	Nepal, 24 sites [NE24]: 2 private, 2 co-operative and 20 community-owned	Pre and post-installation technical issues. In some cases, the collected income from tariffs was not sufficient to pay repairs.	Regular maintenance in most sites. Communities were paying tariffs. Communities were actively engaged.
Njoh *et al.* (2019) [101]	Mixed methods - primary data analysis via direct in-situ observations including site survey, data collection on homes and energy consumption, and project records; secondary data analysis via published and unpublished materials	Solar system	Cameroon, Esaghem village [CAES1]: Esaghem Solar PV Electrification Project	Prolonged or heavy rainfalls affected power efficiency. High equipment costs due to low densities and area inaccessibility. No previous/appropriate infrastructure for such renewable type in the village. Lack of pre and post installation/maintenance personnel. Insufficient funding from both community and non-community sources. Hydropower marketing and demand neglected solar solutions. Overall lack of interest in renewable energy systems. Authorities showed no high interest in renewables investing.	The village is located on a hill and exposed to sunlight - good conditions for solar installation. Community was willing to participate in the project.

Arnaiz *et al.* (2018) [46]	Mixed methods - evaluation of 17 remote communities (site/community visits, engagement with local developers, and community interviews)	Micro-hydropower systems	Bolivia, 9 communities in the regions of [BO9]: -Andean -Sub-Andean -Llanos	Television and refrigerators contributed to cultural changes and children's obesity according to the elderly.	Sense of empowerment, teamwork, general comfort. Job creation (e.g. system's operation and maintenance. personnel) and income increase Improvements in health and diet due to refrigerator uses (e.g. for prolonging medical supplies), reduced kerosene uses and increased lighting (e.g. lights at night reduced stumbling for the elderly). Power used in devices for emergency services (radio and phone). Improvements in children's education.
			Philippines, 8 communities in the regions of [PH8]: -Cordillera -Negros Island	No significant improvements in health and diet as the communities did not use refrigerator and emergency lines.	Sense of empowerment, teamwork, general comfort. Job creation (e.g. system's operation and maintenance personnel) and income increase. Improvements in children's education.

Ikejemba *et al.* (2017) [54]	Mixed methods - ethnographic approach (interviews with stakeholders and site visit observations)	Hydropower and solar systems (small and larger scales)	Sub-Sahara, several communities and sites [SUS8]: -Ethiopia -Gabon -Ghana -Kenya -Malawi -Mozambique -Nigeria -Tanzania South Africa – excluded from this research	Publicly funded projects presented prolonged timelines due to limited budget and multiple stakeholders. Poor management, maintenance and reparability in post-installation stages. Local communities hesitated to accept such systems due to insufficient benefits. Lack of technical know-how, supportive regulations, logistics and supply chain. Incidents of project completion failure or sub-completion (e.g. their scale is smaller than initially intended). Conflicts between landowners and project managers due to insufficient benefits. In some cases, ownership was not shared fairly. Local communities were unwilling to participate in processes (e.g. repair and maintenance) due to complicated tasks, lack of education/training, and insufficient benefits. Jealously, sabotage, theft and vandalism.	-
Shoaib and Ariaratnam (2016) [47]	Mixed methods - two-phase analysis: assessment of existing literature and technologies, and data collection via questionnaire development, pilot project selection, data collection and data analysis	micro-hydropower systems, windmills, and solar home systems	Afghanistan, 2 communities [AF2]: -Sheikh Ali -Shebar	No major improvements in economic conditions (i.e. limited job creation and no new/improved enterprises) possibly due to power delivery primarily to homes and not industries/production.	Improvements in well-being and daily activities. Improvements in health. Improvements in education and government services.

Crossland *et al.* (2015) [102]	Mixed methods – four week socio-technical field study using measured demand data, system surveys and semi-structured interviews	Off-grid solar systems	Rwanda, rural communities and sites [RW9]: -8 health centres, and -1 school	High power demand during night hours in all sites. Poor installation, maintenance, repair and monitoring due to high costs or lack of technical understanding and education. Power failure due to overloading. Consumers' perception that solar energy is unlimited. Solar panels were under-sized and battery could not fully charge. Systems were vulnerable to extreme weather events (e.g. lightnings). Power shortage during raining season.	Improvements in security, safety, lighting, communication, education and administration. Improvements in health services - prolonged conditions for medical supplies, and equipment sterilization. Improvements in health due to the reduced kerosene uses.
Kenfack *et al.* (2014) [103]	Mixed methods - data collection during implementation phase, literature survey, interviews with stakeholders in power sector, and field observations	Micro-hydropower systems	Central Africa, rural communities and projects [CEA4]: -Cameroon -Central African Republic -Chad -Republic of Congo	Unfitting size, design and construction. Lack of durable materials, second handed or wrong equipment. Pool local capacity in systems' design and development. Lack of maintenance. Lack of local infrastructure for manufacturing. Power failure due to weather extremes (e.g. during low or high-water levels). Circuit failure due to overloading. Poor community engagement. High cost compared to traditional energy sources (e.g. firewood, petrol and gas generators).	Systems operated well when communities participated in the processes and there were available technical solutions.

		Solar systems		Poor institutional management and regulations. Lack of know-how. Poor actors' capacity. Unfitting size, battery type, regulation and control of charger/discharger. High cost compared to traditional energy sources (e.g. firewood, petrol and gas generators).	Systems operated well when sizing and maintenance were proper. Popular renewable type due to sufficient promotion.
Hong and Abe (2012) [30]	Case study using multiple correspondence analysis	Centralised off-grid solar plant	Philippines [PH1], Pangan-an Island Solar Electrification Project	Monthly tariffs could not be paid, and this discouraged connections. Operational costs increased when connections reduced. Capacity development and maintenance required external funding. Plant's insufficiency resulted in people turning to conventional power sources.	Improvements in life quality. Improvements in education and daily activities.
Nfah and Ngundam (2012) [104]	Review of existing renewable energy applications	Solar and pico-hydropower systems	Cameroon, Djetcha-Baleng [CA1]: Health centre	Not all medical equipment could be used due to limited power rating of the inverter. Lack of funding and other support by local authorities. Local residents had to visit health centers in other areas for services that could not be delivered at this center due to the lack of power. Issues within the management committee as one of their members used energy for personal purposes.	Improvements in health services improved (e.g. prolonged life of medical supplies and medical operations during night hours). A non-governmental organization assisted the local community in the hydropower system's conceptualization, fund raising and problem solving in management committee matters. Community members assisted in the construction works of the hydropower system.

		Two wind turbines	Cameroon, Ndoh-Djutitsa [CA2]: Sub-divisional hospital	Power failure due to overloading – the inverter was linked to a greater capacity tank. Lack of skilled personnel for post installation management and maintenance. Lack of a proper management committee. Lack of funding and documentation for missing/broken parts replacement.	Two universities from Cameroon ad France initiated the procedures for funding and equipment purchase. Improvements in health – pumped water consumption reduced stream water related diseases. Reduced electricity costs for the hospital.
		Pico-hydropower system	Cameroon, Bangang [CA3]: African Center for Renewable and Sustainable Technologies	-	The system operated well during the wet season (excessive water amounts). The Center investigates the development of other renewable systems.
Gurung *et al.* (2011) [14]	Mixed methods - in-depth interview (213 households), key informant opinion (4 participants), focus group discussions (in Sikles and Pokhara), and site visit for observation	Micro-hydropower system	Nepal, 3 sites [NE3]: -Sikles, -Parche, and -Khilang	Insufficient power - system originally designed for Parche and Sikles villages; Khilang village included after some years. Two landslides caused damages - repairs occurred about one year later due to the lack of funding and skills. Incidents of power supply cheating and faulty monitoring.	Community-owned, equitable benefits. Improvements in life quality. Improvements in education, daily activities and communication. Improvements in health due to the reduced firewood and kerosene uses.

Sovacool *et al.* (2011) [105]	Mixed methods - primary data analysis via 36 semi-structured research interviews with government, banking, planning agencies, companies and consumers, site visits (3 provinces), field research (7 rural villages), and literature review	Solar home systems	Papua New Guinea [PA10], -Provinces: Goroka, Madang and Port Moresby -Rural villages: Akameku, Asaroka, Kundiawa, Lufa, Okifa, Simbu and Talidig	Lack of high-quality product availability. Lack or improper maintenance. Problems in logistics and distribution to rural areas. Insufficient income - local communities live in poverty. Lack of external funding. Poor institutional capacity. High cost compared to traditional energy sources (e.g. fossil fuels and main grid electrification). Consumers' perception that solar energy is unlimited Conflicts, jealously, sabotage, theft and vandalism. Local communities are unfamiliar with the system.	-
International Centre for Integrated Mountain Development (2018) [95]	Project report with description and function of the community-based flood early warning system	Community-based flood early warning system	Hindu Kush Himalaya [HKH4]: -Kunduz River, Afghanistan -Jiadhal, Singora and Ratu Rivers, India -Ratu, Gagan and Rangoon Rivers, Nepal -Gilgit River, Pakistan	-	Simple and low-cost system. Self-powered (by solar panels). Managed and operated by local communities. Increases collaboration between upstream and downstream communities.

Cools *et al.* (2016) [106]	Case studies	Flood early warning system	Egypt, communities in [EG1]: Red Sea Mountains	Flood management knowledge was limited in local communities. System's lead time was small (48 hours). The region was affected by flash floods (short-lived and destructive type of flood). The system was managed by professionals – system operators decide when to alert authorities which in turn, alert communities. System was not reliable as the operators did not work 24/7. Warnings dissemination was limited to local communities due to poor telecommunications in the area.	The system allowed emergency authorities to prepare and respond faster.
		Flood early warning system	Mali, communities in [MA1]: Niger Delta	Conflicts between different groups (e.g. fishermen and herders) due to the lack of water.	Flood management knowledge was substantial in local communities. System's lead time was long (2 weeks to seasonal). Floods were beneficial for local residents (fishery, agriculture). Both peak flood and floodwater retreat information was disseminated to the authorities and local communities. Information was broadcasted by radio in many languages and is available online. Community chiefs were responsible for planning important activities such as fishery and cattle river crossing.

Baudoin *et al.* 2014 [15]	Case studies	Multi-hazard and people-centred early warning system – CLIM-WARN Project, United Nations Environment Programme (UNEP)	Kenya, 4 sites/12 communities [KE12]: -Nairobi, 2 peri-urban villages, and an informal settlement -Kisumu, a peri-urban village, and 2 rural villages -Turkana, 3 rural villages -Kwale, 3 rural villages	Limited access to television, radio, phone, etc. in rural communities could make access to warnings difficult – chiefs/elders or other traditional institutions deliver such information. Low education in rural areas may affect response if the system is not flexible/ adjustable to local capabilities. Local urban communities had multiple sources of income, higher education and access to different warning devices – this reduced their need for additional early warning systems.	Early warning was essential for local rural communities with one form of income (monoeconomy) due to their dependency on weather conditions.
		Community-based flood early warning systems	Sri Lanka, 2 Districts [SR2]: -Matale -Nuwaraeliya	Ensuring active community involvement for longer periods in such programs was difficult. Only a limited number of national and international non-governmental organizations were engaged in community-based early warning programs. There was a need for more participatory community work involving all actors.	Local communities received education and training. Portable, plastic, color warning rain gauges were introduced as low-cost, low-tech warning equipment. Local residents monitored and read the gauges, and verbally informed nearby communities of the water level status. Community participation was important for the success of the system and effective community response.

Table A2. Appropriate technology and systems evaluation tool

FAILURE IDENTIFIED CASE STUDIES	DIMENSIONS OF SYSTEM SUSTAINABILITY	INDICATORS OF TECHNOLOGY "APPROPRIATENESS"	SUCCESS IDENTIFIED CASE STUDIES
PH1	Institutional	Autonomy (Community Self-Sufficiency)	BO9, PH8
SUS8, CEA4	Institutional	Co-Creation (Local and Professional Stakeholders)	CA1, CA2,
SUS8, SR2	Institutional	Community Input (Engagement)	NE24, CEA4, CA1, CAES1, SR2, HKH4
SUS8	Institutional	Community Controlled (Managed, Owned)	NE3, SR2, HKH4
SUS8, CEA4, CA1, CAES1, SR2	Institutional	Legal and Regulatory	-
SUS8, CEA4, CA1, CA2, CAES1, PA10, SR2	Institutional	Support (Technical, Administrative, Financing)	-
-	Environmental	Habitat Neutral	-
-	Environmental	Low Emergy	-
-	Environmental	Low Emissions	all case studies
-	Environmental	Renewable Energy	all case studies
-	Environmental	Renewable Resources Availability	CAES1, SR2
RW9, CAES1	Environmental	Scaled for Conditions (Resources, Weather, Land)	CA3, SR2
-	Environmental	Waste Utilization and Reduction	-
SUS8, CAES1, KE12	Social / Ethical	Acceptability	KE12
-	Social / Ethical	Aesthetics	-
SUS8	Social / Ethical	Ease of Use	SR2
-	Social / Ethical	Gender Appropriate (e.g. women in staff/management)	-
-	Social / Ethical	Indigenous Techniques	MA1
RW9, NE3, SUS8, CEA4, CA1, CA2, PA10, KE12, EG1	Social / Ethical	Knowledge, Skills, Feedback	SR2, EG1, MA1
-	Social / Ethical	Social Entrepreneurialism	BO9, PH8
BO9, PH8, NE3, SUS8, CA1, PA10, MA1	Social / Ethical	Socio-Cultural -incl. health, education, harmony, etc.	BO9, PH8, RW9, NE3, PH1, CA1, CA2, AF2
RW9, NE3, PH1, SUS8, CEA4, CA1, CA2, CAES1, PA10	Economic	Affordability	NE24, HKH4
AF2	Economic	Income Generating	BO9, PH8, KE12, MA1
AF2	Economic	Job Creating	BO9, PH8
PH1, AF2	Economic	Money Saving	BO9, PH8, CA2
-	Economic	Labor Intensive	-
-	Economic	Resource Efficiency	-
SUS8, CAES1	Economic	Selling Appropriate	CEA4
CEA4, KE12	Technical	Adaptability	SR2, MA1
NE24, RW9, PH1, SUS8, CEA4, CA2, CAES1	Technical	Constructability and Replicability	CEA4
CA1, KE12	Technical	Compatibility	-
RW9, NE3, CEA4	Technical	Durability (e.g. against time or extremes)	-
EG1	Technical	Effectiveness	SR2, MA1
RW9, NE3, PH1, SUS8, CEA4, CA2, CAES1	Technical	Energy Efficiency	SR2
-	Technical	Low Power	SR2
RW9, PH1, SUS8, CEA4, CA2, CAES1, PA10	Technical	Maintainability	NE24
SUS8	Technical	Modification vs Invention	CA3
-	Technical	Multi-Purpose	CA2, KE12, MA1
CEA4	Technical	Open Source Manual and Design	CEA4, SR2
NE24, RW9, CAES1, PA10	Technical	Parts and Hardware	SR2
CEA4, PA10	Technical	Raw Materials Availability	CEA4, SR2,
SUS8, EG1,	Technical	Reliability	-
RW9, NE24, NE3, SUS8	Technical	Reparability	-
-	Technical	Reusability	-
SUS8	Technical	Scalability	-
SUS8, EG1	Technical	Simplicity	SR2, HKH4
EG1	Technical	System Independence	-

Region Keys	Country Keys			
CEA: Central Africa	AF: Afghanistan	CAES: Cameroon (Esaghem Village)	MA: Mali	PH: Philippines
HKH: Hindu Kush Himalaya	BO: Bolivia	EG: Egypt	NE: Nepal	RW: Rwanda
SUS: Sub-Sahara	CA: Cameroon	KE: Kenya	PA: Papua New Guinea	SR: Sri Lanka

Note: Region/Country keys detailed in Table 1

Paper IV

Sustainability Science
https://doi.org/10.1007/s11625-020-00890-y

SPECIAL FEATURE: ORIGINAL ARTICLE

The Sustainability–Peace Nexus in the Context of Global Change

Humanitarian engineering at the sustainability-development nexus: mapping vulnerability and capability factors for communities at risk of water-based disasters

Spyros Schismenos[1,3] · Garry J. Stevens[1] · Dimitrios Emmanouloudis[2,3] · Nichole Georgeou[1] · Surendra Shrestha[4] · Michail Chalaris[5,6]

Received: 15 July 2020 / Accepted: 26 November 2020

Abstract
Access to resources that is equitable and sustainable provides a critical foundation for community harmony and development. Both natural and human-induced disasters present major risks to sustainable development trajectories and require strategic management within regional and local plans. Climate change and its impacts, including intensified storms, flash floods, and other water-based disasters (WD), also pose a serious and increasing threat. Small, remote communities prone to weather extremes are particularly vulnerable as they often lack effective early warning systems and experience energy insufficiency. Humanitarian engineering provides a transdisciplinary approach to these issues, supporting practical development resources such as renewable energy, which can also be adapted for disaster response. This study details an exploratory investigation of community vulnerability and capability mapping (VCM) that identifies communities with high WD risk and limited response capability which may benefit from risk reduction engagement and program co-development. By presenting criteria appropriate for VCM, we highlight the anthropocentric characteristics that could potentially be incorporated within community-led action as part of a comprehensive scheme that promotes sustainable development.

Keywords Off-grid renewable energy · Early warning · Sustainable development goal · Community

Introduction

During 2019, over 90% of all natural disasters involved extreme weather events (EWE) which include floods, storms, landslides, extreme temperatures, droughts, and wildfires (CRED 2020). Floods and storms are the most

Handled by Ayyoob Sharifi, Hiroshima University IDEC Higashi Hiroshima, Japan.

✉ Spyros Schismenos
s.schismenos@westernsydney.edu.au

Garry J. Stevens
g.stevens@westernsydney.edu.au

Dimitrios Emmanouloudis
demmano@teiemt.gr

Nichole Georgeou
n.georgeou@westernsydney.edu.au

Surendra Shrestha
s.shrestha@westernsydney.edu.au

Michail Chalaris
chalarismichail@gmail.com

1 School of Social Sciences, Humanitarian and Development Research Initiative (HADRI), Western Sydney University, Sydney, Australia

2 Department of Forestry and Natural Environment, International Hellenic University, Drama, Greece

3 UNESCO Chair on Conservation and Ecotourism of Riparian and Deltaic Ecosystems, International Hellenic University, Drama, Greece

4 School of Engineering, Western Sydney University, Sydney, Australia

5 Department of Chemistry, School of Sciences, International Hellenic University, Kavala, Greece

6 School of Fire Officers, Hellenic Fire Corps, Athens, Greece

Published online: 03 January 2021

frequent types of natural disasters and associated with the highest cumulative number of people affected (CRED 2020; Wahlstrom and Guha-Sapir 2015). The devastation wrought by such water-based disasters (WD) is substantial, but its relative health and socio-economic effects are disproportionately high in low and lower-middle-income countries (L/LMIC), where hazard-resistant infrastructure and response resources are often more limited (Strömberg 2007). Goal 13 of the United Nations 2030 Agenda for Sustainable Development highlights this issue and focuses on the importance of 'strengthening resilience and adaptive capacity to climate-related hazards and natural disasters in all countries' (UNSD 2020).

Sustainable energy in sufficient amounts is a major capacity factor and is linked to both socio-economic development (Howells et al. 2017; UN 2015) and disaster resilience and response capabilities (Phillips 2017). The latter can play a key role in protecting community-developed assets that contribute to livelihoods and community cohesion. Goal 7 prioritizes universal access to affordable and reliable energy services (UNSD 2020). It also encourages an increased proportion of renewable energy sources in the global energy mix, improvements in energy efficiency, and international cooperation to facilitate broader access to clean energy research and technology over the next decade, so more Goals can be reached (Howells et al. 2017; UN 2015; UNSD 2020). Importantly, expediting the transition to renewables and increased efficiencies may allow climate reparations to occur and provide long-term socio-economic benefits (Amin 2018). Hydropower, wind energy and solar energy are important developing technologies and potential 'game changers', especially for those in remote areas where main power grids cannot be accessed. In such scenarios, off-grid renewable energy systems (OGRES) are a preferred source of power for local communities (IRENA 2018).

Despite these benefits, the transition to renewables may be costly, particularly in L/LMIC where fossil fuels are readily available (Manley et al. 2017). These countries often face the dilemma of development and poverty reduction that occurs at the cost of environmental and health impacts (Dincer 1999; Manley et al. 2017). Furthermore, wealth effects may be poorly distributed and this can affect social harmony. In that sense, fossil fuel production and use in L/LMIC may cause more harm than good. Ross (2015) describes the 'resource curse'; a paradox where counties often L/LMIC rich in natural resources do not reach expected developmental, environmental, and socio-political outcomes due to wealth inequity. The Niger Delta, Nigeria is a notable example, having unique biodiversity that has supported the traditional livelihoods of many communities, but now hosts one of the world's richest crude oil reserves (UNDP 2014). Exploitation of delta oil and other resources has damaged local ecosystems while offering few economic benefits to local communities, who continue to experience high poverty, health problems, and a lack of basic services (Omeje 2006; UNDP 2006). These conditions have led to societal tensions and conflicts between different groups (Omeje 2006). Such phenomena are common in L/LMIC with more pronounced ethnic and cultural divides, political corruption, and ongoing socio-economic imbalances (Stewart et al. 2002).

The common perception that renewables represent a ready 'step change' for many L/LMIC communities must be tempered with recognition of the structural inequities and forms of environmental injustice that many face, as detailed in the example above. Development and humanitarian actors may play a pivotal role in supporting their use within longer term, community-led development, but also risk the 'short-termism' of narrowly conceived technical 'solutions' with little ongoing support in resource-constrained environments. For example, renewable energy projects in Sub-Sahara have been found to fail to or have sub-optimal long-term outcomes due to bad management and planning, and lack of maintenance and local stakeholder involvement (Ikejemba et al. 2017). These are central considerations in the emerging theme of humanitarian engineering.

Humanitarian engineering can be defined as the urgent or longer term application of engineering concepts appropriately designed, installed, and used to serve populations in great need. It approaches engineering aspects with community needs as the core focus, and considers the context of communities in terms of culture, existing strengths, institutional structures, etc. (Gosink et al. 2003; Hill and Miles 2012; Sheroubi and Potvin 2018). It supports disaster resilience mechanisms, and contributes to sustainable livelihood and socio-economic development (Mazzurco and Jesiek 2017; Sheroubi and Potvin 2018; Younger et al. 2018). This conceptualization of humanitarian engineering is informed by, and overlaps with, two related fields; development engineering, which investigates solutions in societal challenges through science and technology (Nilsson et al. 2014), and global engineering, which addresses worldwide challenges that are ongoing (e.g., poverty, water sanitation, and energy) as a practical driver of increased equity (Thomas 2019). Humanitarian and development engineering solutions can be considered practice elements of 'developmental-relief' transitional frameworks within the development sector (including community 'resilience' programming; Mosel and Levine 2014), and as a sub-set of global approaches which address challenges to humanity as a whole.

