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Feasibility Assessment of a Small-Scale Agrivoltaics-Based Desalination Plant with Flywheel Energy Storage—Case Study: Namibia

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Abstract: As climate change and population growth threaten rural communities, especially in regions like Sub-Saharan Africa, rural electrification becomes crucial to addressing water and food security within the energy-water-food nexus. This study explores social innovation in microgrid projects, focusing on integrating micro-agrovoltaics (APV) with flywheel energy storage systems (FSSs) and small-scale water desalination and purification plants. Employing a mixed-methods approach to assess the economic viability of FSS and APV-powered desalination, we believe that social innovation could serve as a significant tool for rural development, requiring collaboration between governments, the private sector, and nonprofit organizations. While FSS technology for microgrids has not been entirely developed, it holds promise as an alternative energy storage solution. Our capital budgeting analysis, presented within the context of social innovation, reveals positive Net Present Values (NPV) and a short payback period over the project's 20-year lifespan.

Keywords: agrivoltaics; community microgrid; social innovation; energy storage; NPV; Namibia

Citation: Kádár, J.; Abdelshakour, O.; Zohar, T.; Hamed, T.A. Feasibility Assessment of a Small-Scale Agrivoltaics-Based Desalination Plant with Flywheel Energy Storage—Case Study: Namibia. *Sustainability* **2024**, *16*, 3685. https://doi.org/10.3390/su16093685

Academic Editors: Michael Peters, Gaetano Zizzo, Dylan Tutt and Vincent Carragher

Received: 15 November 2023
Revised: 3 April 2024
Accepted: 11 April 2024
Published: 28 April 2024

1. Introduction

Climate change poses significant challenges to rural societies, particularly in Sub-Saharan Africa [1,2]. With a population of 1.17 billion, the majority of whom live on less than $1.5 a day, Sub-Saharan Africa faces frequent natural disasters, such as droughts, floods, and desertification [3,4]. Rapid population growth and climate change have exacerbated challenging socioeconomic conditions [5,6]. The region's dependence on climate-sensitive renewable resources (water, fertile land, and agriculture), poor institutional capacity, and limited financial resources make it exceptionally vulnerable to climate change [7]. The capacity of agricultural societies to adapt to sudden environmental changes is limited, and the UN's Sustainable Development Goals (SDGs) for poverty reduction, health improvement, and environmental protection are threatened by climate change [8,9]. This paper uses Namibia as a case study to examine the impact of climate change on rural communities, the importance of microgrids in rural electrification, and the utilization of social innovation as a catalyst for procuring funding and fostering community involvement to build a climate resilient society. The primary objective of this study was to demonstrate the potential of microgrid agrivoltaics systems to advance a sustainable energy-water-food nexus in rural areas within the context of social innovation initiatives.

Climate change severely affects human well-being, including limited access to water, food, and shelter. Its myriad risk factors for rural societies include water stress, food security [10], health, and conflict. Water stress in developing regions results from inadequate state management of renewable resources [11] and the population's dependence on climate-sensitive resources [12]. Climate change has impacted freshwater availability and accessibility [13], leading to shortages, deterioration of water quality, food insecurity, and transboundary water disputes [14]. In Sub-Saharan Africa, the rural population accounts for a significant 58% of the total population, yet they face a significant disparity in accessing clean drinking water compared to urban areas [15,16]. While urban areas are expected to have basic water infrastructure such as pipelines, protected wells, boreholes, and bottled water, the reality is quite different. Surprisingly, even within urban settings, only 56% of the Sub-Saharan urban population has access to improved water sources [14], highlighting the pressing need to address water accessibility issues in urban and rural regions.

In Sub-Saharan Africa, agriculture accounts for 70–80% of employment and the main household income, climate change significantly impacts both income and food security [8]. Extreme evapotranspiration can harm rainfed agriculture yields [17], while rainfall variation and limited water availability make rainfed practices vulnerable and potentially ineffective [13]. As a result, food production in Sub-Saharan Africa has declined, contributing to poverty, 90% of which affects remote areas. Furthermore, tropical forests, vegetation, and wildlife, which depend on rainfall, are affected by increasing temperature and rainfall variations [11].