To address common hazards such as EWE exposure and energy insufficiency, steps for reliable early warning, proper management of natural resources, national policy reformation, and equitable benefits distribution are essential (Thomas et al. 2020). At the same time, supportive and cross-disciplinary actions at the community level should aim for a wider and stronger impact. These can include idiosyncratic approaches that are a 'best fit' for a single community, but also common solutions that can support design durability and the efficiency of manufacturing, distribution, and installation (Thomas 2019).

This paper focuses on communities with high vulnerability and limited capability, particularly remote populations in L/LMIC with energy insufficiency and high exposure to WD. It presents an exploratory investigation of community hazard vulnerability and capability mapping (VCM). For the purpose of this study, we focus on communities that may benefit from WD risk reduction engagement and program co-development reinforced by renewables. Our goal is to collect information based on internationally known, comparable, and evidence-informed metrics that can support community vulnerability and capability mapping (VCM) and serve as a cross-sectional measuring tool for the following considerations:

- Evaluate one or more communities in pre- and post-hazard phases, focusing on hazard preparedness and socio-economic sustainability indicators
- Identify communities with potentially greater need for development and hazard management resources (e.g., OGRES or EWS)
- Compile and present clear and accessible information as part of community consultation, risk assessment, and mitigation planning
- Determine the effectiveness of humanitarian and development program interventions in a single community over time (i.e., post-intervention assessment tool)

In the following sections, we focus on the definitions of community vulnerability and capability. We present conceptual and operational frameworks that support community hazard risk assessments, including technical, economic, and environmental metrics. Following that, we detail a provisional application of the VCM framework to three case examples of communities with different vulnerability and capability levels that were recently exposed to WD. Our goal is to map how OGRES and/or EWS can support affected populations and minimize losses caused by natural disasters. This approach accords with the principles of the Agenda 2030 for Sustainable Development (UN 2015) and Sendai Framework for Disaster Risk Reduction (Pearson and Pelling 2015).

Understanding vulnerability and capability factors

The severity of disasters is subject to the vulnerability level of the affected populations, that is, the extent to which an individual or a group is predisposed to experience losses in relation to a hazard event (Burnham 2008). The United Nations Office for Disaster Risk Reduction defines vulnerability as 'the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard'. It is one of the defining components of the common disaster risk formula (Disaster Risk = Hazard × Exposure × Vulnerability/Capability). In this conceptualization, vulnerability is directly mediated by the response assets and cap level of the affected population (UNISDR 2009 p. 30).

Due to their nature, commonly used warning and forecasting systems are not always capable of predicting EWE severity with sufficient lead time and accuracy (Alcántara-Ayala and Oliver-Smith 2019). For instance, the African Flood Forecasting System that is used for medium- and large-scale river basins in Africa is accurate in forecasting riparian floods, but only across large areas (10,000 km^2 or more) and with relatively long lead times (i.e., 1 week or more) (Thiemig et al. 2015). This information is not always helpful in smaller scale areas where sudden and short-duration floods occur. To warn populations in such locations, a different approach is required.

The United Nations Framework Convention on Climate Change and the International Centre for Integrated Mountain Development have showcased the successful use of community-based flood early warning systems in the Hindu Kush Himalaya region (Shrestha Pradhan 2000; UNFCCC 2020). These are low cost and simple in their operation and use. A flood sensor detects rising river water levels. When critical thresholds are reached, signals are sent to the receiver and then warnings are disseminated to agencies and nearby communities. Local communities participate in the processes (i.e., they jointly determine flood thresholds). Once the flood management plan is established in an area, local communities can take ownership and overall management of the EWS. This management transition has been found to increase the longer term sustainability of the system and create synergies between stakeholders (UNFCCC 2020). For instance, local caretakers receive training and are responsible for the maintenance of the system. They also monitor flood data and send reports. Local authorities cross-check alternations in flood status, circulate information, and deploy rescue teams when required. Focal agents receive and disseminate warnings, and local media broadcast alerts. Meanwhile, a flood risk management committee overseas operations and coordinates with participating stakeholders including community representatives (Shrestha Pradhan 2020). Maintenance and operating costs are often supported by donations and agencies when self-funding is insufficient (Shakya 2020). This example shows how autonomous EWS in WD-prone areas can be effectively managed at the local level through collaborations between professionals

Table 1 Focal hazard assessment areas, processes, and outcomes

Focal assessment areas	Assessment processes	Outcomes
Social	Assessment	Evaluate and specifying risks
Technical	Diagnosis	Understand risks and their causes
Administrative	Planning	Prioritize actions and their sequences
Political	Empowerment	Increasing community capability and self-sufficiency
Legal		
Economic		
Environmental		

and community members. Such collaborations are a key aspect of humanitarian engineering planning and management (Mazzurco and Jesiek 2017).

Other community-centered EWS strategies that focus on EWE and other global emergencies are available in the SERVIR Global, a worldwide network that allows resilience, developmental, and environmental capacity strengthening by linking satellite data to potential community hazards (SERVIR 2020). Similarly, the Famine Early Warning Systems Network informs about food insecurity and livelihood conditions, EWE, armed conflicts, energy insufficiency, and other crises that affect food and water supplies (FEWSNET 2020). As it can be observed, early warning is a critical factor for building resilience and supporting the development of vulnerable communities.

For this study, communities defined as vulnerable to WD have one or more of the characteristics presented below. A higher number of such features is associated with greater vulnerability (Schismenos et al. 2018, 2020):

- Reside in remote, rural areas (small settlements such as villages or towns)
- Low/lower-middle income (based on minimum wage, purchasing power per capita, etc.)
- Reside in riparian or deltaic ecosystems
- Experience power insufficiency (off-grid and/or unstable power supply)
- High flood risk probability
- Insufficient flood early warning (minor or no EWS or other warning mechanisms)
- Poor telecommunications (no mobile phones or landlines in residencies)
- Mono-economy.

Capacity can be defined as 'the combination of all the strengths, attributes, and resources available within an organization, community, or society to manage and reduce disaster risks and strengthen resilience. This may include infrastructure, institutions, human knowledge and skills, and collective attributes such as social relationships, leadership, and management' (UNISDR 2009 p. 5). Capability is a related concept, and in this context refers to established plans, structures, and associated actions to prevent or mitigate hazard impacts. Community response capability can be achieved by developing, transmigrating, maintaining, and improving related knowledge, tools, and resources (Coles and Buckle 2004).

According to the United Nations Office for Disaster Risk Reduction, a combination of physical, social, economic, and environmental metrics determines vulnerability and capability levels, especially in hazard risk mapping (UNISDR 2009 p. 26). Furthermore, political, cultural, historical, psychological, and institutional elements could also be taken into consideration as complementary factors (Field et al. 2012; Twigg 2004). Such metrics are important for predicting the potential consequences of a disaster and directing the establishment of disaster resilience and response resources at the local level. The evaluation of resilience and response level of existing structures and services to potential disasters, such as the WD, requires engineering knowledge and practices.

There are many tools for measuring the aforementioned metrics. Most of them include a risk analysis process that summarizes the review of technical characteristics of a disaster (e.g., location, magnitude, and probability), analysis of risk exposure and vulnerability, and effectiveness of coping capacity to risk scenarios (UNISDR 2009 p. 26). These are highly reliable when evaluating local communities because structures and techniques may differ from one local population to another (e.g., different available recourse materials, culture, weather conditions, etc.). Therefore, local engineers and humanitarian professionals are preferred in the relative assessments, as they are more familiar with the local building 'culture' (UNISDR 2013). Examples of such assessments can be the evaluation of localized EWS (e.g., water level and velocity sensors), the installation of OGRES (e.g., hydropower generators and solar panels), and structures that support such systems (e.g., local bridges and irrigation systems). Table 1 presents a framework of community-level hazard risk assessment and management. It is an adapted framework drawing upon the focal assessment areas described within the STAPLEE model (FEMA 2008) and with assessment processes and outcomes as described

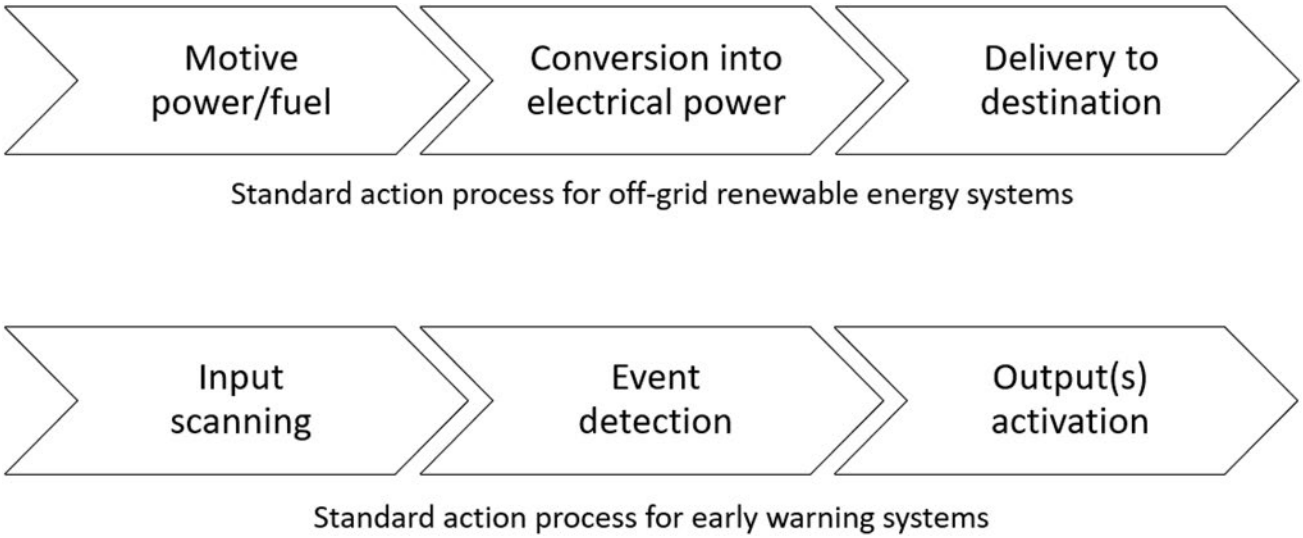


Fig. 1 Standard action process for OGRES and EWS

by Benson et al. (2007). We see these focal assessment areas, assessment processes and outcomes as a compatible framework.

Devising VCM and its metrics

When documenting vulnerability and capability factors, assessments on community scale, via community participatory approaches, are more reliable and precise; therefore, they are often preferred by local governments and organizations (Ostadtaghizadeh et al. 2015; Renschler et al. 2010; UNISDR 2009 p. 23). However, such assessments focus on a single community, making comparison between different populations problematic particularly as some of the metrics are based on qualitative factors (e.g., social, cultural, and political metrics). Even though these factors can be used for qualitative or mixed analysis, practitioners and policymakers find quantitative data more useful due to their universal character (Simmons et al. 2017).

Another issue arises when community capability level changes due to uncertainties (e.g., power blackout due to WD). Often, community vulnerability to EWE increases both intra- and post-disaster. Moreover, vulnerabilities that relate to pre-existing inequalities will often be exacerbated by such events (Peek 2008). The duration and impact of this change are dependent on the pre-existing capability level but with this often reflecting underlying socio-economic and equity issues within a given population. Therefore, when developing community hazard risk assessments, indicators that influence vulnerability and capability levels under both normal and disaster-specific conditions should be taken into consideration. It is also important that such assessments are able to detect incremental shifts, especially when investigating changes in communities starting with lower baseline capabilities. By relying on criteria with universal and objective characteristics, appropriate for such contexts, the development of guides suitable for community comparison is possible. The following information investigates technical, economic, and environmental criteria. Those of universal/commonly accepted profile will be included in the VCM.

Technical criteria

As previously stated, infrastructure and services may vary between different communities. Yet, energy availability and hazard detection are key elements for disaster resilience and sustainable development. This study emphasizes the investigation of OGRES, EWS, and hybrid systems. The reasons for selecting these specific metrics are the following:

Significant input in community capability levels: Both the OGRES and EWS can contribute to EWE resilience, conflict prevention, and socio-economic growth, if they are designed to be anthropocentric and useful in more than one area (e.g., disaster response, agriculture, and ecotourism) (Howells et al. 2017; Schismenos 2017; Schismenos et al. 2020).

Standard action process: Both OGRES and EWS have standard action processes, regardless of their type or complexity. Figure 1 draws information from Waidyanatha (2010) and Schismenos et al. (2020), and presents these processes.

Large product availability: Both OGRES and EWS products can be found in the market. They vary in cost, features, and requirements. In general, OGRES are either: (i) conventional (e.g., portable diesel generators, firewood), or (ii) renewable energy systems (e.g., wind, hydro, and solar power). Basic EWS can either be: (i) indoor systems (e.g., radio, television, phone, computer connected to the internet), (ii) outdoor systems (e.g., sirens, lights, LED signs), or (iii) portable/other (e.g., smartphone, tablet) (Schismenos et al. 2020).

Known factors and universal use: Most communities are aware of OGRES and EWS, and their functions. When communities cannot afford these technologies, they use alternative disaster response and energy solutions. These include traditional means and 'know-how' or improvised systems made from readily sourced materials. These solutions are usually do-it-yourself and easy-to-deploy-and-operate (Jaglin 2019; Schismenos et al. 2020; Smith 2011).

The above criteria, at least in their broad terms (disaster preparedness, disaster response, and energy availability under both normal and extreme conditions) can be used for universal comparative analysis. Therefore, they are included in the VCM.

Economic criteria

There is no doubt that vulnerability and capability levels are highly connected to poverty conditions (Wisner et al. 2004). Poverty is not only a driver, but also a consequence of disasters, regardless of whether they are natural or human-induced. People with no or low income, including women, children, people with disabilities, the elderly and migrants often live in disaster-prone areas and under unsafe conditions (Wisner et al. 2004). Even though poverty is not the only parameter to be considered when investigating vulnerability and capability, it is perhaps the most critical (Twigg 2004; Wisner et al. 2004). This is supported in studies investigating poverty and WD impacts in rural and unplanned communities in L/LMIC (Di Baldassarre et al. 2010; Dube et al. 2018; Kumar et al. 2016). Therefore, income represents a potential VCM indicator.

For this metric, the sufficiency level of community income is determined based on the average income of the residents of a community. This method follows the concept of the World Bank Atlas method in which the gross national income (GNI) per capita—US$ value of a country's final income in a year is divided by its population. If the community average income cannot be calculated (i.e., due to lack of data), the national minimum wage or purchasing power per capita is selected. This criterion is objective, and since it can be used for universal comparative analysis, it is included in the VCM. Specifically, the income in the VCM refers to community income status (pre-hazard conditions) and income flow (post-hazard conditions). Higher income communities have more diversified markets, multiple income sources, and greater purchasing power, factors likely to afford better hazard-related resilience (Strömberg 2007). Using data reported by the World Bank, Table 2 presents how income status is defined based on the GNI per capita (WB 2019).

Table 2 How economies are defined based on their GNI per capita

Economy	US$ (2019)
Low-income	995 or less
Lower-middle-income	996–3895
Upper-middle-income	3896–12,055
High-income	12,056 or more

Environmental criteria

For flood preparedness and forecasting, the historical data of local atmospheric conditions can be used for weather evaluations, whereas the botanical and hydrogeomorphological conditions for investigating characteristics of the local ecosystem (Wilhelm et al. 2019). These criteria cannot be used as universal factors, since the WD are not standard. However, they are valuable for environmental observations of an area over time. They also contribute to the development of hierarchical flood models at the local level, which is suitable for selecting optimal locations when installing localized OGRES and EWS (Schismenos et al. 2018).

VCM compilation and format

Table 3 presents the technical and economic indicators that can be included in the VCM. These include objective and internationally known/accepted criteria and other evidence-informed metrics for both pre- and post-hazard conditions. It also defines what these indicators measure.

As indicated by Table 3, hazard preparedness and response, energy availability under any condition, and continuous income could increase community capability. One way to achieve that is the establishment of OGRES combined with EWS at the local level. For instance, the OGRES would generate energy and provide power to EWS (e.g., sirens and evacuation lights) and other community needs (e.g., public lights and agricultural activities) (Schismenos et al. 2020). The most vulnerable communities will typically need external assistance to develop these capabilities. The success or failure of such programs can be measured when one or more indicators in Table 3 change.

The metrics in VCM are informed by open access secondary sources (e.g., international minimum wage rates) and national statistics when no primary sources at the community level are available. These include objective, comparable indicators (e.g., income, energy access, and available EWS) and evidence-informed estimates based on situation reports and other available site information (e.g., post-disaster

Table 3 Criteria under pre/post-hazard conditions

Pre-hazard			Post-hazard		
Disaster preparedness	Energy availability	Income status	Disaster response	Emergency energy availability	Income flow
WD response plan; EWS; evacuation plan; disaster education	Power generation covering daily/basic needs	Secure income/minimum wage/purchasing power	WD warning efficacy and evacuation/sheltering	Power generation supports disaster response mechanisms/sheltering	Ongoing income source unaffected during/after hazards

energy access, statistics, and media). A list of open access secondary sources for the VCM is presented in Appendix 1. These are widely recognized and objective sources of secondary data. For the purposes of the current VCM, the 'selected sources' were considered the most reliable source of such data. In the case of recent hazard events, news media represented the only available source of data.

The VCM could act as a process template for humanitarian and development non-governmental and government agencies that are responsible for multiple communities. It could also act as a supplementary report to other formal assessments to compile additional data on the characteristics of communities (e.g., community energy mapping).

It should be noted that the mapping outputs do not measure direct proportional changes, per se, but the achievement of a basic or 'minimally effective' resource standard than can support hazard preparedness/response and related development outcomes (e.g., available flood detection system, access to energy, and reported income). The suggested ranking includes a simple, 1–3 scale (low, intermediate, and high) to detect three resource/capability levels that affect EWE preparedness. These levels also use the semaforo ('traffic light') color system, where red, yellow, and green represent concerning, intermediate, and satisfactory capability status, respectively (Mahmoudi et al. 2018). Their presentation in this format can provide clear information in an accessible way when consulting with community groups and other stakeholders.

The VCM categories are presented as follows:

- Green (high capacity/resource) with a value of 3
- Yellow (effective minimal capacity/resource) with a value of 2
- Red (no effective minimal capacity/resource) with a value of 1.

The following section presents three recent cases of rural communities affected by WD, examining their pre- and post-response capabilities and assets.

Community case examples of water-based disasters

From February 2019 to April 2020, three major WD occurred in flood-prone communities in different parts of the world: a combined WD event across eastern Australia, a storm in southern Nepal, and a flash flood in southern Yemen. The latter are low-income countries but in quite different social and political contexts affecting their response resources and infrastructure. The Australian community presents a high-income context with substantial resources and response infrastructure and is included for comparative purposes.

Flood: Bluewater, Queensland, Australia

In February 2019, the convergence of a monsoon and a slow-moving tropical low generated a serious flood event in Townsville, Queensland, Australia. According to the local media, this WD resulted in six fatalities; four people died during the floods and two more died later due to a soil-borne bacterial infection (Melioidosis) that occurred because of the flood. This infection affected ten more people but without causing significant health impacts. While news media announced bad weather conditions and a high risk of flash flooding, the Bureau of Meteorology did not predict the scale of this flood, which would normally trigger an evacuation warning. As a result, many of the affected people were sleeping and trapped indoors when their properties started flooding (ABC 2019b). The flood ultimately resulted in hundreds of evacuations and significant property damage. The local cattle industry is the main income source (Johnston 2020) and was heavily affected. Almost 11,300 residents remained without power for several days due to both damage in the power supply system but also safety-related shutdowns. Bluewater, a rural suburb in Townsville with 1040 residents was severely affected (ABC 2019b). Although electricity and telecommunications were available during the early stages of the disaster, power blackouts occurred when the flood reached critical levels. Despite the impacts, disaster response and recovery mechanisms were reported to have worked well (ABC 2019a, b; Rafferty 2019).

Heavy Storm: Pheta (Ward 6), Nepal

On March 31, 2019, a powerful storm hit Bara and Parsa provinces in southern Nepal. The municipalities of Pheta (Ward 6), Parwanipur, and Bharbalia in Bara were highly affected. This disaster resulted in at least 28 fatalities, more than 600 casualties and several missing persons (9news 2019). These municipalities are remote, low-income communities with poor disaster response infrastructure. For example, the people in Pheta (Ward 6) are mainly subsistence farmers and have limited disaster preparedness knowledge or resources. Their homes are typically made of mud and bricks. There is no localized EWS in the area and having little understanding of the magnitude of the storm most people tried to shelter in their huts. Many homes were destroyed, causing deaths and injuries as they collapsed (9news 2019; Bidari 2019). Communities remained without power for days due to damaged electricity poles (Bidari 2019). The provincial government later advised that the families of people who died in this disaster would receive compensation in the amount of US$ 4000 (9news 2019).

Flash flood: Aden Governorate, Yemen

In mid-April 2020, at least 100,000 people in Yemen were affected by extreme flash floods. Districts in Aden were among the most seriously impacted with eight confirmed fatalities and severe infrastructure damage including roads, energy grids, and drinking water supply systems (MEE 2020). There was no EWS, thousands lost their homes, and had no immediate access to food and medical supplies. Yemen is currently in the grip of a protracted civil conflict and humanitarian emergency, with at least 30% of its population currently living in pre-famine conditions (UNHCY 2020). The civil war between the government forces and Houthi rebels has continued since 2014, and resulted in the destruction of major health, energy, and water supply facilities due to the bombings and ground fighting (MEE 2020; UNHCY 2020). This loss of health infrastructure has contributed to one of the worst cholera outbreaks seen internationally in recent years, with 3,886 Yemeni's dying from this disease during 2016–2019 (WHO 2019). Having little public health infrastructure is also seriously hampering the management of COVID-19 spread during 2020 (UNHCY 2020).

These three cases present communities with different capability level:

- Bluewater—a high-income community in a stable environment
- Pheta (Ward 6)—a low-income community in a stable environment
- Aden—a low-income community in a conflict-disrupted environment.

The cited examples show that some outcomes (e.g., property damages) were similar for the three communities. Warning systems either did not work effectively or did not exist at all. This increased vulnerability to adverse outcomes from these hazards, including fatalities and injuries. All three communities are rural and have direct exposure to the type of WD which occurred. Due to the lack of local disaster preparedness data for each community, relevant metrics that contribute to their respective national risk indices are considered. Specifically, as indicated in the World Risk Index Report 2019 (Day et al. 2019), Australia has high exposure to natural hazards, low vulnerability and susceptibility, and high coping and adaptive capacities. Therefore, the Disaster Preparedness metric of Bluewater is estimated as 3. Both Nepal and Yemen have very low exposure to natural hazards; however, their vulnerability and susceptibility levels are concerning, with coping and adaptive capacities that are substantially lacking. For this research, Pheta (Ward6) and Aden are estimated as 1.

Table 4 Observed capability rates of communities experiencing WD

Community, Country	Pre hazard*			Post hazard**			
	Disaster Preparedness	Energy Availability	Income Status	Disaster Response	Emergency Energy Availability	Income Flow	Total Rating
Bluewater, Australia	3	3	3	2	2	2	15
Pheta (Ward 6), Nepal	1	2	2	1	1	1	8
Aden Governorate, Yemen	1	1	1	1	1	1	6

*6 months or more.

**1 month or less.

Another notable observation is that prior to the hazard events, energy availability was different among the communities. The Energy Statistics Pocketbook 2020 reports that the energy use in Gigajoules per capita for Australia is 218.9, Nepal 19.5, and Yemen 5.0 on a scale of < 15 to ≤ 100 (UNDESA 2020). This translates to 3, 2, and 1 for Bluewater, Pheta (Ward 6), and Aden, respectively, in the Energy Availability metric.

The income of these communities varies significantly. The approximate minimum monthly wage in Australia is US$ 1,738, in Nepal US$ 74, and in Yemen US$ 0 (no reported average wage) (MW 2020). The lack of data in Yemen is possibly due to the ongoing conflict and socio-economic instability which does not support formal work benefits or reporting (MW 2020). Given the aforementioned wages, the Income Status metric is estimated as 3, 2, and 1 for Bluewater, Pheta (Ward 6), and Aden, respectively.

Regarding the post-hazard metrics, all of the examined communities were affected by WD. The community in Australia was aware of the event but not its magnitude. While evacuations did occur, a loss of lives still ensued (Disaster Response: 2). The communities in Nepal and Yemen had poor infrastructure and no EWS, so the impacts were more severe (Disaster Response: 1 for both). Power was available in Bluewater during the early stages of the disaster, but not after its climax (Emergency Energy Availability: 2). Both Pheta (Ward 6) and Aden experience power insufficiency of some sort (UNDESA 2020). Based on these known infrastructure issues affecting reliable supply, and extrapolating to the response phase, it is high likely that power was insufficient during the WD (Emergency Energy Availability: 1 for both). Despite the economic losses, Bluewater recovered in a short period due to additional income sources (e.g., government support and insurance) and sufficient disaster relief planning (i.e., State Recovery Plan)[1] (Income Flow: 2). By contrast, Nepal is one of the poorest countries in the world (UNCDP 2018). While the government provided some financial assistance, it could not redress financial losses for all those affected (Income Flow: 1). Yemen is in civil conflict and the government cannot financially support much of its population, nor offer financial assistance to flood-affected communities in Aden without the support of humanitarian organizations (Income Flow: 1).

Table 4 summarizes the key outcomes of each case based on the VCM template and the above estimates. By applying these metrics, we map the vulnerability and capability levels of these communities in a way that supports cross-jurisdictional comparisons.

As detailed in Table 4, Bluewater has sufficient capacity with a total rating of 15 (short-term problems in post-hazard phase only). It should not be considered as vulnerable community, particularly as it did not require external assistance. Conversely, both Pheta (Ward 6) and Aden are vulnerable communities with rates of 8 and 6, respectively. Both were found to have low WD resilience and response capability, including no EWS or energy supply that could support the WD response. Further support is indicated if the Nepalese

[1] North and Far North Queensland Monsoon Trough State Recovery Plan 2019–2021 https://www.qra.qld.gov.au/sites/default/files/2020-03/Monsoon-Trough-2019-State-Recovery-Plan.pdf

Table 5 Hypothetical capability rating communities at risk of WD post-installation (OGRES and EWS)

Community, Country	Pre-hazard*			Post-hazard**			
	Disaster Preparedness	Energy Availability	Income Status	Disaster Response	Emergency Energy Availability	Income Flow	Total Rating
Bluewater, Australia	3	3	3	3	3	2	17
Pheta (Ward 6), Nepal	2	3	2	2	2	1	12
Aden Governorate, Yemen	2	2	1	2	2	1	10

*6 months or more.

**1 month or less.

and Yemeni communities are to develop these key capabilities. The installation of OGRES and EWS could be a key solution for energy generation and strengthening WD resilience at the local level.

Table 5 presents notional capability rating for each community had they installed OGRES and EWS before the WD occurred. Even though this is a hypothetical scenario, in practice, disaster preparedness and response should increase, since EWS and appropriate training would support community WD resilience. Similarly, energy availability under any condition should also increase. The average of total primary energy per capita in L/LMIC is less than 300 Watts (Kolbert 2008; Schismenos et al. 2020). This amount can be easily generated by OGRES (e.g., pico-hydropower systems) and support common energy needs. During WD, 300 Watts can act as emergency power supporting evacuation planning and possibly reducing fatality rates (Schismenos et al. 2020).

As detailed in Tables 4 and 5, the total rate change for Bluewater is not significant (15 17). However, the positive change shows that OGRES and EWS could still be used as a supplementary asset for emergency response within the existing WD response system, as there is an improvement in the post-disaster metrics. Within this model, the substantial rate change for Pheta (Ward 6) (8 12) is the result of positive changes related to the intervention in pre- and post-hazard conditions, since it improves both routine energy generation and WD response capability. In this case, we estimate that after the WD occurrence, the community will most likely lose income (e.g., impacts on agriculture or cattle) within a period of 1 month, since it is a mono-economy and highly dependent on its primary income source. The total rate change in the case of Aden is also substantial (6 10), achieving an incremental shift-related particularly to WD awareness/alerts and energy access (including intra-hazard). Income estimates necessarily remain low, but would likely see increases in a post-conflict, stabilized environment, and with potential flow-on to hazard mitigation.

Results and discussion

Natural disasters affect human settlements in various ways, with WD being the most frequent type and affecting the greatest number people through direct losses and dislocation. Their consequences are more intense in L/LMIC where insufficient infrastructure, poor governance, and lack of emergency services are more common. Within these countries, small communities which lack political and financial power may experience further resource inequities, including forms of environmental exploitation that may degrade their environments and sustainable livelihoods. Humanitarian engineering works with communities to co-develop solutions in climate adaptation, sustainable development, and community harmony and development—practical expressions of the United Nations Agenda 2030 for Sustainable Development. While there are existing methods for assessing community vulnerability and capability for a single community, a universal and evidence-informed approach based on internationally accepted criteria has been lacking. Our findings suggest that the use of VCM to assess disaster response capability offers a potentially reliable means of community evaluation and comparison of areas for targeted development. The VCM can also assess incremental shifts in WD resilience, energy, and income, in a format that is easily understood by community actors and may assist in initial engagement regarding these issues.

To display the applications of VCM, this paper presented three examples of communities vulnerable to WD. Each community had different capability and vulnerability levels. According to the VCM, Bluewater capability against WD was high, while Pheta (Ward 6) and Aden were not. The focus of VCM is to support community participatory responses to hazard assessment, prioritizing disaster resilience, and capability development. Where solutions include the development and trialing of OGRES and EWS, and other technology-related capabilities, community participation will be critical to their ongoing success. Often however, these are determined by the approaches and resources offered by the support and implementing partners. Such initiatives, while laudable, are only ethical and feasible when they come with the longer-term resource 'footprint' needed for genuine development impact within these communities. For example, multi-year funded projects with ongoing training, maintenance, and technical supports budgets supporting measurable capacity building. For enhancements in EWE capability, several major issues at the community level need to be considered.

First, such systems may be vulnerable to EWE and human-induced threats. In Yemen's example, Aden is not only affected by flash floods but also civil conflicts. If the systems are vulnerable to floods and their products (e.g., floating debris), as well as vandalism and sabotaging incidents, they may not be an appropriate humanitarian engineering solution. Therefore, systems' design, location, installation, and surveillance should be considered. Second, if the systems are expensive, 'foreign' to local know-how or complex, local residents are unlikely to stay involved longer-term. In other instances, conflicts between community user-groups may ensue if the benefits are insufficient or unfairly distributed (Ikejemba et al. 2017). It is important from the outset that community end-users become familiar with the systems' operations, maintenance, and their working limits. Such understandings and agreements can be created via community participatory approaches, including VCM and a range of related assessment tools. Community disaster education workshops can also support the wider aims of this work. Thirdly, OGRES and EWS can act as the driver for increasing community resilience and sustainable development, but only with substantial program support over time. Importantly, these capabilities have the potential to act as a development 'base' for other health and socio-economic benefits. For example, we observed, in the case of Bluewater, other health risks of flood water (i.e., infection due to water-borne bacteria). Such systems could also be equipped with bacteria detection sensors to analyze water quality and specific risks. This could be a great asset which enhances its perceived value, particularly for the vulnerable communities in L/LMIC where general and flood water quality may vary. Finally, it should be highlighted that while humanitarian engineering interventions are essential, they can only be successful when efforts for climate reparation and sustainable, socio-economic development are made at a wider, more comprehensive level with the engagement of local, national, and international stakeholders.

Limitations and future work

The case examples used in the VCM are recent and based on news media information that is not validated with scientific data (e.g., flood risk analysis and direct impacts of the WD). The lack of consistent data may have affected the ranking in some metrics. When updated data from potentially more reliable sources are available (e.g., government reports and non-governmental organizations that provided aid to these affected communities), this study can be updated with these corroborative data inputs.

The continuation of this study could result in the identification of more objective open access sources for all the VCM metrics. These will further increase the reliability of the outputs. The development of a case study analysis in collaboration with humanitarian and developmental agencies would allow testing the VCM applications across a wider range of communities (e.g., communities in need of OGRES and findings in pre- and post-system installation).

Conclusions

In a climate context where WD are frequent and severe, reducing hazard impacts in remote communities can be a challenging task. Populations in L/LMIC experience greater disaster vulnerability, not only due simply to limited resources, but also structural and environmental inequities. Such injustice predisposes communities to societal tensions and conflicts. The strengthening of disaster resilience via OGRES, EWS, and related systems can be key drivers of community equity and harmony, but also need bold, State, and international actions for fair environmental resource management. The VCM could inform humanitarian engineers and practitioners about the essential needs of vulnerable populations and improve the livelihood and dignity of those at risk.

Appendix 1

List of open access secondary sources for informing VCM metrics.

	Source	Database/Link	Information
Disaster preparedness (pre-hazard)			
Selected Source*:	Global Risk Map, United Nations, Environment Programme Principles for Sustainable Insurance (PSI) Initiative	http://globalriskmap.terria.io/About.html	Related data (e.g., flood data)
Source:	World Risk Report 2019, Bündnis Entwicklung Hilft and Ruhr University Bochum	https://reliefweb.int/sites/reliefweb.int/files/resources/WorldRiskReport-2019_Online_english.pdf	Related data (e.g., vulnerability level, exposure to natural hazards)
Source:	International/National bodies and agencies, non-governmental organizations	Various	Related data (e.g., vulnerability and capability analysis, EWS)
Source:	News Media (local/international)	Various	Related data (e.g., disaster preparedness mechanisms)
Energy availability (pre-hazard)			
Selected Source*:	Energy Statistics Pocketbook 2020, United Nations Statistics Division	https://unstats.un.org/unsd/energystats/pubs/documents/2020pb-web.pdf	Energy use per capita, electricity consumption per capita, etc
Source:	Energy Consumption by Country 2020 by Population 2020, World Population Review	https://worldpopulationreview.com/country-rankings/energy-consumption-by-country	Energy consumption (kWh) per capita
Source:	2017 Electricity Profiles, United Nations Statistics Division	https://unstats.un.org/unsd/energystats/pubs/eprofiles/	Renewable energy statistics, electricity production and consumption, etc
Source:	Tracking SDG 7: The Energy Progress Report 2020	https://www.irena.org/publications/2020/May/Tracking-SDG7-The-Energy-Progress-Report-2020	Data regarding renewable energy, energy efficiency, OGRES potential, etc
Income status (pre-hazard)			
Selected Source*:	International Minimum-Wage Rates 2020	https://www.minimum-wage.org/international	Minimum wage per county
Source:	Country Comparison: GDP per capita, The World Factbook	https://www.cia.gov/library/publications/the-world-factbook/rankorder/2004rank.html	Purchasing power per capita (comparison by country)
Source:	Ministry of Finance/Economy/Labor	Various	Purchasing power per capita, income, etc
Disaster response (post-hazard)			
Selected Source*:	News Media (local/international)	Various	Related data (e.g., sufficient emergency response)
Source:	Ministry of Civil Protection, Internal Affairs, other authorities	Various	Related data (e.g., emergency response mechanisms)
Source:	Civil society groups, local/international non-governmental organizations	Various	Related data (e.g., emergency response and recovery)
Emergency energy availability (post-hazard)			
Selected Source*:	News Media (local/international)	Various	Related data (e.g. energy availability during and after the disaster)
Source:	Ministry of Energy, Civil Protection, Internal Affairs, other authorities	Various	Related data (e.g., energy availability during EWE)
Source:	Civil society groups, local/international non-governmental organizations	Various	Related data (e.g., energy availability during EWE)
Income flow (post-hazard)			
Selected Source*:	News Media (local/international)	Various (Database:)	Related data (e.g., damages in income sources)
Source:	Local/international non-governmental organizations	Various	Related data (e.g., income flow, purchasing power during and after the disaster)

Source:	Ministry of Finance/Economy/ Labor, other authorities
Database/Link:	Various
Information:	Related data (e.g., income support and other initiatives)

*The selected source is the source/source type used in this study to inform the preliminary version of VCM, community case examples and Table 4

References

9news (2019) Death toll from powerful Nepal rainstorm rises to 28 as survivors search for food. 9news. https://www.9news.com.au/world/news-world-nepal-rain-storm-death-toll-regional-area-national-emergency-weather/ebf91ba3-d480-411a-aac2-fee2663e4b7e. Accessed 22 Dec 2019

ABC (2019a) Townsville flood authorities confirm death from soil bacteria, several others in intensive care. ABC News. https://www.abc.net.au/news/2019-02-12/townsville-flood-claims-life-soil-bacteria-infection-outbreak/10804540. Accessed 22 Dec 2019

ABC (2019b) Townsville flooding continues as hundreds wait for waters to recede. ABC News. https://www.abc.net.au/news/2019-02-05/townsville-flood-continues-as-bluewater-locals-sent-alert/10778958. Accessed 22 Dec 2019

Alcántara-Ayala I, Oliver-Smith A (2019) Early warning systems: lost in translation or late by definition? A FORIN approach. Int J Disaster Risk Sci 10:317–331

Amin AZ (2018) Ramping up renewables. Climate 2020. https://www.climate2020.org.uk/wp-content/uploads/2018/11/040-042-C2020-AMIN.pdf. Accessed 20 Sept 2020

Benson C, Twigg J, Rossetto T (2007) Tools for mainstreaming disaster risk reduction: guidance notes for development organisations. ProVention Consortium.

Bidari S (2019) Toll expected to double to 50 in tornado. Nepali Times. https://www.nepalitimes.com/latest/toll-expected-to-double-to-50-in-tornado/. Accessed 22 Dec 2019

Burnham G (2008) Disaster definitions. In: Rand EC (ed) The Johns Hopkins and Red Cross Red Crescent Public health guide in emergencies, second edition, International Federation of Red Cross and Red Crescent Societies, Geneva, pp. 24-39. https://reliefweb.int/sites/reliefweb.int/files/resources/Forward.pdf

Coles E, Buckle P (2004) Developing community resilience as a foundation for effective disaster recovery. Australian Journal of Emergency Management, The 19(4):6-15. ISSN: 1324-1540. https://search.informit.com.au/documentSummary;dn=375435145094637;res=IELHSS

CRED (2020) Human cost of disasters: an overview of the last 20 years. Centre for Research on the Epidemiology of Disasters (CRED), Brussels. https://www.emdat.be/publications

Day S, Forster T, Himmelsbach J, Korte L, Mucke P, Radtke K, Theilbörger P, Weller D (2019) World Risk Report 2019—focus: water supply. Bündnis Entwicklung Hilft and Ruhr University Bochum—Institute for International Law of Peace and Armed Conflict (IFHV). ISBN 978-3-946785-08-8

Di Baldassarre G, Montanari A, Lins H, Koutsoyiannis D, Brandimarte L, Blöschl G (2010) Flood fatalities in Africa: from diagnosis to mitigation. Geophysical Research Letters 37(22). https://doi.org/10.1029/2010GL045467

Dincer I (1999) Environmental impacts of energy. Energy Policy 27(14):845–854

Dube E, Mtapuri O, Matunhu J (2018) Flooding and poverty: two interrelated social problems impacting rural development in Tsholotsho district of Matabeleland North province in Zimbabwe. Jàmbá: J Disaster Risk Stud 10(1):1–7

FEMA (2008) Using the hazard mitigation plan to prepare successful mitigation projects. Federal Emergency Management Agency (FEMA).

FEWSNET (2020) Famine Early Warning Systems Network (FEWSNET). https://fews.net/

Field CB, Barros V, Stocker TF, Dahe Q (2012) Managing the risks of extreme events and disasters to advance climate change adaptation: special report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge

Gosink J, Lucena J, Moskal B (2003) Humanitarian engineering at the Colorado School of Mines: an example of multidisciplinary engineering. Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition. Nashville, Tennessee, pp 8.647.1-8.647.15. ISSN 2153-5965 https://doi.org/10.18260/1-2--11871

Hill S, Miles E (2012) What do students understand by the term 'humanitarian engineering'. Proceedings of the EE2012 International Conference on Innovation, Practice and Research in Engineering Education. Coventry University, UK. pp 1-11. http://cede.lboro.ac.uk/ee2012/papers/ee2012_submission_186_gp.pdf

Howells M, Rogner HH, Mentis D, Broad O (2017) Energy access and electricity planning. Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/628541494925426928/Energy-access-and-electricity-planning

Ikejemba EC, Mpuan PB, Schuur PC, Van Hillegersberg J (2017) The empirical reality and sustainable management failures of renewable energy projects in Sub-Saharan Africa (part 1 of 2). Renew Energy 102:234–240

IRENA (2018) Off-grid renewable energy solutions. International Renewable Energy Agency (IRENA). https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Jul/IRENA_Off-grid_RE_Solutions_2018.pdf

Jaglin S (2019) Electricity autonomy and power grids in Africa: From rural experiments to urban hybridizations. In: Lopez F, Pellegrino M, Coutard O (eds) Local Energy Autonomy: Spaces, Scales, Politics, Volume 1, Wiley Online Library, Hoboken, New Jersey, pp. 291-314. https://doi.org/10.1002/9781119616290.ch13

Johnston J (2020) Live export boom at Townsville port. North Queensland Register. https://www.northqueenslandregister.com.au/story/6843652/northern-cattle-kings/#:~:text=Townsville%20is%20the%20cattle%20live,in%20a%20record%20financial%20year. Accessed 25 Sept 2020

Kolbert E (2008) The island in the wind. New Yorker 7:68–77

Kumar V, Cheng SYC, Singh AK (2016) Impact of flood on rural population and strategies for mitigation: a case study of Darbhanga district, Bihar state. India Contemp Rural Social Work 8(1):5

Mahmoudi M, Fattahpour V, Velayati A, Roostaei M, Kyanpour M, Alkouh A, Sutton C, Fermaniuk B, Nouri A (2018) Risk assessment in sand control selection: introducing a traffic light system in stand-alone screen selection. In: Society of petroleum engineers, international heavy oil conference and exhibition, Kuwait City, Kuwait

Manley D, Cust JF, Cecchinato G (2017) Stranded nations? The climate policy implications for fossil fuel-rich developing countries. The Climate Policy Implications for Fossil Fuel-Rich Developing Countries. OxCarre Policy Paper 34

Mazzurco A, Jesiek BK (2017) Five guiding principles to enhance community participation in humanitarian engineering projects. J Hum Eng. https://doi.org/10.36479/jhe.v5i2.80

MEE (2020) Yemen declares Aden a 'disaster area' after flash floods kill eight. Middle East Eye (MEE). https://www.middleeasteye.net/news/yemen-aden-disaster-area-flash-floods. Accessed 30 Apr 2020

Mosel I, Levine S (2014) Remaking the case for linking relief, rehabilitation and development: how LRRD can become a practically useful concept for assistance in difficult places. Humanitarian Policy Group, the Overseas Development Institute, London
MW (2020) International minimum wage rates 2020. Minimum-Wage (MW). https://www.minimum-wage.org/international. Accessed 30 Apr 2020
Nilsson L, Madon T, Sastry SS (2014) Toward a new field of development engineering: linking technology design to the demands of the poor. Procedia Eng 78:3–9
Omeje K (2006) The rentier state: Oil-related legislation and conflict in the Niger Delta, Nigeria: analysis. Conflict Secur Dev 6(2):211–230
Ostadtaghizadeh A, Ardalan A, Paton D, Jabbari H, Khankeh HR (2015) Community disaster resilience: a systematic review on assessment models and tools. PLOS Currents Disasters. https://doi.org/10.1371/currents.dis.f224ef8efbdfcf1d508dd0de4d8210ed
Phillips C (2017) Combining energy efficiency and disaster mitigation efforts in residential properties. office of policy development and research. https://www.huduser.gov/portal/periodicals/em/spring17/highlight2.html#:~:text=Energy%20efficiency%20is%20an%20essential,provides%20social%20and%20economic%20benefits.&text=Reduced%20operating%20costs%20and%20increased,energy%20bills%20and%20insurance%20premiums. Accessed 10 Oct 2020
Pearson L, Pelling M (2015) The UN Sendai framework for disaster risk reduction 2015–2030: negotiation process and prospects for science and practice. J Extreme Events 2(01):1571001
Peek L (2008) Children and disasters: understanding vulnerability, developing capacities, and promoting resilience—an introduction. Child Youth Environ 18(1):1–29
Rafferty S (2019) Townsville flooding crisis leaves almost 1000 displaced two months on. ABC News. https://www.abc.net.au/news/2019-04-02/townsville-flooding-leaves-a-thousand-homeless-two-months-on/10959250. Accessed 22 Dec 2019
Renschler CS, Frazier A, Arendt L, Cimellaro G, Reinhorn A, Bruneau M (2010) Developing the 'PEOPLES' resilience framework for defining and measuring disaster resilience at the community scale. Proceedings of the 9th US national and 10th Canadian conference on earthquake engineering. Toronto, Canada.
Ross ML (2015) What have we learned about the resource curse? Annu Rev Polit Sci 18:239–259
Schismenos S (2017) Anthropocentric principles for effective early warning systems. In: Youth Science Policy Interface Publication (ed) Special edition: disaster risk reduction: a road of opportunities, United Nations Major Group of Children and Youth, Cancun, Mexico, pp 08–12
Schismenos S, Emmanouloudis D, Chalaris M, Katopodes N, Stevens G (2018) Renewable energy generated by the impacts of natural and accidental water-based disasters. Proceedings of the Safe-Kozani 2018: New Technologies and Civil Protection. Kozani, Greece, pp 378–384
Schismenos S, Stevens GJ, Emmanouloudis D, Georgeou N, Shrestha S, Chalaris M (2020) Humanitarian engineering and vulnerable communities: hydropower applications in localized flood response and sustainable development. Int J Sustain Energ 39(10):941–950
SERVIR (2020) Service catalogue. SERVIR Global (SERVIR). https://www.servirglobal.net/ServiceCatalogue/
Shakya S (2020) At the ready for floods in the Koshi: CBFEWS orientation trainings during the pandemic. International Centre for Integrated Mountain Development. https://www.icimod.org/at-the-ready-for-floods-in-the-koshi-cbfews-orientation-trainings-during-the-pandemic/. Accessed 21 Sept 2020
Sheroubi A, Potvin G (2018) Humanitarian engineering: a new interdisciplinary course on the application of engineering skills to local and global humanitarian challenges. Proc Can Eng Educ Assoc. https://doi.org/10.24908/pceea.v0i0.12963
Shrestha Pradhan N (2020) What is CBFEWS? International Centre for Integrated Mountain Development. https://www.icimod.org/mountain/cbfews. Accessed 21 Sept 2020
Simmons DC, Dauwe R, Gowland R, Gyenes Z, King AG, Riedstra D, Schneiderbauer S (2017) Qualitative and quantitative approaches to risk assessment. Publications Office of the European Union
Smith E (2011) DIY solar projects: How to put the sun to work in your home. Quarto Publishing Group USA. ISBN: 1589236033.
Stewart F, Holdstock D, Jarquin A (2002) Root causes of violent conflict in developing countries commentary: conflict—from causes to prevention? BMJ 324(7333):342–345
Strömberg D (2007) Natural disasters, economic development, and humanitarian aid. J Econ Perspect 21(3):199–222
Thiemig V, Bisselink B, Pappenberger F, Thielen J (2015) A pan-African medium-range ensemble flood forecast system. Hydrol Earth Syst Sci 19(8):3365–3385
Thomas E (2019) Toward a new field of global engineering. Sustainability 11(14):3789
Thomas E, Jordan E, Linden K, Mogesse B, Hailu T, Jirma H, Thomson P, Koehler J, Collins G (2020) Reducing drought emergencies in the Horn of Africa. Sci Total Environ. https://doi.org/10.1016/j.scitotenv.2020.138772
Twigg J (2004) Disaster risk reduction: mitigation and preparedness in development and emergency programming. Overseas Development Institute (ODI)
UN (2015) Transforming our world: the 2030 agenda for sustainable development resolution adopted by the General Assembly. United Nations (UN)
UNCDP (2018) List of least developed countries (as of December 2018). United Nations Committee for Development Policy. https://www.un.org/development/desa/dpad/wp-content/uploads/sites/45/publication/ldc_list.pdf
UNDESA (2020) Energy Statistics Pocketbook 2020. United Nations Department of Economic and Social Affairs (UNDESA)
UNDP (2006) Niger Delta Human Development Report. United Nations Development Programme (UNDP). http://hdr.undp.org/sites/default/files/nigeria_hdr_report.pdf
UNDP (2014) Environmental Justice—Comparative experiences in legal empowerment. United Nations Development Programme (UNDP). https://www.undp.org/content/dam/undp/library/Democratic%20Governance/Access%20to%20Justice%20and%20Rule%20of%20Law/Environmental-Justice-Comparative-Experiences.pdf
UNFCCC (2020) Community-based flood early-warning system—India. United Nations Framework Convention on Climate Change (UNFCCC) https://unfccc.int/climate-action/momentum-for-change/information-and-communications-technology-solutions/community-based-flood-early-warning-system-india
UNHCY (2020) Yemen is hit by once-in-a generation floods; tens of thousands of families lose everything. United Nations Humanitarian Coordinator in Yemen (UNHCY) https://reliefweb.int/report/yemen/yemen-hit-once-generation-floods-tens-thousands-families-lose-everything-enar
UNISDR (2009) 2009 UNISDR Terminology on Disaster Risk Reduction. United Nations International Strategy for Disaster Reduction (UNISDR). https://www.unisdr.org/files/7817_UNISDRTerminologyEnglish.pdf
UNISDR (2013) From shared risk to shared value: the business case for disaster risk reduction. Global Assessment Report on Disaster Risk Reduction. United Nations International Strategy for Disaster Reduction (UNISDR)