Health is a major risk factor. 80% of infectious diseases in developing regions are associated with poor-quality drinking water [18], and rising temperatures, rainfall issues, and poor sanitation have led to an increase in water-related diseases, such as cholera, typhoid, and malaria [19]. Warm, humid weather creates favorable conditions for bacteria and fungi, causing food spoilage [20]. In addition, mass displacements due to climate change create environments conducive to the spread of pathogens, chronic diseases, and epidemics, while droughts lead to malnutrition and starvation [21].

Furthermore, climate change has emerged as a complex contributing factor to conflicts, particularly in regions where communities heavily rely on climate-sensitive resources [22,23]. Recent studies highlight a link between global warming and increased conflict in Sub-Saharan Africa, a region highly dependent on the rainy season, with agriculture constituting 50% of its GDP [23]. Rural communities engaged in farming and herding are especially vulnerable to the negative impacts of climate change [24]. As natural resources become scarcer due to temperature rise and rainfall variations, competition erupts between these groups [25]. In normal circumstances, resource allocation is fair, but as resources diminish, those with political and armed strength gain a disproportionate share, leading to inter-communal violence [26]. For example, prolonged droughts in Darfur/Sudan over three decades triggered clashes between nomadic and sedentary groups, exacerbating economic and ecological imbalances [27].

The ongoing civil war in Darfur, dating back to the 1980s, originated in sporadic fighting between sedentary and nomadic communities over grazing land and water [28]. Severe droughts in the early 1980s further intensified the conflict, leading to famine. Continuous inter-communal violence over scarce natural resources eventually led to the formation of a rebel force by the farming sedentary group opposing the government [29]. In response, the central government mobilized the nomadic group for counterinsurgency, resulting in the infamous war in Darfur [27]. The UN Secretary-General emphasized that climate change is a contributing factor to the civil war in Sudan, with 29 out of 40 conflicts in Darfur between 1956–2003 associated with grazing and water [22,30]. Empirical research in Sub-Saharan Africa between 1980–2002 confirms a positive correlation between rainfall variation and civil conflict, highlighting climate change as a threat multiplier in developing nations with high rates of resource stress, social marginalization, and poverty [31].

Climate change significantly affects human well-being in rural areas, presenting challenges in accessing water, food, and shelter [10]. In Sub-Saharan Africa, where 58% of the population resides in rural areas, water stress is exacerbated by inadequate state management of renewable resources [15,16]. Agriculture, a vital source of employment and income, faces threats from climate change, contributing to heightened poverty in remote areas [4]. Extreme evapotranspiration can harm rainfed agriculture yields [6,17], while rain variation and limited water availability make rainfed practices vulnerable and potentially ineffective [7,13]. As a result, food production in Sub-Saharan Africa has declined, contributing to poverty, 90% of which affects remote areas. Furthermore, tropical forests, vegetation, and wildlife, which depend on rainfall, are affected by increasing temperature and rainfall variations [11]. This results in issues such as water stress, food security threats, health concerns, and conflicts [8,14].

Mitigating the environmental impact on rural societies requires a holistic approach that involves government, market, and grassroots social activities. Adaptation policies to minimize exposure and maximize rural communities' resilience to climate change [9] should focus on managing water resources, eliminating energy poverty through rural electrification [8], and enhancing rural farming techniques [17]. Integrating modern technologies and resources, such as renewable energy and small-scale desalination, can improve the coping capabilities of disadvantaged groups [13], while access to electricity can support water redistribution, conservation, quality, and water security [18]. Globalization can be key in distributing these technologies and innovations to remote areas [32,33].

This study explores the importance of microgrids in rural electrification, the utilization of social innovation as a vehicle for procuring funding and fostering community involvement and uses Namibia as a case study to examine the impact of climate change on rural communities. The primary objective of this study was to demonstrate the potential of microgrid agrivoltaics systems to advance a sustainable energy-water-food nexus in rural areas within the context of social innovation initiatives. The following section is an overview of the primary technologies involved.