UNSD (2020) Global Sustainable Development Goals Indicators Database. United Nations Statistics Division (UNSD). https://unstats.un.org/sdgs/indicators/database/

Wahlstrom M, Guha-Sapir D (2015) The human cost of weather-related disasters 1995–2015. United Nations International Strategy for Disaster Reduction (UNISDR)

Waidyanatha N (2010) Towards a typology of integrated functional early warning systems. Int J Crit Infrastruct 6(1):31

WB (2019) World Bank Country and Lending Groups. World Bank (WB). https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups

WHO (2019) Cholera situation in Yemen: November 2019. World Health Organization (WHO). https://applications.emro.who.int/docs/YEM/YEM-Chol-Nov-2019-eng.pdf?ua=1&ua=1. Accessed 2 May 2020

Wilhelm B, Ballesteros Cánovas JA, Macdonald N, Toonen WH, Baker V, Barriendos M, Benito G, Brauer A, Corella JP, Denniston R, Glaser R (2019) Interpreting historical, botanical, and geological evidence to aid preparations for future floods. Wiley Interdiscipl Rev: Water 6(1):e1318

Wisner B, Blaikie PM, Blaikie P, Cannon T, Davis I (2004) At risk: natural hazards, people's vulnerability and disasters. Psychology Press, East Sussex

Younger JS, Booth DJ, Parry DE, Kurniawan K (2018) Sustainable humanitarian engineering in practice—the east Bali poverty project. In: Proceedings of the Institution of Civil Engineers-Municipal Engineer. Thomas Telford Ltd 171(2): 67–77.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Paper V

Humanitarian and Developmental Research Engagement during COVID-19: A Remote Research Approach

Spyros Schismenos[1,3*], Garry J. Stevens[1], Nichole Georgeou[1], Dimitrios Emmanouloudis[2,3], Surendra Shrestha[4], Biraj S. Thapa[5]

[1]School of Social Sciences, Humanitarian and Development Research Initiative (HADRI), Western Sydney University, Sydney, Australia.
[2]Department of Forestry and Natural Environment, International Hellenic University, Kavala, Greece.
[3]UNESCO Chair on Conservation and Ecotourism of Riparian and Deltaic Ecosystems, International Hellenic University, Drama, Greece.
[4]School of Engineering, Western Sydney University, Sydney, Australia.
[5]Department of Mechanical Engineering; Green Hydrogen Lab, Kathmandu University, Nepal

ABSTRACT

Background: Floods and storms are the most common natural hazards. Communities in remote, riparian areas are the most vulnerable in such disasters, particularly when local populations lack reliable energy and early warning systems for hazard response. Our study will investigate energy and flood resilience issues in such communities and use remote methods to enable research continuity in intra and post-pandemic contexts.

Methods/Design: A two-round Delphi process will be used to interview 16 participants from Nepal and Greece to understand their priorities and preferred solutions for energy and flood resilience issues. In Round One we aim to understand the current capabilities and vulnerabilities of our focus communities in these areas. In Round Two, we seek feedback on potential options that are either market-available/evidence-informed solutions or co-developed conceptual systems. Remotely deployed semi-structured interviews are the principal method for both rounds. The Round Two structured comparative review also employs choice-based conjoint analysis and SCORE analysis.

Discussion: By collecting information from both professionals and non-experts, we aim to understand what options are perceived as reliable, realistic and appropriate for flood-prone communities. The remote research design enables continuity and community access to development-focused research and its outputs, and a flexible, cost-effective approach for researchers and partner organizations.

Keywords: Delphi method, choice-based conjoint analysis, SCORE analysis, humanitarian engineering, sustainable development, renewable energy, flood

* Correspondence to Dr Spyros Schismenos, School of Social Sciences, Humanitarian and Development Research Initiative (HADRI), Western Sydney University, Sydney, Australia. Email: S.Schismenos@westernsydney.edu.au

http://dx.doi.org/10.7565/ssp.v4.6487

1. Background

1.1 Introduction to the literature

Water-based disasters such as floods and storms are the most frequent types of natural disasters (CRED, 2020). They affect the highest number of people worldwide, particularly in riparian settlements where early warning systems and energy generation and/or distribution infrastructures are limited or poorly developed (CRED, 2020; Wahlstrom & Guha-Sapir, 2015). Reliable and sufficient energy supply drive increases in community capability, including sustainable development (Howells et al., 2017), and disaster resilience (Phillips, 2017). Energy insufficiency (including interruption and supply limits) is a common issue in remote communities in both low and high-income countries (Howells et al., 2017). Off-grid renewable energy systems such as small-scale hydropower generators and solar energy panels offer a solution, especially if linked with localized early warnings (Schismenos et al., 2020, 2021a).

Despite the progress in research and product variations for energy generation and flood early warning at the local level, such systems are not always efficient and sustainable for a range of reasons (technical, social, economic, administrative, etc.) (Ikejemba et al., 2017). As a result, they frequently fail over time as they cannot support (or be supported by) end-users in a realistic manner (Schismenos et al., 2021c). The need for robust design, implementation and maintenance of such systems is critical. The integration of these functions could provide greater advantages to local end-users, particularly where these systems are co-developed and managed by community members to address priority needs in their contexts (e.g. reliable, sustainable energy including emergency power). Based upon these needs, the study will draw upon technical and community engagement models, and theoretical frameworks to structure the engagement process with a panel of community and professional stakeholders, determine key needs in the communities of interest (remote, riparian communities) and potential development and management options that may be available to such communities.

1.2 Community participation and remote research

Community engagement in humanitarian and developmental research is important as it increases plurality in thinking, fairness in decision-making and trust between involved stakeholders. Moreover, it has an important role in community self-determination as it supports access to, and ownership of, research processes and their products, such as social programs or physical assets (Georgeou & Hawksley, 2020; Schismenos et al., 2021b). In this study, the active participation of community members in the processes is essential for the detailed analysis and acceptance of the suggested solution. Participatory Action Research (PAR) is a suitable approach to support the engagement and active participation of a range community stakeholders (e.g. community members and professionals) regarding research-related issues, and who represent a diversity of views regarding their community and its needs. This method typically employs a three-phase process: (i) ideation information development, (ii) ideation process development and (iii) co-design development (Hur, Cassidy & Thomas, 2013). The PAR is commonly used to evaluate community needs within local contexts and systems (Gautam & Phaiju, 2013; Lebel et al., 2019).

A key limitation of PAR is where physical access to communities is restricted, such as interaction with remote communities or during crises such as the COVID-19 pandemic. As a result of COVID-19 restrictions, research studies in many fields, including humanitarian, engineering, environmental and clinical, have been postponed, or otherwise altered, often in ways that diminished or excluded community participation (Schneider et al., 2020). International research projects involving sites in more than one country have been particularly impacted. Remote research methods have been increasingly deployed during this period to permit research continuity and community access, albeit this likely reflects the acceleration of an existing trend regarding such approaches (Richardson, Godfrey & Walklate, 2021). These frameworks are appropriate for our study and will allow us to examine how community and professional stakeholders (hereinafter, panel members) of communities vulnerable to natural hazards perceive the local establishment of a renewable energy source and its uses.

This article details how we will assess community and professional perceptions of energy needs and flood hazard preparedness at the local level including possible applications with existing energy generation and flood early warning, and conceptual systems that could integrate these functions. The views of panel members will be gathered remotely, using the Delphi method - a structured communication technique that can be used for needs/capability assessments and process development including potential community and technical solutions. Our methodology presents a pragmatic approach that can be adopted by other humanitarian and development researchers unable to conduct face-to-face interviews and in-situ field-work due to pandemics and other restrictions to physical access.

2. Methods/Design

2.1 Aims

Our study aims to determine what are the priority energy and flood resilience needs in remote, riparian communities in low and high-income countries. To achieve that, we will investigate whether market available energy and flood warning systems or conceptual prototypes designed for local-level applications are an acceptable solution for the panel members. An additional aim is to confirm whether remote research is an acceptable approach to conduct interviews in the context of pandemic restrictions. Positive findings can contribute to humanitarian, development, engineering, energy generation/distribution, and flood resilience programs that can respectively improve and save lives, especially among vulnerable groups such as the elderly and those with mobility issues which affect timely evacuation. This research could also enhance collaborations between community groups and professionals, particularly in locations or conditions where a physical interaction is not realistic.

2.2 Research questions

Research questions were drawn in five discrete areas of the study:

(i) Evidence-based literature (literature review, including 'grey' literature)

- What does the available literature indicate are the elements of efficient and sustainable off grid renewable energy systems within remote, riparian communities experiencing energy insufficiency and flood risks?
- What does the available literature indicate are the elements of efficient and sustainable localized flood early warning systems for floods in such communities?
- Are hybrid systems detailed in the literature?

(ii) Community energy needs

- What do panel members perceive to be the current status regarding electrical power supply under normal and extreme (flood) conditions?
- Is renewable energy nominated as a preferred energy source? - What types and preferred features?

(iii) Community flood-hazard needs

- What do panel members perceive to be key vulnerabilities regarding flood risk and community warning/response?

- Is flood early warning nominated as a priority for dealing with floods? - What types and preferred features?

(iv) Preferred community assets

- What do panel members perceive would be the most useful asset for their community – What system type and attributes based on strengths, challenges, opportunities, responses and effectiveness?
- What are panel members perceptions of a conceptual system which combines renewable energy generation and flood warning services?

(v) Remote research

- What are panel member perceptions of remote research regarding participation, understanding, access, and refinement?

2.3 Selection of community sites

Our focus communities and sites will be:

(i) Dhuskun village, Tripura Sundari Rural Municipality Ward no.3, Sindhupalchowk District, Bagmati Province, and Sunkoshi River in Nepal, and

(ii) Aggitis village, Drama Regional Unit, Eastern Macedonia and Thrace Region, and Aggitis River in Greece

These proposed sites have been identified as meeting the study selection criteria. Specifically, they are small, remote, riparian communities, with poor/no flood early warning mechanisms, and which experience power insufficiency, particularly during extreme weather events. Their local economy is dependent on agriculture and ecotourism, income sources that are highly affected by floods and power outages. While this research has greater applications in community development and disaster resilience in low-income countries where flood impacts are more intensified, the recent floods in Germany[1], the United States[2], and China[3] showed that flood extremes can affect everyone. Accurate early warning and continuous energy generation under any conditions are essential to support remote communities who are often incapable of evacuating in time. Thus, this study includes communities in both low and high-income countries, and this will allow a comparison of community perspectives in these regions.

2.4 Selection of methods

The study will examine community perceptions of available off-grid renewable energy and early warning systems, and conceptual hybrid systems. Based on the findings of both peer-reviewed and 'grey' literature, a review process with panel members from a range of demographic and socio-economic backgrounds will occur using the Delphi method. The Delphi method typically takes place via several rounds of survey-based review and feedback. Outcomes may include improved processes, prototypes, optimized technologies, or determinations of non-viability (Brent & Kruger, 2009; Dick, 1991; Helmer-Hirschberg, 1967). In our study, this will occur in two rounds of a survey following an individual work format (participants work individually, without discussion).

---

[1] https://www.theguardian.com/world/2021/jul/19/german-villages-could-be-left-with-no-drinking-water-after-floods
[2] https://www.nytimes.com/2021/09/03/nyregion/nyc-ida.html
[3] https://www.bbc.com/news/world-asia-china-57861067

The main data collection method for both rounds will be online semi-structured interviews. In Round Two, this will be augmented with two structured review formats; choice-based conjoint analysis (CBCA) and strengths, challenges, opportunities, responses, and effectiveness (SCORE) analysis. These frameworks will support a systematic, comparative analysis across different options, including single market-available/evidence-informed solutions, their combination, and the co-development of conceptual prototypes (via CBCA), and detail any strengths, challenges, opportunities (or risks), responses, and effectiveness of the preferred option (via SCORE analysis). The thematic analysis will then be used for data analysis. These methods and the rationale regarding their selection are detailed below.

Delphi method

The Delphi method is commonly used in needs assessments and prototype development studies. It provides equal access and contribution opportunities to all participants (Brent & Kruger, 2009; Dick, 1991). Through this method, disagreements are used for pooled information and shared understanding (Dick, 1991). It does not require face-to-face interaction and is often conducted remotely (Dick, 1991), making it a suitable method for community research during pandemics and other contexts affecting community access and safety. It has been found to be an efficient strategy for community consensus regarding priority needs and development proposals (Brent & Kruger, 2009; Helmer-Hirschberg, 1967), and is a preferred method compared to other decision-making techniques, such as multi-voting, as it limits the range of responses and results in 'close to expert consensus' (Helmer-Hirschberg, 1967).

In our study, a two-round interview is considered appropriate to order to understand community needs and then assess processes and resources that may address these needs. Round One aims to identify community vulnerabilities and capabilities through local stakeholders' perceptions. Round Two is informed by Round One and suggests appropriate humanitarian and developmental interventions that are acceptable to local communities. This approach provides a suitable pathway for researchers to acquire the necessary technological, humanitarian, social and environmental knowledge 'through the eyes' of local participants – a step that is often absent in engineering-based solutions.

For the panel composition, we suggest a mix of both professionals and non-experts who are familiar with their community and local needs. We propose the size of 16 participants (eight per community) for the panel as this is an acceptable number of participants for projects using the Delphi method. Ogbeifun et al. (2016) state that the size of a Delphi panel can be as small as three members, depending on the topic and expertise of panel members. In health applications, size can be as low as four panel members (Cantrill, Sibbald & Buetow 1996, p. 69), while other studies have presented data from several Delphi studies which involve participant panels with three or four members (Skulmoski, Hartman & Krahn 2007). It should be highlighted that the Delphi method has received unfounded criticism due to its panel size, as it is often confused with conventional qualitative surveys (Mullen, 2003).

Consistent with previous research the selection of participants should be based on their familiarity with their community, and expertise. Other studies using the Delphi method indicate that selecting participants who are knowledgeable about the focal topic is more critical than the number of panelists (Cantrill, Sibbald & Buetow, 1996; Grisham, 2009; Mullen, 2003). In the current study, energy insufficiency and flood risk in the proposed communities are the issues of focal interest.

While the Delphi method usually involves groups, it is also recommended for one-to-one interviews and questionaries (Skulmoski, Hartman & Krahn, 2007). Van Dijk (1990) investigated different methodological approaches to using Delphi including individual interviews, surveys and focus groups. They found that individual interviews offer important advantages for both participants and researchers, including the ease of oral expression compared to written expression, and the freedom to express one's own view, in a manner that is not disturbed, interrupted, or changed by others (as in the group interview). Importantly, individual online interviews provide safety for the participants during the COVID-19 pandemic, thus, we will be using them in this study.

Remote research

Remote research involves any research process in which the primary researchers and participants do not physically interact (in person) but do so digitally, via videoconferencing, emails, phones and other electronic devices. These media have multiple benefits, allowing researchers to determine participants' perceptions, activities and behaviors safely, through distance, and often in manner convenient to both parties. In order to increase the validity of the contextual information (e.g. in an interview), researchers often prefer a live interaction with study participants, an approach known as time-aware research (Asjes, 2014). The rapid development of videoconferencing and cell phone technology permits cost-effective access and, importantly, has been shown to be acceptable to participants for these purposes (Asjes, 2014; Richardson, Godfrey & Walklate, 2021). In our study, while most research activities (interviews with panel members, project meetings, etc.) will be conducted remotely, some lab and field testing that requires real-time data and is necessary (e.g. river monitoring under different seasonal conditions, hydrogeological analysis) will be taken in-situ with the assistance of local partners.

Semi-structured interviews

Semi-structured interviews are a common method of data collection in qualitative studies as they provide in-depth exploration of a topic, as well as the latitude to explore related issues that emerge in the course of the interview which can further add to our depth of understanding. They also help understand the 'reality' of the interviewees. In societies like Nepal, were status and gender play a major role in social relations, a group discussion could affect results (e.g. female participants may not express their opinions openly, if men participate; local residents may not disagree with professionals or other participants higher in hierarchy). In this sense, individual, open interviews can support genuine plurality in opinions and provide fair and open expression to all participants (Georgeou & Hawksley, 2020).

Choice-based conjoint analysis

Choice-based conjoint analysis, also known as discrete choice experiment, is suggested in this study (Round Two) because it helps understand how participants value individual options, products and services based on different attributes including features, functions and advantages. The goal of CBCA is to determine which combination of limited number of attributes is the most influential on respondent choice or decision-making. The combination of limited number of attributes is usually presented in either a 'table' or a 'catalogue' format (Mansuy, Verlinde, & Macharis, 2020; Tanujaya et al., 2020). Participants must choose only one option based on preferable attributes, typically by answering a question similar to '*if these were the only options, which one would you prefer?*'.

The CBCA is used in many of the social, health, and applied sciences including marketing, product management, healthcare, and operations research. Lebeau et al. (2012) used this method to estimate the market potential for hybrid electric vehicles in Flanders, Belgium, and to formulate recommendations for the further deployment of electric vehicles. Mansuy, Verlinde, & Macharis (2020) used this method to understand the preference of consumers for electronic and electrical collection services - focusing on mobile phones, coffee machines and washing machines as examples. Lee, Huh & Yoo (2018) used CBCA to investigate the value given by people to the attributes of the installation of small-scale solar power plants in South

Korea. Tanujaya et al. (2020) used this method to understand and measure the opinion of the public and local inhabitants living near renewable energy projects in South Korea.

This method presents many strengths for studies with similar research topics to ours. It is used frequently in testing customer acceptance of new product designs/prototypes (Lee, Huh & Yoo, 2018). It is suitable for gathering information for the optimization of existing or developing products (Mansuy, Verlinde & Macharis, 2020; Tanujaya et al., 2020). It is a preferred technique for cross-country and cross-community analysis (Ebers et al., 2017; Tanujaya et al., 2020), and there is a growing interest in using CBCA in health policy and planning studies in low-income countries (Mangham, Hanson & McPake, 2009; Spilker et al., 2020).

However, the CBCA may present some weaknesses such as the fact that it is primarily found in studies involving participants from high-income countries. According to Mangham, Hanson & McPake (2009) the reasons for the limited use of CBCA in low-income countries potentially relate to different cultural settings, language barriers between participants and researchers, low level of literacy, and unfamiliarity with research techniques. To address the challenges noted, Mangham, Hanson & McPake (2009) suggest pre-testing the CBCA-based questionnaires, and participant selection where education and socio-cultural effects are minimized. In our study we will address these potential issues by including two communities (Dhuskun and Aggitis villages) with similar contextual characteristics (riparian, remote) and vulnerabilities (energy insufficiency during weather extremes, and high flood risk). We will also address potential socio-cultural limitations/variations by:

(i) conducting interviews in local languages (i.e. Nepali and Greek) to minimize any language barriers,
(ii) selecting participants who have the educational/occupational background necessary to respond to our question sets (basic knowledge or higher), and providing educational materials prior the interviews (i.e. a task orientation module)
(iii) preparing our Round Two questions based on participants' responses from previous round and include an orientation module before the interviews; these action increase participants' familiarity with the topic and process.
(iv) validating Round One and Two interview question sets with local residents, professionals, and a psychometrician before we interview our panel members (Burton & Mazerolle, 2011; Collingridge, 2021).

Given this approach, we suggest the CBCA which, compared to other similar techniques such as rating-based conjoint, best-worst conjoint, and ranking-based conjoint analyses better matches with our research design.

SCORE analysis

The SCORE analysis is suggested in Round Two as it evaluates decisions, technology, and other entities of concern on five main variables corresponding with its identifying acronym. It is mainly used in business and organization related studies. Despite being a relatively new model, and not as popular as SWOT (strengths, weaknesses, opportunities, and threats) analysis, we select this method for the following reasons:

- According to Njoh (2016), SWOT has received criticism that contains pejorative labels [W (weakness) implies inadequacy; T (threats) implies a sense of danger]
- Njoh et al. (2019) argued that SWOT is rather too simplistic and does not add significant value for analytic purposes
- Njoh et al. (2019) successfully used this method in a community-based solar energy project

We should note that SCORE, SWOT, and NOISE (needs, opportunities, improvements, strengths, and exceptions) are used in decision-making, business and energy related studies. However, in our study we suggest the use of SCORE because we find this method as the most appropriate to provide a detailed review of the attributes in our options.

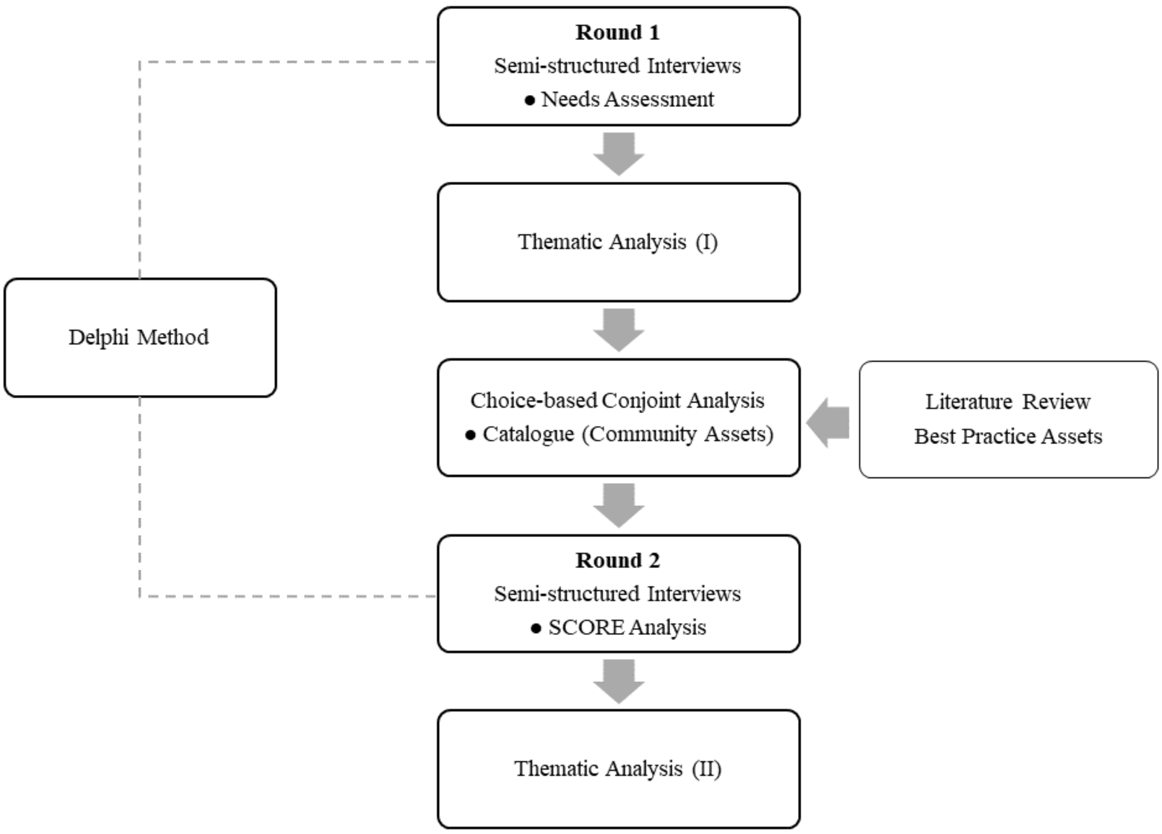
Thematic Analysis

We consider the Braun & Clarke's (2014) approach to thematic analysis as the most appropriate method to analyze data derived from the Delphi process and semi-structured interviews. This approach allows in-depth exploration of the perceptions of community and professional stakeholders. It is also suited to research in areas which have limited theoretical and empirical background.

2.5 Study design

A two-round semi-structured interview using the Delphi method, and delivered remotely, is considered to be the most appropriate approach to engaging panel members in the context of the pandemic and to address our research questions. This approach is augmented with review and decision-support frameworks, specifically, CBCA and SCORE analysis. Thematic analysis will be used to analyze the interview data. Figure 1 visualizes our study design.

Figure 1. Visualization of study design.



2.5.1 Project steering and risk management committee

A project steering committee with oversight of the research plan, its deployment, review, and risk assessment and management aspects will be made up of representatives of three organization:

i. Western Sydney University, School of Social Sciences - Humanitarian and Development Research initiative (HADRI) in Australia (overall responsibility),
ii. International Hellenic University, UNESCO Chair on Conservation and Ecotourism of Riparian and Deltaic Ecosystems (responsibility for the community site in Greece), and
iii. Kathmandu University, Department of Mechanical Engineering - Green Hydrogen Lab (responsibility for the community site in Nepal).

This includes the principal researcher (SS) operating remotely from Australia, as well as members in-situ in Nepal and Greece.

2.5.2 Risks during data collection

Working with committee and panel members at our respective sites, country specific protocols for COVID-safe research will be developed and regularly reviewed to ensure processes are compliant with required health practices. In addition, we will seek recommendations from panel members regarding energy and flood warning systems' features and uses in Dhuskun and Aggitis villages. The participants will provide us with their feedback. Interaction with the principal researcher (SS) will be virtual (online, one-to-one interviews). Should participants experience distress or anxiety in relation to the topic of floods (for example), they will be able take a break or, if they prefer, to withdraw from the research project without any consequence.

2.6 Recruitment and data collection

2.6.1 Participants

For this study, gender equality, wide age distribution, fair distribution between professionals and community stakeholders, and representation of people with disability needs will be major factors for the selection of participants. These factors guarantee plurality in opinions, as well as a wider representation of different groups within the communities (Georgeou & Hawksley, 2020).

The panel will consist of 16 members (eight from Dhuskun, and eight from Aggitis, respectively). All panel members will have specific knowledge of the selected site and community needs.

<u>General categories/roles of panel members:</u>

- Resident of the selected community (e.g. local business owner, homemaker, retired person);
- Academic with knowledge of the selected community;
- Emergency management professional/representative (e.g. civil protection authority, fire/police department);
- Technology expert

<u>Inclusion criteria</u>

- Knowledge of local community (either Dhuskun or Aggitis).
- 'Fitting' in one of the roles described above (based on experience, occupation, etc.)

Exclusion criteria

- Unfamiliarity with the local communities, sites and needs.
- People who are not adults

2.6.2 Recruitment

Our partners at International Hellenic University and Kathmandu University will recommend a list of individuals who would be appropriate members for our research panel, and who would be interested in participating as panel members. The principal researcher (SS) will email each person and provide them with information about the research (invitation email and participation information sheet). If needed, the researchers will have further conversations (via email or teleconferencing) with potential participants in order to provide more about the research as required.

The potential participants will have two weeks to consider whether they would like to participate in the research. When a potential participant shows interest, the researchers will be responsible for screening them. The screening will be either online (interview or email) or via the phone. This will take place before consent is requested. The potential participants will be notified of the decision (accepted or rejected) by the principal researcher (SS) within a two-week period after they have expressed their interest in participating in the research. If accepted, a consent form will be sent to them to sign.

2.6.3 Reimbursements and/or tokens policy

For this study, no reimbursements will be offered. It is important participation be voluntary (i.e., a contribution to local community benefits). It should be noted that, for the participants in Nepal, as there is limited internet coverage and access to a computer, we will cover reasonable expenses incurred due to participation (e.g., transport to Kathmandu University campus where there is a computer and internet access which enable participation in the research. The expenses could also cover refreshments and a meal). For the participants in Greece, no such expenses are required, as the participants will be interviewed at their own home/office (via teleconferencing or phone).

2.6.4 Privacy protection

In this study, basic identifying and demographic information will be gathered during the recruitment process and at the point of consent [name, age, gender, work, any primary carer role, marital and family status (i.e. number of children), familiarity with specific site (yes/no), some knowledge/awareness of local renewable energy sources (yes/no), some knowledge/awareness of usual flood warnings (yes/no)]. All of this information will remain confidential, but is necessary to the analysis, as it informs our understanding of participants' views and concerns (e.g. carer roles with children could be at higher risk during flood hazard events). During the data analysis, a unique code (pseudonym) will be generated to identify specific individuals. Thereafter, all data outputs and any reporting of the data relating to individuals will be in a de-identified form.

2.6.5 Data collection

The panel members will participate in two rounds of interviews, both of which include an initial orientation. Table 1 presents a general description of each round.

Table 1. Round One and Two description

ROUND 1	ROUND 2
Orientation	
Here, the principal researcher (SS) will provide initial orientation to the project: • the focus of the research • the topics it will cover • the requirements of panel members • how their insights about local community needs and capabilities can assist the research	Here, the principal researcher (SS) will present a 'catalogue' of market available/evidence-informed, and conceptual options regarding: • panel solutions identified in Round 1 • potentially applicable market or technical solutions
Semi-structured interviews (online 'one-to-one' questions)	
The purpose of this section is to gather information regarding: • perceptions of energy reliability • satisfaction with current energy access • perceived need for other energy solutions/options including renewable energy • flood risks and local site conditions (e.g. areas of higher flood risk, historic events) • understanding of current flood warning approach and capabilities • perceived need for improved local flood response/warning systems • perceptions of other needs greater than energy/flood issues (e.g. COVID-19 response)	From the 'catalogue', panel members will be asked: • to identify the most useful and feasible option for their community (only one option, subject to panel's perception of greater community need) • to provide further feedback on the selected option via SCORE analysis • other relevant perceptions of the preferred option (i.e. there is interest/willingness to participate and trial the option in their community) • whether a combination of systems or a hybrid system could feasibly support identified community energy and flood-related needs

2.6.5 Follow up

Follow up with participants after data collection will be conducted using two approaches. Firstly, we will send a letter (newsletter) that provides a summary of the study and its key findings. A second letter and/or email will alert interested participants to related publications, conference papers, etc.

4. Discussion

This paper details a humanitarian and development research design that addresses restrictions to community research engagement that have occurred due to the COVID-19 pandemic. The research aims to explore the perceptions of community and professional stakeholders regarding energy availability and flood hazard risks in Dhuskun and Aggitis. It also investigates what options may be feasible and acceptable in these communities (i.e. those that could be trailed or further developed in local contexts) in order to identify potential solutions with ecological validity from informed local sources.

We will apply the Delphi method (two rounds) in data collection process, and link our research with frameworks that focus on PAR and remote research. In Round Two we will use the CBCA, and SCORE analysis to evaluate the feasibility of market-available and evidence informed options, as well as the development of conceptual systems. Lastly, we will employ thematic analysis to derive our primary data from the completed interviews. The combination of methods is an appropriate way to support our research in energy and flood disaster management remotely. Importantly, our research design is flexible, cost-effective, and could guide other researchers in the field who face similar issues.

Due to the COVID-19 restrictions, visits to Dhuskun and Aggitis villages are only possible though our local partners in Nepal and Greece. These visits include the seeking of panel members, atmospheric and hydrological data collection (e.g. water flow and level data, precipitation data, etc.), visits to local energy generation and/or distribution plants, etc.

Declarations

Competing interests: The authors declare that they have no competing interests.

Funding: This research is funded by the School of Social Sciences, Western Sydney University, Australia.

Ethics approval: Ethical approval for this research has been granted by the Western Sydney University Human Research Ethics Committee (HREC Approval Number: H14269). This research meets the requirements of the National Statement on Ethical Conduct in Human Research 2007 (Updated 2018).

References

Asjes, K. (2014). The hidden benefits of remote research. *uxBOOTH*. Available at: https://www.uxbooth.com/articles/hidden-benefits-remote-research/ (accessed 12 September 2021).

Braun, V., & Clarke, V. (2014). What can "thematic analysis" offer health and wellbeing researchers?. *International Journal of Qualitative Studies on Health and Well-being*. https://doi.org/10.3402/qhw.v9.26152

Brent, A. C., & Kruger, W. J. (2009). Systems analyses and the sustainable transfer of renewable energy technologies: A focus on remote areas of Africa. *Renewable Energy*, 34(7), 1774-1781. https://doi.org/10.1016/j.renene.2008.10.012

Burton, L. J., & Mazerolle, S. M. (2011). Survey instrument validity part I: Principles of survey instrument development and validation in athletic training education research. *Athletic Training Education Journal*, *6*(1), 27-35. https://doi.org/10.4085/1947-380X-6.1.27

Cantrill, J. A., Sibbald, B., & Buetow, S. (1996). The Delphi and nominal group techniques in health services research. *International Journal of Pharmacy Practice*, *4*(2), 67-74. https://doi.org/10.1111/j.2042-7174.1996.tb00844.x

CRED (2020). Human cost of disasters: an overview of the last 20 years. *Centre for Research on the Epidemiology of Disasters (CRED)*. https://www.emdat.be/publications

Collingridge, D. (2021). Validating a questionnaire. METHODSPACE. Available at: https://www.methodspace.com/blog/validating-a-questionnaire (accessed 23 August 2021).

Dick, R. (1991). Helping groups to be effective: skills, processes & concepts for group facilitation. *Interchange*. ISBN: 978-1-875260-09-6.

Ebers, A., Wüstenhagen, R., Tabi, A., Kostyuchenko, N., Smolennikov, D., & Joller, L. (2017). *Local acceptance of wind energy in switzerland, estonia and ukraine. A Cross-Country Analysis based on Choice Experiments*. https://sustainability.unisg.ch/publications/local-acceptance-of-wind-energy-in-switzerland-estonia-and-ukraine-a-cross-country-analysis-based-on-choice-experiments/

Gautam, D. K., & Phaiju, A. G. (2013). Community based approach to flood early warning in West Rapti River Basin of Nepal. *Journal of Integrated Disaster Risk Management*, *3*(1), 155-169. http://dx.doi.org/10.5595/idrim.2013.0060
Georgeou, N., & Hawksley, C. (Eds.) (2020). *Enhancing research impact in international development: a practical guide for practitioners and researchers*. Deakin, A.C.T.: Research for Development Impact Network. https://rdinetwork.org.au/resources/enhancing-research-impact-in-international-development-a-practical-guide-for-practitioners-and-researchers/
Grisham, T. (2009). The Delphi technique: a method for testing complex and multifaceted topics. *International Journal of Managing Projects in Business*, *2*(1), 112-130. https://doi.org/10.1108/17538370910930545
Helmer-Hirschberg, O. (1967). Analysis of the future: The delphi method. *RAND*. https://www.rand.org/pubs/papers/P3558.html
Howells, M., Rogner, H. H., Mentis, D., & Broad, O. (2017). Energy access and electricity planning. *The World Bank*.
Hur, E. S., Cassidy, T., & Thomas, B. G. (2013). Seeding sustainability through social innovation in fashion design. Proceedings of the crafting the future. In: *The Crafting the Future: the 10th European Academy of Design Conference*. The European Academy of Design. https://eprints.whiterose.ac.uk/81259/1/seeding_sustainability.pdf
Ikejemba, E. C., Mpuan, P. B., Schuur, P. C., & Van Hillegersberg, J. (2017). The empirical reality & sustainable management failures of renewable energy projects in Sub-Saharan Africa (part 1 of 2). *Renewable Energy*. 102, 234-240. https://doi.org/10.1016/j.renene.2016.10.037
Lebeau, K., Van Mierlo, J., Lebeau, P., Mairesse, O., & Macharis, C. (2012). A choice-based conjoint analysis on the market potential of PHEVs and BEVs in Flanders. *World Electric Vehicle Journal*, 5(4), 871-880. https://doi.org/10.3390/wevj5040871
Lebel, P., Lebel, L., Singphonphrai, D., Duangsuwan, C., & Zhou, Y. (2019) Making space for women: civil society organizations, gender and hydropower development in the Mekong region. *International Journal of Water Resources Development*, *35*(2), 305-325. https://doi.org/10.1080/07900627.2018.1425133
Lee, H. J., Huh, S. Y., & Yoo, S. H. (2018). Social preferences for small-scale solar photovoltaic power plants in South Korea: A choice experiment study. Sustainability, *10*(10), 3589. https://doi.org/10.3390/su10103589
Mangham, L. J., Hanson, K., & McPake, B. (2009). How to do (or not to do)… Designing a discrete choice experiment for application in a low-income country. *Health Policy and Planning*, *24*(2), 151-158. https://doi.org/10.1093/heapol/czn047
Mansuy, J., Verlinde, S., & Macharis, C. (2020). Understanding preferences for EEE collection services: A choice-based conjoint analysis. *Resources, Conservation and Recycling*, *161*, 104899. https://doi.org/10.1016/j.resconrec.2020.104899
Mullen, P. M. (2003). Delphi: myths and reality. *Journal of Health Organization and Management. 17*(1), 37-32. https://doi.org/10.1108/14777260310469319
Njoh, A. J. (2016). *Tradition, culture and development in Africa: Historical lessons for modern development planning*. Routledge. https://doi.org/10.4324/9781315235868
Njoh, A. J., Etta, S., Ngyah-Etchutambe, I. B., Enomah, L. E., Tabrey, H. T., & Essia, U. (2019). Opportunities and challenges to rural renewable energy projects in Africa: Lessons from the Esaghem village, Cameroon solar electrification project. *Renewable Energy*, *131*, 1013-1021. https://doi.org/10.1016/j.renene.2018.07.092
Ogbeifun, E., Agwa-Ejon, J., Mbohwa, C., & Pretorius, J. (2016). *The Delphi technique: A credible research methodology*. In International conference on industrial engineering and operations management, Kuala Lumpur.

Phillips, C. (2017). Combining energy efficiency and disaster mitigation efforts in residential properties. *Office of Policy Development and Research*.

Richardson, J., Godfrey, B., & Walklate, S. (2021). Rapid, remote and responsive research during COVID-19. *Methodological Innovations, 14*(1), 20597991211008581. https://doi.org/10.1177%2F20597991211008581

Schismenos, S., Stevens, G. J., Emmanouloudis, D., Georgeou, N., Shrestha, S., & Chalaris M. (2020). Humanitarian engineering and vulnerable communities: hydropower applications in localised flood response and sustainable development. *International Journal of Sustainable Energy*, *39*(10), 941-950 https://doi.org/10.1080/14786451.2020.1779274

Schismenos, S., Stevens, G. J., Emmanouloudis, D., Georgeou, N., Shrestha, S., & Chalaris, M. (2021a). Humanitarian engineering at the sustainability-development nexus: mapping vulnerability and capability factors for communities at risk of water-based disasters. *Sustainability Science*. https://doi.org/10.1007/s11625-020-00890-y

Schismenos, S., Stevens, G. J., Emmanouloudis, D., Georgeou, N., Shrestha, S., & Katopodes, N. D. (2021b). Using off-grid hydropower for community-led flood resilience: An Integrated systems Aapproach. *International Journal of Sustainable Energy*. https://doi.org/10.1080/14786451.2021.1961773

Schismenos, S., Stevens, G. J., Emmanouloudis, D., Georgeou, N., Shrestha, S., Katopodes, N. D., & Wali, N. (2021c). Humanitarian engineering for renewable energy and flood early warning in remote communities: a scoping review of enabling factors and sustainability. *Journal of Sustainable Development of Energy, Water and Environment Systems*. 1090406. https://doi.org/10.13044/j.sdewes.d9.0406

Schneider, R. B., Myers, T. L., Tarolli, C. G., Amodeo, K., Adams, J. L., Jensen-Roberts, S., & Dorsey, E. (2020). Remote administration of the MDS-UPDRS in the time of COVID-19 and beyond. *Journal of Parkinson's Disease*, *10*(4), 1379-1382. https://doi.org/10.3233/JPD-202121

Skulmoski, G. J., Hartman, F. T., & Krahn, J. (2007). The delphi method for graduate research. *Journal of Information Technology Education: Research*, *6*(1), 1-21. https://www.learntechlib.org/p/111405/

Spilker, G., Nguyen, Q., Koubi, V., & Böhmelt, T. (2020). Attitudes of urban residents towards environmental migration in Kenya and Vietnam. *Nature Climate Change*, *10*(7), 622-627. https://doi.org/10.1038/s41558-020-0805-1

Tanujaya, R. R., Lee, C. Y., Woo, J., Huh, S. Y., & Lee, M. K. (2020). Quantifying public preferences for community-based renewable energy projects in South Korea. *Energies*, *13*(9), 2384. https://doi.org/10.3390/en13092384

Van Dijk, J. A. (1990). Delphi questionnaires versus individual and group interviews: A comparison case. *Technological Forecasting and Social Change*, *37*(3), 293-304. https://doi.org/10.1016/0040-1625(90)90029-U

Wahlstrom, M., & Guha-Sapir, D., 2015. The human cost of weather related disasters 1995–2015. *United Nations International Strategy for Disaster Reduction (UNISDR.* https://www.unisdr.org/files/46796_cop21weatherdisastersreport2015.pdf

Paper VI

geosciences

MDPI

Article

Flood and Renewable Energy Humanitarian Engineering Research: Lessons from Aggitis, Greece and Dhuskun, Nepal

Spyros Schismenos [1,2,*], Garry J. Stevens [1], Nichole Georgeou [1], Dimitrios Emmanouloudis [2,3], Surendra Shrestha [4], Biraj S. Thapa [5] and Supriya Gurung [1]

1 School of Social Sciences, Humanitarian and Development Research Initiative (HADRI), Western Sydney University, Sydney 2747, Australia; g.stevens@westernsydney.edu.au (G.J.S.); n.georgeou@westernsydney.edu.au (N.G.); supriya.gurung@naturalhazards.com.au (S.G.)
2 UNESCO Chair on Conservation and Ecotourism of Riparian and Deltaic Ecosystems, International Hellenic University, 66100 Drama, Greece; demmano@teiemt.gr
3 Department of Forestry and Natural Environment, International Hellenic University, 66100 Drama, Greece
4 School of Engineering, Western Sydney University, Sydney 2747, Australia; s.shrestha@westernsydney.edu.au
5 Department of Mechanical Engineering, Green Hydrogen Lab, Kathmandu University, Dhulikhel 45200, Nepal; bst@ku.edu.np
* Correspondence: s.schismenos@westernsydney.edu.au

Abstract: Climate and energy crises are increasing worldwide. Community-led humanitarian engineering interventions for localized sustainable development and disaster resilience could support populations at risk. This article presents findings from a study that investigated flood response and energy needs of two riparian communities in Greece and Nepal. The findings indicate that the co-development of a hybrid unit for hydropower generation and flood warning is most preferred. This prototype could find applications in different riparian areas as either a main or supplementary system.