2. A Review of Microgrids: Their Use and Key Components

A. What are microgrids?

In recent years, the energy sector has undergone a transformation driven by advancements in renewable energy technologies coupled with environmental and economic factors [34]. With this shift, the energy sector has been moving away from being traditionally controlled by the government and toward liberalization of the energy sector [35]. The microgrid system (MGs) was developed to support energy market liberalization, driven by goals including cutting costs, encouraging clean energy, and eliminating corruption in the industry while giving small players business opportunities in this emerging decentralized energy market [36]. A MG refers to a relatively compact, interconnected network for load and distribution within well-defined electrical boundaries. MGs are designed to function either autonomously or integrated into larger utility grids [37]. This study examines microgrids that encompass three key components, each discussed in the following subsections: renewable energy production through agrivoltaics, energy storage (with an emphasis on flywheel storage), and water desalination (with a focus on solar-powered desalination).

The key differences between utility grids and MGs are the power plant size, the distance of distribution networks from the plant, system management and control, and the end users [38]. Utility networks are large power companies comprising end-user systems, transmission lines, and large hydropower, coal, gas, and nuclear power plants [39]. MGs are smaller networks that benefit villages, residential areas, and local industries and are characterized by the ability to integrate multiple renewable energy sources and exchange energy with other MGs [40].

MGs are rapidly becoming an alternative for rural electrification in communities with little or no access to large-utility infrastructures [41]. They provide economic, social, and environmental benefits to all stakeholders. Moreover, the market penetration of renewable energy provides opportunities to operate power grids more simply, thereby increasing the quality and reliability of the energy output [42]. For example, MGs are less vulnerable to outages due to weather and other nationwide events [43] and can be designed with backup power sources such as solar panels or batteries. MGs design varies according to the grid's purpose, such as integrating renewable energy or cutting energy costs, transmission loss management, or carbon footprint [42]. In other words, community-based MGs are smaller versions of distributed networks [34]. Advances in communication technology allow consumers to operate these systems without relying on utility operators, while smart grid technologies have contributed significantly to MGs performance and control. For example, active interaction technology helps local energy consumers to determine and control their energy consumption [39]. Other smart technologies, such as cyber-physical systems (CPS), offer advanced control over grid configuration to ensure power distribution quality, reliability, and security [38].

Modern energy networks allow consumers to participate actively in the energy market [41], and the nexus of MGs and local communities creates new organizational and microfinance models that help to break large energy monopolies [44]. This consumer-centric approach enables even utility companies to transform from passive to active networks, interacting effectively with end users to create local energy communities [34]. Community microgrids can create affordable electricity for remote and disadvantaged communities, enabling rural communities to participate in reducing carbon emissions [43]. According to Trivedi et al., community microgrids often customize their design and operational decisions to align with the specific interests and needs of the community they serve [41]. Microgrids in remote areas can be built in stages, starting with a small grid that can be expanded over time, thus reducing upfront costs to the community [45]. Access to electricity can stimulate sustainable economic development by generating new businesses and entrepreneurial opportunities in rural areas [41], with local ownership and control of the grid ensuring improved energy availability at a lower cost.

While MGs offer valuable benefits to rural communities, challenges persist in the realm of grid infrastructure. Aspects like distribution networks, energy trading mechanisms, and system management and control are still not well-defined and require policy adjustments for effective integration. Our research focuses on rural areas without access to the main grid infrastructure [46]. We advocate for the adoption of adaptable microgrid solutions designed specifically for rural communities. This approach allows for gradual expansion and ensures long-term sustainability. By addressing these challenges, our work not only simplifies the complexities associated with microgrid control but also paves the way for improved energy access and grid reliability in underserved rural regions [34].

In the following chapters, a brief description of the three key components of the microgrid model used in this study is introduced. The model involves electricity production by agrovoltaics facility, flywheel energy storage, and water desalination.

B. Agrivoltaics

The first component of microgrids is renewable energy technology. The rapid expansion of renewable resources entails massive land usage, with wind and solar technologies expected to grow as energy transition efforts increase [47]. Population growth and land degradation create competition over land used for food and energy production, especially in densely populated areas [48]. Concern over excessive land use by ground-mounted (GM) photovoltaic modules (solar panels) has led to the development of integrated solutions that allow for farming and energy production on the same land [49].