Keywords: renewable energy; flood hazard; early warning; prototype development; remote research

Citation: Schismenos, S.; Stevens, G.J.; Georgeou, N.; Emmanouloudis, D.; Shrestha, S.; Thapa, B.S.; Gurung, S. Flood and Renewable Energy Humanitarian Engineering Research: Lessons from Aggitis, Greece and Dhuskun, Nepal. *Geosciences* **2022**, *12*, 71. https://doi.org/10.3390/geosciences12020071

Academic Editors: Pedro Pinto Santos and Jesus Martinez-Frias

Received: 7 December 2021
Accepted: 1 February 2022
Published: 3 February 2022

1. Introduction

Floods and storms are the most frequent natural hazards worldwide and pose a serious threat in many countries [1]. In October 2021, flash flooding and landslides caused by heavy late monsoon rain in Nepal and India resulted in more than 180 fatalities and major damage to homes, public infrastructure, and farms [2]. In the same month, a similar disaster also struck Greece. Heavy rainfall caused floods and mudslides in many parts of the country, with Evia, an island that was significantly damaged by wildfires in August, being the most impacted [3]. While the exposure to climate crises may be similar in many countries, low-income countries are disproportionally affected as they have fewer resources needed for disaster resilience [1], such as reliable energy and hazard response infrastructure. The transition to renewable energy sources, including off-grid systems, seems a pragmatic way to deal with both energy and climate threats [4]. However, this is not an easy task, particularly at the local level, where riparian communities often face the dual dilemma of energy and flood resilience insufficiency.

Large-scale systems for disaster management and energy generation tend to fail at smaller scales. Generalized early warning systems that focus on large basins cannot detect flash floods and other localized water hazards [5]. Small, off-grid communities in remote locations do not receive the benefits of main power networks or large renewable energy plants, a factor contributing to development constraints and poverty. While the construction of additional renewable energy stations to satisfy more populations sounds promising, this may come with substantial social and ecosystemic costs. For example, the excessive and unchecked building of larger-scale hydropower plants on the steep slopes of Nepal has affected local environmental conditions and intensified some flood and landslide phenomena [6].

Increasingly, small, community-based renewable energy systems are being used to support the daily power needs of off-grid communities, augment those with unstable mains access, and are proving reliable during extreme weather events [7]. One such example is Bihar, one of the poorest states in eastern India, which has limited mains energy infrastructure but where many of its districts are transitioning to off-gird renewables, such as solar energy. In August 2017, the state experienced extreme floods that affected more than 12 million people. Among the impacted areas, Araria, a rural village that runs on solar panels was under one meter of water but able to provide continuous power to thousands of people as the panels kept operating, unlike other emergency energy sources (diesel generators) that were damaged by the floods [8]. In Hackbridge, United Kingdom, solar panel operation during floods powers buildings in flood zones and supports "in-place" sheltering when evacuation is not possible [9]. In Hoboken, New Jersey, small-scale energy grids support early warning of coastal floods and alert local residents when the waters reach critical levels [9,10]. These examples highlight that localized renewables can support flood emergency management as a primary source for off-grid communities and as critical augmentation in higher-income countries.

Humanitarian engineering could be the key to re-thinking energy self-sufficiency and disaster resilience at the local level. This approach involves applications of both urgent and longer-term engineering solutions that center on community needs and consider the social, cultural, and environmental characteristics inherent to local requirements and capabilities [11,12]. A major difference with other engineering practices is that it proactively seeks the co-development of solutions with end-user populations using appropriate technologies, "traditional" knowledge, and local views [13]. When directed to prototype development, it can support the creation of sustainable, community-focused interventions that accord with the principles of both the United Nations 2030 Agenda for Sustainable Development and Sendai Framework for Disaster Risk Reduction. However, a major risk in humanitarian engineering research relates to the level of genuine trust and understanding developed between local stakeholders and (often) output-focused professionals. Lack of local engagement in all phases, power inequities and resistance to learning and adapting may undermine solutions and ultimately result in program failures [14,15].

While the literature showcases many community-based projects in renewable energy and early warning, there is little information regarding the development of combined and hybrid systems which integrate these key functions or community perceptions of the feasibility of such options [5,16]. Our study focus aligns with humanitarian engineering principles and prioritizes local stakeholders' views as essential elements for developing sustainable solutions. This article presents findings from our cross-country analysis of off-grid renewable energy generation and flood early warning needs in riparian communities, specifically their appraisals regarding (i) market available stand-alone systems (early warning systems, renewable energy generators), (ii) combined systems, and (iii) a conceptual hybrid prototype. To better understand common and context-specific needs and acceptable solutions, we compared two riparian communities—an on-grid, peri-urban village in a high-income country (Aggitis, Greece) and a remote, off-grid village in a low-income country (Dhuskun, Nepal). While these communities present differences (e.g., infrastructure, socio-culture), they share similar threats and experiences, such as power outages during/after weather hazards. The findings of this study may not only support the engaged communities with practical solutions based on their capacity, but also draw lessons for other riparian communities with flood resilience and energy issues (e.g., in urban areas).

2. Materials and Methods

2.1. Methods Selection

The principal method was a semi-structured interview conducted over two rounds using the Delphi method. Round One took place from 23 April 2021 to 14 May 2021; Round Two from 19 to 25 July 2021. Interviews were conducted remotely as an appropriate approach to

engage with international study participants under pandemic conditions. To support asset
neworks;
esponses,
iew data.
A more
].

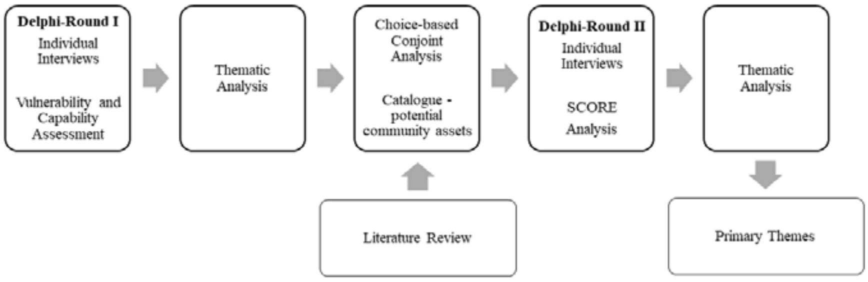


Figure 1. Study components and process.

2.1.1. Delphi Method

The Delphi method is a common decision-support technique in vulnerability and capability analysis [18], and prototype development research [19]. It draws on the informed views of those familiar with a topic area or resource, allows equal access and participant contribution, does not require face-to-face interaction and, through an iterative process, leads to "close to expert consensus" regarding a solution or application over a series of rounds [20]. This approach was appropriate to address the study's focal areas over two rounds. Round One examined perceptions of major hazard types affecting the community, related vulnerabilities and needs, and capabilities that could support their management. Round Two sought participant perceptions of appropriate solutions to address the priority needs identified in Round One. This employed a catalogue of community assets developed using Round One feedback and was additionally informed by a scoping review [16], and a literature review [15] of available options.

2.1.2. Remote Research

Remote research involves any research enquiry where the researcher and participants are not in the same physical space (in person) [21]. Our data collection was conducted digitally (via emails, phones, and videoconferencing) to ensure participant safety during the pandemic. Participant perceptions of the remote research process were assessed to determine potential impacts on access or expression of views and its acceptability for future research in this field.

2.1.3. Semi-Structured Interviews and Validation

Semi-structured interviews are a common method of data collection in qualitative research as they allow deep exploration of a topic, particularly areas where little data is available [22]. An orientation module and question set were developed for each round based on the study's research questions and tested in pilot interviews. Round Two questions were also based on the Round One responses. The final interview schedule (available as supplementary information–Tables S1 and S2) was validated with non-participating local residents and professionals, and a psychometrician to ensure clarity of meaning and content understanding [23,24]. All interviews were conducted in local languages (Greek, Nepali) to allow participants to most easily express their views [25]. The principal researcher (first author) conducted the Greek interviews and was assisted by a Nepalese interpreter (in-situ) for the Dhuskun interviews.

2.1.4. Choice-Based Conjoint Analysis

Choice-based conjoint analysis is widely used in social, health, energy, and prototype development research [26–29]. It provides an understanding of how participants perceive the value of products, services, and options based on a comparison of their functions and features (attributes). The attributes are usually limited in number and presented in a catalogue format or a table [28,29]. The catalogue used in Round Two presents six options which were derived from a combination of a review of market-available options for such sites and participants' preferences for energy and flood hazard types from the Round One interview. This decision-support framework is appropriate for cross-community and cross-country analysis [29,30]. Figure 2 presents the catalogue of community assets participants reviewed in local languages during the Round Two interviews and which canvassed these options:

(1) Option 1. Small-scale hydropower system (Option and attributes based on SMART HYDRO, https://www.smart-hydro.de/ assessed on: 10 November 2021)
(2) Option 2. Set of solar panels (Option and attributes based on GPM-250 W, Zhejiang G New Energy Technology Co., Zhejiang Province, China)
(3) Option 3. Flood siren system (Option and attributes based on Telegrafia flood siren system, https://www.telegrafia.eu/en/solution/mass-public-warning/flood-warning-system/ accessed on: 10 November 2021)
(4) Option 4. Flood alert SMS/email system (Option and attributes based on LEVELINE-EWS, https://www.aquaread.com/products/water-level/leveline-ews accessed on: 10 November 2021)
(5) Option 5. Combination of a set of solar panels and SMS/email flood alert system (Options 2 and 4)
(6) Option 6. Hybrid system—hydropower and flood siren (Options 1 and 3)

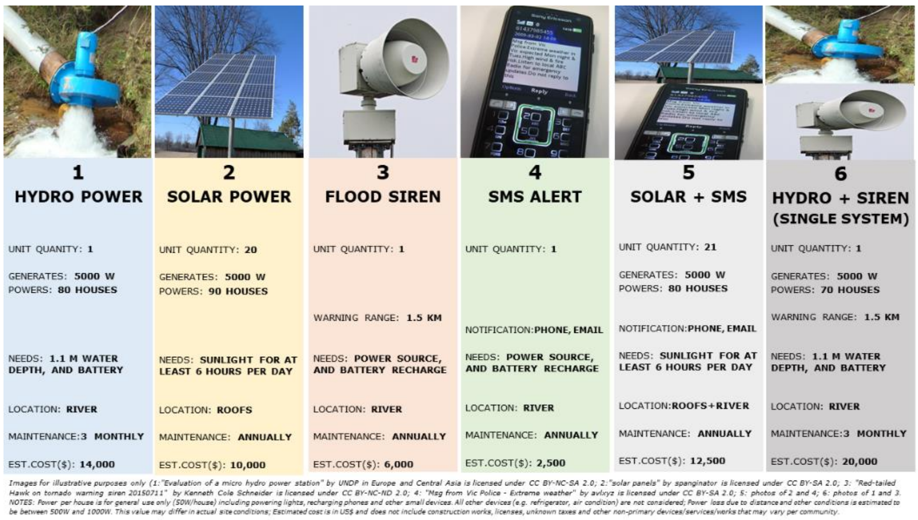


Figure 2. Catalogue of six community assets and their attributes.

Despite the differences in function (i.e., energy generation, flood warning, both) and output, the options were evaluated based on their relative priority and deliverability as assets for the community. The CBCA allows comparisons between options that vary if attributes are common and measurable. For example, Mansuy, Verlinde, and Macharis (2020) [28] compared mobile phones, coffee machines, and washing machines to understand the preference of consumers for "electronic and electrical devices". In this study, participants were asked to choose only one option that best supports their community, based on either single or combined/integrated functions. Their choice helps us understand which community needs (energy, flood warning, or both) should be prioritized for further program development.

2.1.5. SCORE Analysis

This analytical framework supports a detailed evaluation of perceived benefits and potential costs/concerns related to proposed processes or interventions. It readily integrates with the CBCA (Round Two) as it helps understand why participants chose their preferred community asset when assessed against multiple criteria, specifically, which attributes presented strengths, challenges, opportunities, etc., and for what reasons [31].

2.1.6. Thematic Analysis

Thematic analysis was used to analyze the data from both rounds of semi-structured interviews using the method described by Braun and Clarke (2014) [32]. This involved familiarization with the data through initial readings of transcripts and analyzing and grouping similar phrases deemed relevant to the research themes into codes. The codes were then grouped together based on similarities and distinctions, which formed the foundation for the sub-themes. The primary coder (first author) and two additional coders participated in the coding process to provide multiple perspectives of the data and act as a validity check [33]. Each coder had a different background discipline (engineering, psychology, journalism), but all were familiar with the development sector. All worked independently following the process described above, then consulted regarding their initial findings resulting in further refinements and creation of the overarching themes.

2.2. Data Credibility

Data credibility and validity were ensured using the methods described by Barbour (2001) and Berends and Johnston (2005) [23,34]. We employed heterogeneous sampling, a form of purposive sampling, as the selection of participants with diverse characteristics was required to ensure maximum variability with our primary data [35]. Participants were selected based on specific inclusion criteria (familiarity with local conditions, needs, hazards and energy) and to provide a broad cross-section of end-user perspectives (i.e., community residents and business owners, emergency professionals or academic/technology experts with local knowledge). Verbatim transcription (exact conversion of speech to text) was conducted as it captures all views and emotions of the interviewees. All transcribed data were sent to the interviewees for validation. This allowed the participants to verify and correct, if necessary, their transcribed data before its translation to English. The coding phase included multiple coders to reduce researcher influence and was conducted only with the translated scripts (English) to maintain linguistic consistency [34].

2.3. Selection of Study Sites

The selection of the study sites was based on three criteria:

(1) Site appropriateness: As the primary focus of the study related to flood risk and energy insufficiency in riparian settlements, and potential resource development, our focus was on community sites likely to experience such vulnerabilities. Our review of the evidence-based literature [16] identified site characteristics and combinations associated with elevated risk (e.g., high flood risk, remote location, off-grid and/or insufficient/unstable power, lack of flood response planning/infrastructure), and was the basis of site selection in the current study.

(2) Consultation with local partners: Our in-country researchers identified sites that met these criteria in Greece: (a) Aggitis, Drama; (b) Grammeni, Drama; (c) Piges, Drama, and in Nepal: (a) Temal, Kavrepalanchowk; (b) Roshi, Kavrepalanchowk; (c) Dhuskun, Sindhupalchowk.

(3) Participants from identified communities could likely participate in both Round One and Round Two interviews, despite the COVID-19 restrictions in place during the study period.

Aggitis and Dhuskun were assessed to be the most suitable study sites as they most directly addressed these criteria and were representative of high flood-risk locations within the respective country contexts.

2.3.1. Aggitis Community and Site

Aggitis is an on-grid, peri-urban, riparian village, located in the Regional Unit of Drama in Eastern Macedonia and Thrace Administrative Region in northern Greece. The total area of the village is 11.5 km^2 and has 82 permanent residents (2011 census) with most aged 65 years or older. The main spoken language is Greek, and its income is principally derived from agriculture, livestock, and ecotourism. Nearby attractions include the Aggitis River, Aggitis Cave (also known as Maaras Cave), and Aggitis Gorge (nearby tourist attractions). The Aggitis Cave is more than 12 km long, making it the largest cave in Greece and the largest riparian cave in the world.

Aggitis River is the most important tributary of the Strymonas river. It is 75 km long and sourced in the Falakro massif. The river is formed by the discharge of a 12 km underground system and passes though the Aggitis Cave [36,37]. Flooding is a common phenomenon in the Aggitis basin, especially during the snow melt period (February to April) or extreme rainfall events. In 2015, a serious flood event in the Aggitis river caused severe damage in the area. This occurred because the local anti-flooding works were insufficient to hold the large amounts of water due to snow-melting. Over 400 farmers were impacted, more than 50,000 hectares were flooded, and some local livestock units were completely vanished [38]. Other serious water-based disasters occurred in June 2014 (hailstorm) and January 2019 (heavy rainfall). With respect to renewable energy sources, local residents are familiar with hydropower and solar power. There is a pico hydropower plant that operates in the area (max. capacity 1.2 MW). The plant does not operate throughout the year (e.g., during summer months). Some residents have installed solar panels in their homes or businesses.

2.3.2. Dhuskun Community and Site

Dhuskun (also known as Ghuskun) is an off-grid, rural, riparian village, located in Ward no.3 of Tripurasundari Rural Municipality, Sindhupalchowk District in the Bagmati Province in central Nepal. The total area of the village is 16.12 km^2 and has 3116 residents (1991 census). The main languages spoken are Nepali and Newari. Agriculture, animal husbandry, and trade are the main income sources. Dhuskun has potential in the coffee business and ecotourism activities with the Sunkoshi River that flows through the village to be one of the main attractions.

Sunkoshi River is a trans-boundary river that originates from Zhangzangbo Glacier in Tibet and is part of the Koshi River basin in Nepal. The area is very prone to floods and landslides, which occur frequently, particularly during the monsoon season (June to August) or the snow melt period. In 2014 a major landslide occurred in the district and blocked a river creating the artificial lake which is nearby. This caused the surrounded land to erode [39]. Near the village, there is a small hydropower station. Floods and landslides often affect the plant's operations due to its location. Sometimes it remains closed for long periods, leaving Dhuskun and nearby communities with no power. Some government buildings use solar power as backup energy systems.

Figures 3 and 4 show the study site locations maps. Figures 5–8 present scenes from Aggitis and Dhuskun communities.

Figure 3. Local study site map of Aggitis, Greece. Source: Google Earth Pro (accessed on: 10 January 2022).

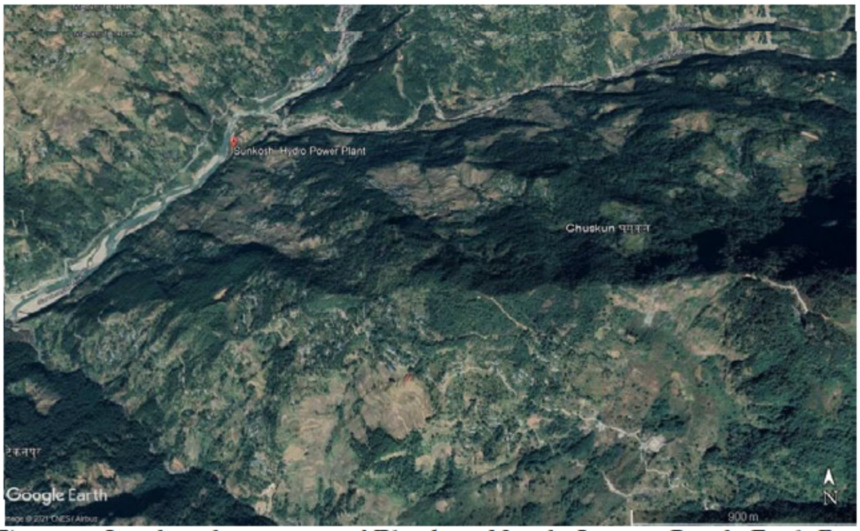


Figure 4. Local study site map of Dhuskun, Nepal. Source: Google Earth Pro (accessed on: 10 January 2022).

Figure 5. Aggitis River (near Aggitis Cave), Greece.

Figure 6. Pico-hydropower system near Aggitis River, Greece.

Figure 7. Dhuskun village, Nepal.

Figure 8. Small hydropower plant near Sunkoshi River, Nepal.

2.4. Participant Recruitment and Panel Description

For this study, local partners in Aggitis (International Hellenic University) and Dhuskun (Kathmandu University) recommended a list of candidates who met the inclusion criteria (knowledge of local conditions, energy sources, hazards, and community needs) and had a potential interest to participate in this research. Three candidates (two from Aggitis and one from Dhuskun) were excluded due to health concerns and unavailability during the time of the interviews. The principal researcher contacted all the remaining participants and used a screening questionnaire to ascertain residency status, familiarity with the local area, energy sources, hazards, and community needs. Based on this screening, all participants were selected for inclusion in this study.

Selected candidates completed a consent form which included identifying and demographic data. These data were gathered to understand the factors affecting different views and concerns. Participants were subsequently de-identified during the data analysis stage and ascribed codes to ensure confidentiality. Purposive sampling was used to ensure a balanced distribution and cross-section of community views, specifically: residents and professionals with local knowledge (i.e., disaster management, academia, technology), gender and age distribution (minimum 18 year), and those with special needs or carer responsibilities (e.g., mobility issues, carers of children or older adults) [15,17,25].

Participants were recruited to form a panel at each site—eight from Aggitis and eight from Dhuskun (16 participants in total). All had basic or higher knowledge of their local site, community energy, and flood resilience needs, renewable energy, and flood early warning concepts. A key requirement of the Delphi method relates to participant familiarity and knowledge with the topic [40,41]. As such, panels of this size and representation were considered suitable for the purposes of this exploratory analysis and are consistent with other studies which employ the Delphi method [19,42]. The demographic characteristics of the study panels are presented in Table 1.

Table 1. Panel demographic data.

Role	Age	Gender (M/F/O)	Occupation	Marital Status (Y/N)—No. of Children
AGGITIS				
Academic	36	F	Academic	Y–2
Academic	40	F	Academic	N–0
Emergency Professional	25	M	Emergency Responder/Forest Warden	N–0
Local Resident	32	M	Farm business owner	Y–1
Local Resident	36	M	Farm business owner	Y–2
Local Resident	49	F	Homemaker	Y–0
Local Resident	52	F	Local business owner	Y–3
Technology Expert	45	F	Entrepreneur (agronomy/flood/irrigation)	Y–2
DHUSKUN				
Academic	70	M	Academic	Y–2
Emergency Professional	30	M	Emergency responder/Police officer	N–0
Local Resident	18	M	University student	N–0
Local Resident	21	M	University student	N–1
Local Resident	30	F	Homemaker	Y–3
Local Resident	31	M	Farm business owner	Y–1
Local Resident	42	F	Homemaker	Y–2
Technology Expert	31	M	Hydropower Technician	Y–0

3. Results

All panel members in Aggitis (A) and Dhuskun (D) supported a priority transition to renewable energy sources, including hydropower and solar power, arguing that local experience and site conditions could support such technologies (Round One). The majority (A: 5/8; D: 5/8) preferred the hybrid prototype (Option 6) as an appropriate community asset for their community, since it integrated two required services (hydropower generation and flood siren warning) as a stand-alone system and was seen as a more efficient means to deliver these due to the riparian resources that were available. The combination of solar energy panels and flood alert SMS (Option 5) was the second most preferred option (A: 3/8; D: 2/8) as it provided free energy from local site conditions (sunlight) and convenience of receiving warning information (via SMS). Asset that offered a single service (i.e., Option 1—small-scale hydropower system was selected by one panel member (D: 1/8) mainly due to its low cost and the available riparian resources (Round Two). Lastly, the remote research approach was viewed positively by all panel members who found that it was convenient and did not restrict their feedback compared to a face-to face interview. The themes that were prominent within the data from each round are presented in the following sections. Table 2 summarizes perceptions of major hazard threats, priority developments for resilience and existing assets (Round One), and preferred assets and related developments (Round Two).

Table 2. Community perceptions of major hazard threats and priority developments.