Introduced by Goetzberger and Zastrow [47], agrovoltaics or agrivoltaics allow for crop cultivation using traditional practices [50], thus fostering the energy-water-food nexus [51] through sustainable energy production, increased crop yields, and efficient water use [52]. Solar panels share sunlight with crops, while advances in technologies such as sun tracking [49] enable the maximization of sunlight absorption, provide the requisite amount of shade for the crops, and reduce soil erosion and soil water evaporation in arid and semiarid regions [53].

The agrovoltaics layout is generally either horizontal or vertical. Earlier agrovoltaics were horizontal and built at least 2 m above the ground to maximize ventilation and sunlight [54]. These layouts are more cost-effective and are primarily designed for shade-tolerant plants [49]. In vertical agrovoltaics layouts, bifacial solar panels stand vertically in rows facing west-east, with the space between the rows utilized for agriculture [47].

Energy production on arable land has been perceived negatively because of the pressing demand for land resources [55]. However, agrivoltaics alleviates this dilemma [56]. It has been demonstrated that 80–90% of the land under agrivoltaics panels can be cultivated using standard agricultural practices. Furthermore, agrivoltaics provide additional protection against adverse weather, increase the productivity of arid land, reduce irrigation requirements, and enable better overall natural resource management [50].

The economic viability of agrivoltaics models has demonstrated positive performance, effectively offsetting initial capital expenditures. For example, a 6 kW/h agrivoltaics system yields an average annual return of $2306.9, resulting in a payback period of 7.5 years and a land equivalent ratio of 1.42 [57]. Additionally, the latest solar panel and sun-tracking technologies can further improve system output and profitability.

Agrivoltaics design has certain limitations, the first and most prominent of which is sunlight allocation between solar panels and crops [47]. Other potential concerns are related to urban and landscape transformations. However, in rural development, small-scale agrivoltaics grids are ideal for fostering a virtuous cycle of energy, water, and food security.

Small-scale agrivoltaics can provide reliable and affordable electricity for water desalination and purification plants, irrigation pumps, lighting, and farming equipment, improving access to potable water, increasing agricultural productivity, and supporting the livelihood of rural farmers [52]. They can also be designed to include sensors and remote monitoring technologies to help optimize irrigation water use and improve water conservation in rural communities.

Like most renewable energy projects, agrivoltaics help rural areas reduce their dependency on fossil fuels and biomass, effectively lowering greenhouse gas emissions [56]. Agrivoltaics models in decentralized energy systems in arid regions, such as Sub-Saharan Africa, could increase farm productivity [49]. Finally, small-scale agrivoltaics systems can provide additional revenue for rural farmers through the sale of excess electricity to neighboring farmers, an income diversification that improves the financial stability of rural communities.

C. Energy storage

Energy Storage System (ESS) forms a crucial component within the modern energy network, playing a pivotal role in the ongoing evolution of contemporary energy systems [58]. ESS is particularly vital in addressing challenges posed by Renewable Energy Sources (RES) and autonomous microgrids [59]. ESS contributes significantly to grid stability, managing frequency, controlling voltage, and regulating intermittent energy output from renewable sources [60]. Furthermore, it absorbs, transforms, and stores power in various forms for backup and future utilization [61]. ESS integration serves to fortify the resilience, reliability, and efficiency of modern grids. The ultimate objective is to harmonize power demand and supply dynamics [62]. However, despite its importance, ESS represents a primary obstacle to the widespread adoption of renewable off-grid initiatives in rural areas [60,63]. ESS accounts for 34% of the total microgrid cost and 50% of the annual operational cost of the microgrid system [64].

ESS technologies can be broadly categorized into five main types: electrical, chemical, mechanical, thermal, and electrochemical [58,60,65]. Each type possesses distinct features, contributing to the formation of a comprehensive and effective modern energy network [66]. Currently, battery storage systems (BSS) dominate microgrid and fast response applications, especially in rural Sub-Saharan Africa, where BSS is widely utilized despite its drawbacks, including higher costs, a short lifespan, and environmental concerns [65,67]. Mechanical energy storage, particularly Flywheel Energy Storage System (FESS), is gaining attention for its low environmental impact and competitiveness for various grid applications [60]. FESS is the focus of this paper. FESS operates as a mass spinning machine placed in a vacuum with low ambient pressure [58], storing energy in the form of rotational or kinetic energy [58,68]. Research suggests that as materials improve and upfront costs drop, long-duration FESS may become fully suitable for various grid applications [66].

The components of FESS involve a rotor, bidirectional motor/generator, magnetic bearing system, power electronic unit, and a vacuum chamber [65]. The bidirectional motor/generator functions as a typical motor during charging and a generator during discharging [69]. Charge and discharge depend on the load angle, where the motor forces the rotor to spin until it reaches the required speed during charging, and during discharging [65], the motor acts as a generator converting kinetic energy into electricity, slowing down the rotating flywheel rotor [58]. Power input-output is managed by power electronic systems [61].

Comparatively, FESS offers advantages such as a wider operating temperature range, environmental friendliness, lower maintenance requirements, longer lifecycle, high energy density and efficiency, fast charging and discharging abilities, and low standby loss [65,70]. Energy Storage on Investment (ESOI) for FESS is more efficient compared to Lithium-ion batteries, making it a suitable choice for various applications, especially isolated microgrid settings [71]. ESOI is the measure of how efficiently technology stores energy compared to the amount of energy it takes to produce that technology [60]. However, FESS has limitations, including the potential for rotor failure due to high-speed moving parts and standby power loss due to friction [58,70]. The current cost of FESS technology is the key factor affecting FESS's competitiveness in the market [72]. Although FESS technology has been employed in various applications, such as in hybrid vehicles, car charging systems, and recently in renewable energy [60], there is limited research on integrating FESS technology in autonomous microgrids intended for rural electrification [65].

Research and development in flywheel technology have seen significant progress, with a focus on new composite materials, superconductive magnetic suspension bearings, permanent magnets for high-speed motors, and advanced control systems [71,73]. The current trend aims at achieving more compact, integrated, and efficient FESS [60,74]. In the context of autonomous stand-alone grids based on renewable energy, FESS stands out as a simple technology and an environmentally friendly option with quick response times and the ability to provide smoother frequency management compared to diesel generators or battery systems [65]. While various energy storage systems play a significant role in voltage volatility control and frequency management of off-grid systems, FESS is becoming a suitable choice for these matters [70].

D. Water desalination

The last part of our microgrid model is the water desalination system. Water scarcity is a major threat to arid regions, with the amount and quality of accessible surface and groundwater continuously diminishing [75]. Approximately 33% of the world's population is experiencing water stress, and it is estimated that about 50% of the world's population will face water shortage by 2025 [76]. Water shortage is an annual water supply of less than 1000 m^3 per person [75,77]. Moreover, as groundwater levels fall within aquifers, potable water becomes saline and unfit for consumption [76]. A contemporary alternative is desalination, which involves removing salt from seawater and other brackish sources to make potable water. However, desalination is energy-intensive and requires a large energy infrastructure [78,79]. Approximately 44% of desalination's operating cost (OPEX) is associated with energy supply, making it an unaffordable technology for low-income countries [80].

One promising solution for tackling water shortages in developing countries is renewable energy-driven desalination plants, which are considerably more affordable than traditional desalination plants and can operate off-grid [81]. Of the various renewables, solar power has been found to be significantly effective in driving desalination plants—an economic advantage in water-stressed regions such as the Middle East and North Africa, which enjoy ample solar irradiation yearlong [77,82]. Moreover, as the price of solar panels decreases, so does the water cost per cubic meter for solar-powered desalination. Numerous studies have pointed to solar energy as a viable solution, especially for small-scale desalination plants in remote arid regions [80]. Solar-driven desalination requires minimal maintenance, and the combination of reverse osmosis technology with a high-pressure pump and an energy-recovery device can reduce energy consumption by up to 2 kWh/m^3 [83–85]. Water desalination utilizes several types of either thermal or membrane processes [77].

Thermal methods include multistage flash (MSF), multi-effect desalination (MED), and vapor compression (VC) [86]. Of these, MED performs better and consumes less energy [87,88]. Renewable-energy-based MED systems require two types of energy sources: thermal solar energy for heating and PV modules to generate electricity for pumping [75]. Membrane methods, which currently dominate the desalination market, use either the chemical process of electrodialysis (ED) or the mechanical process of reverse osmosis (RO) to remove salt from water [79]. While solar-powered ED methods have been developed worldwide, they are not as commercially attractive as RO methods [83].