Theme	Sub-theme	Aggitis	Dhuskun
		ROUND ONE	
Water hazards	Natural disasters	Floods (storms, snow melt): 8/8 COVID-19 pandemic: 1/8	Floods (monsoons, snow melt): 8/8 Landslides (usually during floods): 8/8 Earthquakes: 1/8 COVID-19 pandemic: 1/8
	Flood warning: (i) current systems	No local warning system: 8/8 Flood SMS alert (not real time—does not support evacuation, esp. flash floods): 2/8	No local warning system: 8/8 Flood SMS alert (messages delayed and/or mobile service unavailable—does not assist response): 3/8 Flood siren at nearby hydropower plant (plant specific warning, only partial community coverage): 1/8
	(ii) needs/preferred functions	Combination (siren and SMS alert): 5/8 Flood siren (wide range, loud): 2/8 Combination (siren, SMS alert, lights): 1/8 Hydrometric station: 1/8	Siren (real time warning, wide range, warns at night): 6/8 Combination (siren and SMS alert): 2/8
	Flood evacuation: (i) training/experience	No training/drills: 7/8; self-taught (online): 1/8 No personal evacuation: 8/8	No training: 7/8; participated in evacuation drills: 1/8 Evacuation due to floods and/or landslides: 8/8
	(ii) personal emergency devices - most used or priority need	Mobile phones (contact others, news update): 8/8 Lights: 5/8 Oxygen tanks (priority need for older adults): 8/8	Mobile phones (contact others, news update): 8/8 Lights 5/8 Power banks: 1/8
Community vulnerabilities	Population and infrastructure	Ageing population (younger adults move to cities, low-birth rate): 8/8	Poor roads, education, drinking water supply: 1/8
	Energy supply (extreme conditions)	Unreliable (old infrastructure): 8/8	Unreliable (seasonal impacts, unexpected power outages common): 8/8
Community cohesion	Help one another	Support each other (assist older adults): 8/8	Strong bonds between members (small community is an asset): 8/8

Table 2. *Cont.*

Theme	Sub-theme	Aggitis	Dhuskun
Reliable energy	Energy supply (normal conditions)	Reliable—normal conditions (meets daily needs): 8/8	Reliable—normal conditions: 6/8
	Renewable energy (i) existing assets	Site appropriateness (water and sunlight): 8/8 Technology acceptance (privately-owned local hydro and solar): 8/8	Site appropriateness (water and sunlight): 8/8 Technology acceptance (hydro for community use and solar for private/government use): 8/8
	(ii) asset types needed	Local hydro (community use): 8/8 Solar (individual use supported/upscaled): 7/8 Combination (hydro and solar): 2/8 Wind energy: 2/8	Small hydro (higher output): 8/8 Solar (community access): 3/8 Combination (hydro and solar): 2/8 Wind energy: 1/8
ROUND TWO			
Preferred community asset		Option 6 (hydro and siren hybrid): 5/8 Option 5 (solar and SMS alert combination): 3/8	Option 6 (hydro and siren hybrid): 5/8 Option 5 (solar and SMS alert combination): 2/8 Option 1 (hydro): 1/8
Multiple services	Combining proven functions	Integrated hydro and siren: 5/5 Combined solar and SMS alert: 3/3	Integrated hydro and siren: 5/5 Combined solar and SMS alert: 2/3
	Site appropriateness	Sufficient riparian resources (water flow): 2/5 Sufficient sunlight throughout the year: 2/3	Sufficient riparian resources (water flow, depth): 3/5 & 1/1 Sufficient sunlight throughout the year: 1/2
Development benefits	Stakeholder participation	Collaboration (community stakeholders and government—funding/management): 8/8	Collaboration (community stakeholder, including public-private partnerships): 8/8
	Economic growth	Employment opportunities: 5/5 & 2/3 Tourism increase: 3/5 & 1/3 Exemplar community (role model for other flood-prone communities): 1/5	Employment opportunities: 4/5 & 1/1
Risks and solutions	Post-installation risks	No major risks: 4/5 & 2/3 Aesthetic risks ("ugly"—natural beauty, traditional buildings): 1/5 & 1/3	No risks: 3/5, 2/2 & 1/1
	Issues and management (i) technical	Insufficient energy output [install more units]: 4/5 Lack of energy storage [include batteries]: 4/5 Vulnerable in flood conditions [analysis to find optimal hydro locations]: 2/5 River depth limitation - summer [determine best locations]: 2/5 Insufficient sunlight—cloudy/winter [large capacity batteries]: 3/3 Siren warning coverage insufficient [install more units and/or combine with SMS alert]: 3/5 SMS warning unreliable [augment with siren]: 2/3	No major issues: 4/5 & 2/2 Vulnerable in flood conditions [analysis to find optimal hydro locations]: 2/5 & 1/1 Insufficient sunlight—cloudy/winter [large capacity batteries]: 1/2 Siren warning coverage insufficient [install more units]: 2/5 SMS warning unreliable [augment with siren]: 1/2
	(ii) resources	No funds [funding via stakeholder participation]: 3/5 & 3/3 No human resources for installation and maintenance [works complete via stakeholder participation]: 2/5 & 2/3 Aesthetic risks [community acceptance via broad stakeholder participation]: 2/5	-
Remote research		Satisfied with remote approach: 8/8	Satisfied with remote approach: 8/8 Approach was innovative and comfortable:1/8

Notes: Fractions in Round One refer to participants from Aggitis (up to 8/8) and Dhuskun (up to 8/8). Fractions in Round Two refer to (a) participants from Aggitis (up to 8/8) and Dhuskun (up to 8/8); (b) participants who selected Option 6—hydro and siren hybrid from Aggitis (up to 5/5) and Dhuskun (up to 5/5); (c) participants who selected Option 5—solar and SMS alert combination from Aggitis (up to 3/3) and Dhuskun (up to 2/2); and (d) a participant who selected Option 1—hydropower generator from Dhuskun (1/1).

3.1. Round One

3.1.1. Water Hazards

Participants identified hazard risks affecting their local community and were able to indicate more than one type. The natural disasters of greatest concern were primarily related to flood risks (A: 8/8; D: 8/8) and landslides (D: 8/8), with earthquakes (D: 1/8) and the COVID-19 pandemic (A: 1/8; D: 1/8) reported less often as primary threats. Vulnerabilities related to water hazards included the lack of localized flood warning systems (A: 8/8; D: 8/8) and training/knowledge for evacuation (A: 7/8; D: 7/8). These were considered as priorities in both communities but for different reasons. For Aggitis' participants, insufficient flood warning and lack of flood response planning affected the reliable evacuation of older residents, those with limited mobility, and non-local residents such as tourists (e.g., Aggitis Cave visitors). For Dhuskun, delays in evacuation related to floods and landslides were seen as a particular problem, as these hazards are rapid.

More specifically, all participants said that their community had a high flood exposure risk throughout the year (snow melt period, rainy season, monsoon months in Dhuskun), however, floods were seen more threatening by Dhuskun participants as they could destroy homes and cause casualties. Most panel members from both communities said that despite the high flood risk potential, they did not receive any training for flood evacuation. The Aggitis panel members explained that they did not have to evacuate their homes due to extreme past flood events. This was because most residencies were located a safe distance from the river. However, when floods occurred, they said that there was damage to businesses (e.g., restaurants near the river) and tourism (when Aggitis Cave is flooded, it remains closed to visitors for weeks or months). One Aggitis participant said that they once helped an older farmer to evacuate their flooded farm. Dhuskun panel members who were asked a similar question said that they had to evacuate their house at least once due to floods and/or landslides. This was done either with the support of emergency professionals or other community members. This situation was common in Dhuskun, and any delays could result in lethal outcomes.

> (Male, 30—Dhuskun): *"... I worked in a rescue (team) after a landslide where about twenty to twenty-five people died."*

A serious flood-related vulnerability for both communities was the lack of flood warning systems at the local level. All panel members stated that their community had no localized flood early warning systems.

> (Female, 49—Aggitis): *"Nothing! We have absolutely nothing (no early warning systems)!"*

Some participants said that they sometimes received flood SMS alerts by the Civil Protection Services, but these were unreliable, received slow, or lost due to poor mobile services during extremes. Notably, one Dhuskun participant said that the nearby hydropower plant had a flood warning siren installed to alert workers, but it did not offer direct support to the community—only partial community coverage.

All participants considered the need for a localized, reliable flood early warning systems as a high priority. Expressed preferences for a warning mode were stand-alone sirens (A: 2/8; D: 6/8), combined flood sirens and flood alert SMS/email services (A: 5/8; D: 2/8), combined flood sirens, emergency lights and flood alert SMS/email services (A: 1/8). One Aggitis panel member also suggested the use of a hydrometric station (a device placed near a water body that collects and records water quantity and quality data) as a more comprehensive solution. For Aggitis, combined warning systems (the most preferred choice) would warn both older adults (limited use of mobile phones) and younger adults (more frequent access to phones and laptops). For Dhuskun, outdoor sirens (most preferred choice) would be more efficient since SMS services were not reliable when the weather was bad. As they explained, sirens could provide real-time warning, cover a wide range, and be more useful when people were sleeping. Similar benefits were also discussed by the Aggitis participants who chose sirens as their main system (stand-alone systems or in combination with other types).

In a flood scenario with long power outage, all panel members found mobile phones to be an essential emergency device, mainly for communication and receiving information, with lights (as a function on the phone or a sole device) to be also essential (A: 5/8; D: 5/8). Oxygen tanks were also considered as important emergency devices for Aggitis participants (A: 8/8) due to the large population of older adults in the village.

When asked about the COVID-19 crisis and its significance compared to the flood disasters, only two-panel members (A: 1/8; D: 1/8) described it as a high priority threat, explaining that this is a pandemic (prevalent to the whole world) and everyone is stressed about it at present. The remaining panel members said that the pandemic did not pose a serious threat to their community (it could be controlled), unlike the floods that occurred at any time and without much warning. It should be noted that the interviews took place in April, May, and July 2021 when lockdowns and other restrictions were forced in most countries around the world, including Greece and Nepal.

3.1.2. Community Vulnerabilities

More broadly for Aggitis, a community vulnerability of greatest concern included ageing population (A: 8/8), with some participants highlighting the low-birth rate in their community, the decision of many younger adults to move to bigger cities, and the lack of opportunities for young business owners in the area, despite its ecotourism potential.

> (Male, 36—Aggitis): *"[. . .] the community is made up mostly of people over the age of sixty-five . . . seventy . . . who are retired or nearing retirement age. The younger generation chooses not to live in Aggitis, but in a bigger city and to have a house there, so to live both in Aggitis and in the big city, like I do. Therefore, the community is shrinking."*

During extreme weather events, all panel members found their community's energy supply unreliable and were dissatisfied with the energy status. The main reasons included the condition of technical equipment and systems which were old or poorly maintained, the severe impacts of seasonal conditions (floods, thunderstorms, etc.) in the system, and unexpected power outages (due to technical or other reasons). For Aggitis, continuous power generation was vital because, as they explained some older adults needed oxygen support and any power disruption could cause problems to their health. Both communities said that the power outages could last for hours, however, two Dhuskun participants pointed out that if the water hazards were serious, they would damage the nearby hydropower plant and cause damages that would take months to fix. In addition, for Dhuskun, power outages during extremes could also affect the work of emergency responders (e.g., no power in local police station).

One Dhuskun participant said that besides these vulnerabilities, their community also needed better transportation, education, and water supply infrastructure.

3.1.3. Community Cohesion

All participants highlighted community cohesion as a critical community capacity and the fact that community members still cared for one another. In the scenario where the early warning was insufficient or could not be reached by some sensitive groups (e.g., people with hearing or visibility impairments), all panel members said that other people in their community (family members or neighbors) who lived nearby would notify and assist them. While this seems like an obvious response, some panel members pointed out the fact that their community still cared for their members and would not leave anyone "behind", particularly during flood evacuation.

> (Male, 70—Dhuskun): *"In Nepal, and in Sunkoshi (Dhuskun) community, people tie up in such a way that if one knows about it, they will warn other people. One thing. And second thing is, who is living in which house, because everyone knows everyone's name. That is what I noticed. So, if and when time permits, time permits, those who can hear, they will ask other people and inform them."*

3.1.4. Reliable Energy

Other community capacities included energy reliability under normal conditions (A: 8/8; D: 6/8), and the renewable energy potential in the local site (A: 8/8; D: 8/8). With respect to the energy, all Aggitis panel members stated that the usual supply satisfied their daily needs. The majority of Dhuskun panel members stated the same. Those who disagreed highlighted the scheduled power outages, which sometimes affected businesses.

Notably, all panel members nominated renewable energy types as their preferred energy source due to environmental and socio-economic benefits, "clean" power generation, and low cost. For example, both communities stated that small-scale hydropower systems (A: 8/8; D: 8/8), solar panels (A: 7/8; D: 3/8), and their combination (A: 2/8; D: 2/8) would be ideal for their area since their village was by the river, there was sufficient sunlight, and hydropower and solar panel infrastructures already existed in the area. It should be noted that some participants (A: 2/8; D: 1/8) also suggested the use of small wind turbines but were unsure if this was a realistic option.

3.2. Round Two

In Round Two, we presented a catalogue of six community assets (Figure 2). Most panel members selected Option 6—hydropower, flood siren hybrid prototype (A: 5/8; D: 5/8), followed by Option 5—combination of solar energy panels and flood alert SMS (A: 3/8; D: 2/8), followed by Option 1—stand-alone hydropower generator (D: 1/8).

3.2.1. Multiple Services

The most attractive attributes for Option 6 were its feature to provide combined hydropower generation and siren warning in a hybrid manner (two services under one stand-alone system) and its site appropriateness (river flow). For Option 5, the features of solar power and flood alert SMS services were the most attractive attributes, followed by the convenience of receiving flood alerts on personal electronic devices. It can be observed that the majority of participants (15/16) chose an option that provides multiple services, but with the combination of hydropower and siren warning preferred by twice as many participants (10:5), due to the perceived reliability and feasibility of their respective services as presented in Round One.

The panel member who selected Option 1 found it the most realistic option for Dhuskun, given its low cost and site conditions (river flow). When asked about their preference regarding a combination of systems (Option 5) or a hybrid system (Option 6), they stated that the hybrid has more advantages and seems to be a more feasible solution for their community.

> (Male, 70—Dhuskun): *"Generally, you know, hybrid system is the most better way to do it. [. . .] of course, solar might be necessary, but it will be nominal only so when damage occurs (due to floods), when maintenance might be necessary. At that time, solar can help it, because of batteries and all. But when we install the batteries and all, the batteries will have a life, so once that life will be completed, then another set will be necessary, which is very difficult because it costs money again. And also disposing the batteries is very difficult. In that case, you know, first thing is I prefer to have hydro (Option 1), and second is hybrid system (Option 6)."*

3.2.2. Development Benefits

All panel members found economic benefits after the installation of their preferred community assets, including employment and new business potential. All panel members pointed out the synergy between community groups, academics, local authorities, and others as a crucial requirement for the successful funding, installation, operation, and maintenance of their preferred community asset.

> (Female, 45—Aggitis): *"A combination of these people (professional and non-professional stakeholders who are familiar with the community) and organizations could be involved*

in order to study the area, install the system and manage the project. They can be found in the wider area, within the competent bodies (authorities and organizations). Initially, the competent municipality in collaboration with the local district (authorities) could do research regarding the financing of this program, or set up an auction so the project can be completed by private companies. That is, I think the ideal would be for all the (competent) bodies to work together, because I do not think that the municipality alone has the know-how to do such a thing."

3.2.3. Risks and Solutions

Most panel members envisaged no significant risks for their communities after the installation of their selected community assets (A: 6/8; D: 6/8). For the remaining Aggitis panel members, risks of low concern included aesthetic risks that could affect the tourist traffic if the community asset was "ugly" and did not blend with the local natural scape (both Options 5 and 6). For the remaining Dhuskun panel members, the risks focused on the protection of the system against natural hazards and potential damage in the riparian ecosystem—e.g., alternations in local biodiversity (Option 6).

Participants raised a number of issues of technical and resource nature. Specifically for Aggitis, the greatest challenges were the limited energy output, lack of batteries, and high cost. Participants who raised these issues said that these could be solved by installing more units, including batteries to store power for later use, and involving multiple stakeholders in the project to secure sufficient funding. These issues were not raised by any Dhuskun participants. Additionally, for Option 6, panel members from both communities worried that the unit could be damaged during floods (and landslides for Dhuskun). The need for site analysis in both communities for the selection of appropriate locations for system installation was suggested as a solution. This issue and solution were also raised by the panel member who selected Option 1. Another common concern for both Options 5 and 6 was the need to upgrade the suggested early warning features, so to improve coverage and reliability by either installing more units or combining different warning types (i.e., siren and SMS alert).

(Female, 36—Aggitis): *"There are now sirens that can be combined with safety lights [. . .]. Sirens that could be combined with sending a text message or an email, which would not be difficult to do [..]. Whenever someone who might be away from the sirens (out of range) or, for example, someone who sleeps with earplugs, probably would not be able to hear the siren but maybe they could see the notification alert, if their mobile phone was vibrating."*

For Option 5, both communities discussed the insufficient sunlight during some winter months or cloudy days. The use of larger capacity batteries was suggested as a potential solution. Some Aggitis participants who chose Option 6 mentioned a similar issue as there could be a river depth limitation in some locations; the appropriate investigation of optimal locations was nominated as a solution. Lastly, some Aggitis panel members said that their community may not have the resources to manage such installations over time and that their presence could negatively affect tourist traffic. One counter view was that a well-developed project could attract tourists as a sustainability demonstration project. To solve these concerns, participants recommended the engagement of multiple stakeholders.

3.3. Remote Research Participation

All panel members (A: 8/8; D: 8/8) approved the study's remote research approach. They found it convenient and safe to participate, given the distance and COVID-19 restrictions. They understood all the provided materials and had easy access to the research activities, despite some minor technical/internet issues.

4. Discussion

According to the World Risk Index 2019 (https://reliefweb.int/sites/reliefweb.int/files/resources/WorldRiskReport-2019_Online_english.pdf accessed on: 30 November 2021), Greece's exposure to natural hazards is very high, compared to Nepal's, which is low, however, its coping and adaptive capacities levels are higher than Nepal's. This comparison provides a cogent example of why high-income countries are often more resilient to natural hazards. It does not rest simply with the hazard frequency and severity, but also the available resources and infrastructure invested for disaster resilience [1]. However, when it comes to floods, high-income countries are not always well-prepared, particularly at the local level. Recent record-breaking floods in Germany (https://www.theguardian.com/world/2021/jul/19/german-villages-could-be-left-with-no-drinking-water-after-floods accessed on: 4 December 2021) and the United States (https://www.nytimes.com/2021/09/03/nyregion/nyc-ida.html accessed on: 4 December 2021) show that early warning systems were not adequate at the local level, including urban areas, and could not detect the precise severity and location of the flash floods that occurred because they were designed to operate for larger scales. Conversely, there is some evidence that simpler and "low-tech" flood early warning systems that have strong community participation in low-income communities, such as in the Hindu Kush Himalaya region (https://www.icimod.org/mountain/cbfews/ accessed on: 1 December 2021) are very effective and could find applications in more "developed" areas [43]. Another factor that could support flood resilience is the use of off-grid renewable energy systems. This energy type can run independently and is rarely interrupted during weather extremes [8,9], hence, it should be highly considered in all phases of flood risk management.

Aggitis and Dhuskun face a range of natural hazards and vulnerabilities, with water disasters being a high priority. Hazard frequency (floods occur almost every year), previous losses, and a lack of community preparedness were cited as major reasons why this hazard type was seen as more threatening than others (e.g., earthquakes). For Dhuskun, landslides were of equally high concern, also due to the loss of life and damage caused in past events. In contrast, it is notable that the COVID-19 pandemic was not cited as a major threat or priority management issue in either community. Participants at both sites saw this as a shorter-term issue, national and global in nature, and importantly, it could be controlled through vaccination, and compliance with stay-at-home orders, masks, etc. As such, it was seen as qualitatively different from other natural hazards such as floods. Another possible explanation is that COVID-19 impacts are more visible in urban areas with high population density and not in smaller communities like Aggitis and Dhuskun [44].

Our initial needs assessment (Round One) found that all panel members preferred a complete transition to renewable energy sources, particularly hydropower and solar power. This would increase the communities' energy autonomy, reduce current energy costs and create job opportunities. While most Aggitis participants mentioned both hydropower and solar systems, the majority of Dhuskun participants chose hydropower as their preferred main energy source. This was possibly because Dhuskun was already receiving energy from the local hydropower plant and people were more familiar with this technology, unlike Aggitis residents who primarily received power from the main grid.

Notably, both communities lacked flood early warning mechanisms and there was an expressed need to develop such a capability, particularly flood sirens and SMS alerts. For Aggitis, combining these was seen as an ideal option because they would potentially reach different groups; older adults who lived alone (siren) and younger people (SMS text). Dhuskun participants preferred sirens as they were seen as more reliable (e.g., unaffected by telecommunications issues during storms) and could have wide, localized coverage. These findings are consistent with other literature showing that community-based early warning systems in rural areas generally employ flood siren systems rather than SMS services [16]. This is because rural areas often have poor network services, and sirens are a more efficient and cost-effective means of warning.

Panel members also highlighted a lack of flood education and training (e.g., evacuation drills). This is significant, as lack of procedural knowledge (what to do, when) can increase stress and impair decision-making during emergencies, and may contribute to increased fatalities [45]. Participants pointed out a related factor regarding the importance of continuous power supply, particularly during floods and other emergencies. Participants in Aggitis raised particular concerns for older residents, some of whom had mobility issues, specific health needs (e.g., supplemental oxygen) and lived on their own. Collectively, the findings suggest a constellation of factors likely to result in poor flood emergency flood response in both riparian communities: lack of localized early warning with rapid inundation, vulnerable subgroups (older adults, tourists, non-residents), hazard-related power loss, and lack of flood education and practiced procedures. The absence of flood warning capabilities for both groups is a critical element of this risk profile as this response infrastructure often provides the enabling platform that supports coordinated community preparedness. That is, if sirens/SMS alerts become the "when" (to act), communities can then begin to tackle the "how" in a more coordinated way (e.g., evacuation drills, rally points/signage/shelters, neighbor checks/counts, etc.) [46]. However, as participants also stated, these response systems are critically dependent on uninterrupted power. As such, while participants on both sites endorsed a transition to renewable energy (favoring hydropower and solar power) for daily energy and environmental reasons, power reliability in emergency situations was also a "front of mind" concern usually based on their lived experiences.

Community members noted key capabilities and strengths that could support renewable energy and hazard preparedness projects. These drew on common "foundation" attributes (e.g., sufficient sunlight, river flow), but also key differences across sites—e.g., the Sunkoshi River (Dhuskun) depth remained above 1.1 m throughout the year, but in Aggitis, it dropped below this depth in some locations, especially during summer. Under normal conditions, most panel members reported that the existing energy supply and infrastructure were sufficient for the local communities. In addition, all Aggitis participants said that continuous energy supply was important for the older adults who lived alone and needed medical support. While family unity and connection are strong in both Greek and Nepali cultures, older Greek adults prefer living alone, so they don't become a "burden" to other family members [47]. In Nepali families, older adults usually live with their children [48]. This cultural difference in living arrangements likely accounts for the greater concerns for older residents expressed by all the Aggitis panel members, including the need for continuous power during extreme weather events.

For Dhuskun, power interruptions could affect local businesses, but when these occurred during weather extremes, they had the potential to disrupt emergency operations and potentially contribute to the loss of lives. For such reasons, both communities saw a priority need for continuous, locally managed power, and this is perhaps why they supported the development of new, off-grid renewable energy systems. Such systems could work independently, either as main power sources or supplementary systems, and do so when the main power system is disrupted or offline.

Another interesting finding was that both community panel members believed that local residents would help those at risk, such as older adults, people with disabilities, and others. This is consistent with Winterton and Warburton (2012) [49], who concluded that small communities in rural areas are more "homogenous" and care for one another compared to urban populations.

In Round Two, most panelists selected the hybrid system (Option 6) as the most suitable community asset, due to its low environmental risk potential, use of nearby river resources for power generation, flood siren function, and economic benefits. Option 5 was the second most preferred choice for similar reasons. In part, this reflected a largely common view across the two sites on key issues, notably: preferred energy source, warning optimization, system protection in extreme conditions, and funding strategies). The differences cross-site tended to reflect socio-cultural and environmental perspectives. For example, some Aggitis participants expressed concerns that such an installation would be seen as "ugly" and could affect tourism, while one participant stated that a well-developed project could attract more people and highlight Aggitis' focus on sustainability. Aesthetic risks were not mentioned by Dhuskun panel members, possibly because Dhuskun is less dependent on tourism and hydropower infrastructure is already situated on their river. Other differences related to geomorphology. Dhuskun panel members emphasized landslide risks in their area and were concerned that the intervention would not survive such an event. Aggitis respondents pointed out that the system may not work if it is installed in areas where the river depth can become shallow. These differences highlight that technical interventions are rarely a one-size-fits-all solution and must be tailored, through consultations, to address specific local conditions and needs.

Lastly, our data collection approach, which was largely conducted via videoconference interviews, was reported to be an acceptable method by all panel members. Participants indicated that it did not restrict their access or reporting in any way and offered advantages in terms of convenience and time savings. In fact, several indicated that they preferred it to other approaches. As such, remote research could be considered in other humanitarian engineering research where physical engagement is not feasible or where the travel and logistics costs of a study may be prohibitive.

The following section focuses on the hybrid unit development (Option 6) as the most preferred community asset and presents the next steps for prototype development.

4.1. Research Translation: Developing a Hybrid Prototype

The study findings indicated that there was a strong preference for the hybrid unit that combines hydropower generation and flood early warning. In order to reach longer-term sustainability and wide community acceptance, the development of such prototypes should follow the best strategies used in similar community-based interventions. While the literature presents very limited information on such hybrid systems, information about stand-alone successful or failed renewable energy and early warning case studies could inform this pilot program [15,16]. Table A1 (Appendix A) is informed by the appropriate technology and systems evaluation tool, which frames a checklist of dimensions of system sustainability [16]. This tool is considered in our study for the development of the hybrid prototype, and it presents concerns and suggestions made by the panel members. For all phases of the prototype development, we will follow the SIMILAR Process, which is an appropriate method for industrial engineering and prototype production, and encompasses well with a comprehensive systems approach for hydropower generation and flood resilience [15,50]. Lastly, to allow the continuous mapping of the energy and flood response alternations in Aggitis and Dhuskun, the use of vulnerability and capability mapping is suggested [13]. This tool considers internationally known/accepted metrics for both pre and post-hazard conditions and allows cross-community comparisons.

4.2. Limitations and Future Work

While the principal researcher could conduct interviews with Greek participants directly, it is possible that intercultural awareness may have affected the interview process with Nepali participants. To support intercultural sensitivity, these interviews were jointly conducted with an on-site Nepali researcher, and the interview process was reviewed with Nepali research colleagues to ensure awareness and insights regarding cultural perceptions informed the dataset. The decision to primarily focus on themes related to energy reliability and flood-related risks, limited review of other community hazards and concerns mentioned by some participants (e.g., earthquakes, low-birth rate) that may warrant program support. Similarly, this study examined culturally and infrastructure distinct peri-urban and rural communities, and, therefore, generalizing its findings to other rural, peri-urban, or urban communities would require caution. Our ongoing research will engage a wider range of such riparian communities to strengthen the reliability of its findings and confirm key similarities and differences in flood-prone settlements. Using the information from this initial exploratory study, analyses with more participants, including in-situ studies and co-development of prototype models and other community assets, could be supported.

5. Conclusions

Riparian communities exposed to water disasters and energy insufficiency need humanitarian engineering support and services. Renewable energy and flood warning systems can provide much-needed assets for such communities, but their success is grounded in sustained collaboration between local and professional stakeholders. In this paper, we present a research design that allows effective engagement of a range of such stakeholders and across a range of contexts. Our findings indicate that participants from Aggitis, Greece and Dhuskun, Nepal preferred options with multiple services compared to well-established but monofunctional systems, and that the combination of hydropower and siren offered the most attractive option, endorsed by twice as many participants as the next preferred combination (solar and SMS). Integrating these services into a single unit was seen to offer efficiency gains while also supporting greater community input and control as a co-developed asset. A prototype with such features will be piloted in the next stage of this research and has the potential to promote sustainable development and flood resilience within our partner communities.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/geosciences12020071/s1, Table S1: Interview Questions Round One conducted during April–May 2021, Table S2: Interview Questions Round Two conducted during July 2021.

Author Contributions: Conceptualization, S.S. (Spyros Schismenos), G.J.S., N.G., D.E., S.S. (Surendra Shrestha) and B.S.T.; methodology, S.S.(Spyros Schismenos), G.J.S., and N.G.; validation, S.S.(Spyros Schismenos), S.G., and G.J.S.; investigation, S.S.(Spyros Schismenos), S.S. (Surendra Shrestha), D.E., and B.S.T.; writing—original draft preparation, S.S. (Spyros Schismenos); writing—review and editing, S.S.(Spyros Schismenos), G.J.S., N.G., D.E., S.S. (Surendra Shrestha), B.S.T., and S.G; visualization, S.S.(Spyros Schismenos); supervision, G.J.S., N.G., D.E., S.S. (Surendra Shrestha), and B.S.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the School of Social Sciences, Western Sydney University.

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Acknowledgments: This study was approved by the Western Sydney University Human Research Ethics Committee (HREC Approval Number: H14269). The authors would like to thank Mr Sushobhan Bhattarai, School of Engineering, Kathmandu University, for assisting the team with data collection and analysis.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Checklist for prototype development and sustainability.

	Dimensions of System Sustainability	**Panel Concerns/Suggestions**	**Prototype Features/Services (What Will Be Considered)**
Institutional	Autonomy (Community Self-Sufficiency)	Reliable flood early warning, 24/7 power generation	Real-time flood warning, daily and emergency energy
	Co-Creation (Local and Professional Stakeholders)	Interest in system's development, operation, and maintenance	Multiple stakeholder participation in the program
	Community Input (Engagement)	Interest in system's development, operation, and maintenance	Multiple stakeholder participation in the program
	Community Controlled (Managed, Owned)	Community controlled or co-managed with other stakeholders	Aiming for the unit to be community managed/owned or co-managed/co-owned
	Legal and Regulatory	Public, or private, or joint project	To be considered at a later stage with local communities and governments
	Support (Technical, Administrative, Financing)	Need for multiple stakeholder engagement and synergy	Multiple stakeholder participation in the program

Table A1. *Cont.*

	Dimensions of System Sustainability	Panel Concerns/Suggestions	Prototype Features/Services (What Will Be Considered)
Environmental	Habitat Neutral	Not to affect the local ecosystem	Aiming for low/no environmental risks
	Low Emergy	Not to affect the local ecosystem	Aiming for low/no environmental risks
	Low Emissions	Need for zero emissions	Unit is a renewable energy system (no emissions)
	Renewable Energy	Need for renewable energy transition	Unit supports hydropower generation
	Renewable Resources Availability	Local site resources can support system's operations	Riparian site conditions will be considered
	Scaled for Conditions (Resources, Weather, Land)	Must fit in local site characteristics (e.g., river water depth)	Unit will be modified so to be site appropriate
	Waste Utilization and Reduction	Local site resources can support system's development	Parts of the unit could be made by local waste materials (e.g., plastic)
Social/Ethical	Acceptability	Aggitis and Dhuskun possibly willing to participate in this program	Inform both communities of research study and seek acceptance
	Aesthetics	Not to affect tourism—it should increase visitors' traffic	System's design will be co-decided with professional and local stakeholders
	Ease of Use	Older adults and people with disabilities should be considered	Aiming for the unit to be user-friendly
	Gender Appropriate (e.g., women in staff/management)	Engagement of different community groups, including women	Priority in all project phases
	Indigenous Techniques	Local knowledge to be considered	Priority in all project phases
	Knowledge, Skills, Feedback	Local knowledge to be considered	Priority in all project phases
	Social Entrepreneurialism	Need for youth employment, environmental sustainability	Unit will be designed based on socio-cultural and environmental justice criteria
	Socio-Cultural, incl. health, education, harmony, etc.	Need for community resilience, development, and well-being	Aiming to support community capabilities under this project
Economic	Affordability	Lack of local funds and human resources	Seek support from multiple stakeholders, sponsors, local/national/international funds
	Income Generating	Need for new (and youth) employment opportunities	Aiming to support community capabilities under this project
	Job Creating	Need for new (and youth) employment opportunities	Aiming to support community capabilities under this project
	Money Saving	Low installation and maintenance costs	Priority in all project phases
	Labor Intensive	Lack of human resources/aging population	System will be autonomous/semi-autonomous (low labor-intensive)
	Resource Efficiency	Community has capacity/resources to support this initiative	Priority in all project phases
	Selling Appropriate	Community could become a role model to other communities	Aiming to promote Aggitis and Dhuskun
Technical	Adaptability	Adjust to different conditions (e.g., seasonal)	Unit will be adaptable based on different site conditions
	Constructability and Replicability	Unit to be easily constructible and replicable	Aiming to make the unit DIY (do-it-yourself) and EDO (easy-to-deploy-and-operate)
	Compatibility	-	Will be considered during the development phase
	Durability (e.g., against time or extremes)	Unit not to be damaged/washed away by floods and landslides	Will be considered during the development phase

Table A1. *Cont.*

	Dimensions of System Sustainability	Panel Concerns/Suggestions	Prototype Features/Services (What Will Be Considered)
Technical	Effectiveness	Energy generation to be continuous (24/7) even when unit is not working	Power storage units (batteries) could be included
	Energy Efficiency	Need for prioritizing high needs systems/services (e.g., sirens)	Available energy will support priority needs
	Low Power	-	Unit will be self-powered (incl. early-warning parts)
	Maintainability	Unit to be easily maintained	Maintenance will occur with the support of local volunteers (under training)
	Modification vs Invention	-	Unit will be able to be modified to address different community needs and site characteristics
	Multi-Purpose	Need for combined services (energy and flood warning)	Unit will provide energy generation and flood warning (hybrid system)
	Open Source Manual and Design	Need for more communities to benefit from this initiative	Aiming for open-source system (subject to stakeholders' decision)
	Parts and Hardware	Community has capacity/resources to support this initiative	Parts to be locally/nationally sourced
	Raw Materials Availability	Community has capacity/resources to support this initiative	Parts to be locally/nationally sourced
	Reliability	Early warning and energy under extremes to be reliable	Aiming for unit to operate 24/7
	Reparability	Unit to easily repaired	Reparability will occur with the support of local volunteers (under training)
	Reusability	Unit to be used multiply	Aiming for the unit to be reusable
	Scalability	Unit to generate sufficient power (e.g., >5000 W)	Use of multiple units could be considered
	Simplicity	Unit to be easily 'understood' by local stakeholders	Use of appropriate technology techniques and training
	System Independence	Unit to be autonomous	Independent unit or supplementary to existing infrastructure

References

1. Strömberg, D. Natural disasters, economic development, and humanitarian aid. *J. Econ. Perspect.* **2007**, *21*, 199–222. [CrossRef]
2. Flooding Triggers Landslides in Nepal and India, Killing at Least 150 People and Washing Away Homes. Available online: https://www.abc.net.au/news/2021-10-22/india-nepal-deadly-floods/100558832 (accessed on 30 October 2021).
3. Greece's Wildfires May Be Dying Down on the Island of Evia, but White-Hot Anger Rises in Its Place. Available online: https://www.abc.net.au/news/2021-08-15/greece-wildfires-devour-the-island-of-evia/100368262 (accessed on 30 October 2021).
4. Silverstein, K. The Energy Crisis Is Spreading Faster than the Coronavirus and COP26 Leaders Face a Faustian Choice. Available online: https://www.forbes.com/sites/kensilverstein/2021/10/13/the-energy-crisis-is-spreading-faster-than-the-coronavirus-and-cop26-leaders-face-a-faustian-choice/?sh=56e7cbe168a7 (accessed on 30 October 2021).
5. Schismenos, S.; Stevens, G.J.; Emmanouloudis, D.; Georgeou, N.; Shrestha, S.; Chalaris, M. Humanitarian engineering and vulnerable communities: Hydropower applications in localised flood response and sustainable development. *Int. J. Sustain. Energy* **2020**, *39*, 941–950. [CrossRef]
6. Death Toll Passes 180 in Nepal and India Floods. Available online: https://www.bbc.com/news/world-asia-india-58951456 (accessed on 29 October 2021).
7. Lighting Up Africa: Bringing Renewable, Off-Grid Energy to Communities. Available online: https://www.worldbank.org/en/news/feature/2020/08/13/lighting-up-africa-bringing-renewable-off-grid-energy-to-communities (accessed on 29 January 2022).
8. D'Cunha, S.D. How Off-Grid Renewable Energy Came to the Rescue in India's Flood Zones. Available online: https://www.forbes.com/sites/suparnadutt/2017/09/15/how-off-grid-renewable-energy-came-to-the-rescue-in-indias-flood-zones/?sh=6df386fabc49 (accessed on 27 January 2022).

9. Phillips, C. Combining Energy Efficiency and Disaster Mitigation Efforts in Residential Properties. Available online: https://www.huduser.gov/portal/periodicals/em/spring17/highlight2.html (accessed on 27 January 2022).
10. Cariolet, J.-M.; Vuillet, M.; Colombert, M.; Diab, Y. Building resilient and sustainable: A need to decompartementalise the researches. *E3S Web Conf.* **2016**, *7*, 13012. [CrossRef]
11. Mazzurco, A.; Jesiek, B.K. Five Guiding Principles to Enhance Community Participation in Humanitarian Engineering Projects. *J. Humanit. Eng.* **2017**, *5*. [CrossRef]
12. Hill, S.; Miles, E. What do Students understand by the term 'Humanitarian Engineering'. In *Innovation, Practice and Research in Engineering Education*; Coventry University: Coventry, UK, 2012; pp. 1–11.
13. Schismenos, S.; Stevens, G.J.; Emmanouloudis, D.; Georgeou, N.; Shrestha, S.; Chalaris, M. Humanitarian engineering at the sustainability-development nexus: Mapping vulnerability and capability factors for communities at risk of water-based disasters. *Sustain. Sci.* **2021**, *16*, 1185–1199. [CrossRef]
14. Skokan, C.; Munoz, D. Humanitarian Engineering Program–Challenges in the Execution of Remote Projects. Available online: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.522.2478&rep=rep1&type=pdf (accessed on 27 January 2022).
15. Schismenos, S.; Stevens, G.J.; Emmanouloudis, D.; Georgeou, N.; Shrestha, S.; Katopodes, N.D. Using off-grid hydropower for community-led flood resilience: An integrated systems approach. *Int. J. Sustain. Energy* **2021**, 1–15. [CrossRef]
16. Schismenos, S.; Stevens, G.; Emmanouloudis, D.; Georgeou, N.; Shrestha, S.; Katopodes, N.; Wali, N. Humanitarian engineering for renewable energy and flood early warning in remote communities: A scoping review of enabling factors and sustainability. *J. Sustain. Dev. Energy Water Environ. Syst.* 2021, in press. [CrossRef]
17. Schismenos, S.; Stevens, G.J.; Georgeou, N.; Emmanouloudis, D.; Shrestha, S.; Thapa, B.S. Humanitarian and Developmental Research Engagement during COVID-19. *Soc. Sci. Protoc.* **2021**, *4*, 1–14. [CrossRef]
18. de Brito, M.M.; Evers, M.; Höllermann, B. Prioritization of flood vulnerability, coping capacity and exposure indicators through the Delphi technique: A case study in Taquari-Antas basin, Brazil. *Int. J. Disaster Risk Reduct.* **2017**, *24*, 119–128. [CrossRef]
19. Skulmoski, G.J.; Hartman, F.T.; Krahn, J. The Delphi method for graduate research. *J. Inf. Technol. Educ. Res.* **2007**, *6*, 1–21. [CrossRef]
20. Helmer, O. *Analysis of the Future: The Delphi Method*; Rand Corp.: Santa Monica, CA, USA, 1967.
21. Asjes, K. The Hidden Benefits of Remote Research. Available online: https://www.uxbooth.com/articles/hidden-benefits-remote-research/ (accessed on 27 January 2022).
22. Barriball, K.L.; While, A. Collecting data using a semi-structured interview: A discussion paper. *J. Adv. Nurs.-Inst. Subscr.* **1994**, *19*, 328–335. [CrossRef] [PubMed]
23. Barbour, R.S. Checklists for improving rigour in qualitative research: A case of the tail wagging the dog? *BMJ* **2001**, *322*, 1115–1117. [CrossRef]
24. Collingridge, D. Validating a Questionnaire. Available online: https://www.methodspace.com/blog/validating-a-questionnaire (accessed on 22 September 2021).
25. Georgeou, N.; Hawksley, C. Enhancing Research Impact in International Development: A Practical Guide for Practitioners and Researchers. Research for Development Impact Network: Deakin, Australia, 2020.
26. Lebeau, K.; Van Mierlo, J.; Lebeau, P.; Mairesse, O.; Macharis, C. A choice-based conjoint analysis on the market potential of PHEVs and BEVs in Flanders. *World Electr. Veh. J.* **2012**, *5*, 871–880. [CrossRef]
27. Lee, H.-J.; Huh, S.-Y.; Yoo, S.-H. Social preferences for small-scale solar photovoltaic power plants in South Korea: A choice experiment study. *Sustainability* **2018**, *10*, 3589. [CrossRef]
28. Mansuy, J.; Verlinde, S.; Macharis, C. Understanding preferences for EEE collection services: A choice-based conjoint analysis. *Resour. Conserv. Recycl.* **2020**, *161*, 104899. [CrossRef]
29. Tanujaya, R.R.; Lee, C.-Y.; Woo, J.; Huh, S.-Y.; Lee, M.-K. Quantifying public preferences for community-based renewable energy projects in South Korea. *Energies* **2020**, *13*, 2384. [CrossRef]
30. Ebers, A.; Wüstenhagen, R.; Tabi, A.; Kostyuchenko, N.; Smolennikov, D.; Joller, L. Local Acceptance of Wind Energy in Switzerland, Estonia and Ukraine. A Cross-Country Analysis based on Choice Experiments. University of St. Gallen: Gallen, Germany, 2017.
31. Njoh, A.J.; Etta, S.; Ngyah-Etchutambe, I.B.; Enomah, L.E.; Tabrey, H.T.; Essia, U. Opportunities and challenges to rural renewable energy projects in Africa: Lessons from the Esaghem Village, Cameroon solar electrification project. *Renew. Energy* **2019**, *131*, 1013–1021. [CrossRef]
32. Braun, V.; Clarke, V. What Can "Thematic Analysis" Offer Health and Wellbeing Researchers? *Int. J. Qual. Stud. Health Well-Being* **2014**, *9*, 26152. [CrossRef]
33. Fereday, J.; Muir-Cochrane, E. Demonstrating rigor using thematic analysis: A hybrid approach of inductive and deductive coding and theme development. *Int. J. Qual. Methods* **2006**, *5*, 80–92. [CrossRef]
34. Berends, L.; Johnston, J. Using multiple coders to enhance qualitative analysis: The case of interviews with consumers of drug treatment. *Addict. Res. Theory* **2005**, *13*, 373–381. [CrossRef]
35. Black, K. *Business Statistics: For Contemporary Decision Making*; John Wiley & Sons: Hoboken, NJ, USA, 2019.
36. Novel, J.-P.; Dimadi, A.; Zervopoulou, A.; Bakalowicz, M. The Aggitis karst system, Eastern Macedonia, Greece: Hydrologic functioning and development of the karst structure. *J. Hydrol.* **2007**, *334*, 477–492. [CrossRef]

37. Pennos, C.; Lauritzen, S.; Pechlivanidou, S.; Sotiriadis, Y. Geomorphic constrains on the evolution of the Aggitis River Basin Northern Greece (a preliminary report). *Bull. Geol. Soc. Greece* **2016**, *50*, 365–373. [CrossRef]
38. Serres Farmers in Despair from the Disasters Caused by Strymonas. Available online: https://www.kathimerini.gr/society/809665/se-apognosi-oi-agrotes-stis-serres-apo-tis-katastrofes-poy-prokalei-o-strymonas/ (accessed on 22 September 2021).
39. Manandhar, R. After Lake Burst, Dhuskun Folk Fear More Landslips, Floods. Available online: https://kathmandupost.com/national/2014/09/11/after-lake-burst-dhuskun-folk-fear-more-landslips-floods (accessed on 19 September 2021).
40. Grisham, T. The Delphi technique: A method for testing complex and multifaceted topics. *Int. J. Manag. Proj. Bus.* **2009**, *2*, 112–130. [CrossRef]
41. Mullen, P.M. Delphi: Myths and reality. *J. Health Organ. Manag.* **2003**, *17*, 37–52. [CrossRef]
42. Ogbeifun, E.; Agwa-Ejon, J.; Mbohwa, C.; Pretorius, J. The Delphi technique: A credible research methodology. In Proceedings of the International Conference on Industrial Engineering and Operations Management, Kuala Lumpur, Malaysia, 8–10 March 2016; pp. 8–10.
43. UNFCCC. Community-Based Flood Early-Warning System | India. Available online: https://unfccc.int/climate-action/momentum-for-change/activity-database/community-based-flood-early-warning-system-india (accessed on 10 January 2022).
44. Kang, Y.; Baidya, A.; Aaron, A.; Wang, J.; Chan, C.; Wetzler, E. Differences in the early impact of COVID-19 on food security and livelihoods in rural and urban areas in the Asia Pacific Region. *Glob. Food Secur.* **2021**, *31*, 100580. [CrossRef]
45. Fahy, R.F.; Proulx, G. Toward creating a database on delay times to start evacuation and walking speeds for use in evacuation modeling. In Proceedings of the 2nd International Symposium on Human Behaviour in Fire, Boston, MA, USA, 26–28 March 2001; pp. 175–183.
46. Dufty, N.; Taylor, M.; Stevens, G. Why are people so unkind? Unravelling community responses to floodplain and emergency management. In Proceedings of the 52nd Floodplain Management Association Conference, Batemans Bay, NSW, Australia, 17–20 May 2012.
47. Panagiotopoulos, G.; Walker, R.; Luszcz, M. A comparison of widowhood and well-being among older Greek and British-Australian migrant women. *J. Aging Stud.* **2013**, *27*, 519–528. [CrossRef]
48. Egan, R.; Bowes, S. *Community Support for Seniors: A Case Study of the Newly Emerging Bhutanese Community*; Western Sydney University: Sydney, Australia, 2013.
49. Winterton, R.; Warburton, J. Ageing in the bush: The role of rural places in maintaining identity for long term rural residents and retirement migrants in north-east Victoria, Australia. *J. Rural. Stud.* **2012**, *28*, 329–337. [CrossRef]
50. Bahill, A.T.; Gissing, B. Re-evaluating systems engineering concepts using systems thinking. *IEEE Trans. Syst. Man Cybern. Part C* **1998**, *28*, 516–527. [CrossRef]