While reverse osmosis (RO) is recognized for its substantial energy consumption, especially when considering the Electrical Equivalent for Thermal Energy (kWh/m^3), a closer look at the Total Equivalent Energy Consumption (kWh/m^3) reveals that RO is more energy-efficient compared to other desalination methods. Furthermore, unlike some desalination plants that require a combination of thermal and electrical energy, RO relies solely on electricity. These characteristics contribute to making RO an appealing option in the water production market [75,89].

Traditional desalination plants were designed to operate 24 h per day, making energy consumption the main barrier to setting up desalination in remote regions [83]. Conversely, contemporary renewable energy-driven desalination plants operate under fluctuating and even suboptimal power conditions to compensate for the variability of RE [75]. Furthermore, modern automation, data collection, remote operation, and energy recovery [81] technologies reduce plant maintenance, labor, and overall costs [90], which are critical for small-scale rural operations [82,85,86,91].

As renewable energy costs decline, so do desalination water prices, which currently average around $0.50 per cubic meter of potable water [88]. Although it entails higher capital costs than those of grid-based systems, renewable energy-driven desalination is still far more attractive for reaching rural communities and reducing environmental impact [80,92]. Combining it with social innovation business models—the focus of the following section—can offer a promising solution to water stress in remote communities, as well as good business opportunities [77,90].

3. Empowering Community-Led Energy Initiatives through Social Innovation

Rural development cannot be addressed using technological adaptation alone. Counterbalancing environmental impacts and destructive rivalries over shared resources requires a mechanism of collective self-reliance that will enable rural societies to utilize resources more methodically, sustainably, and harmoniously [93]. The term social innovation refers to a multidisciplinary framework that involves public-private, and local community partnerships, all working together to solve social issues [94]. Social innovation has the potential to address the complex social and economic challenges faced by rural communities through the development of products, services, business models, and policies aimed at well-being [95].

According to Berzin, social innovation facilitates collaboration across sectors to address pressing social issues [96]. Policy creation, regulatory frameworks, infrastructure development, resource allocation, social equality promotion, and rigorous monitoring and evaluation systems are all part of the public sector's role [96]. This comprehensive involvement lays the groundwork for successful social innovation initiatives [97]. The private sector, on the other hand, concentrates on resource mobilization, leveraging financial assistance and investment. It brings innovation by employing specialized skills to find creative solutions to social concerns. The private sector also emphasizes accountability and sustainability, directing efforts toward long-term effects [98]. Local communities, in conjunction, offer a unique perspective. They can identify and have the capacity to prioritize these needs based on their collective condition. Communities add a crucial layer to the joint effort with their extensive local knowledge and cultural sensibilities. Furthermore, communities generate social capital through developing trust and solidarity among members, and they prioritize ownership and empowerment when it comes to achieving real change [99]. This social innovation arrangement linked the responsibilities of different sectors in addressing complex societal issues, highlighting the significance of collaboration and synergy in reaching a common goal.

As a tailored framework for rural development, especially in Sub-Saharan Africa, social innovation is ideally meant to have both the capacity and the resilience to tackle pervasive problems such as poverty, energy poverty, water shortage, starvation, social marginalization, and environmental degradation [100]. It is often considered a grassroots alternative to government in building self-reliant communities through growth and shared values.

Social innovation has three key socioeconomic and entrepreneurial features. The first feature is constant production and expansion: unlike nonprofit or for-profit businesses, community businesses are neither noncommercial nor profit-sharing [99,101]. They generate income and use dividends in a wide range of public-oriented projects, which can then be replicated or scaled up to other rural communities [98]. The second feature is business risk. Social innovation initiatives are inherently risky because they depend on three groups of stakeholders: the benefitting communities, governments, and shareholders [98]. Finally, the third feature is that social innovation promotes workforce diversity by incorporating paid and volunteer workers. Social businesses are usually distinguished by their low reliance on hired employees, reflecting the collaborative nature of social innovation. In this final regard, social innovation is about solving social problems and building a collaborative relationship among different social groups, fostering community resilience, collectiveness, and inclusivity, and ultimately opening new niches and opportunities for improving everyone's quality of life [102].

The social innovation model views energy security as key to the energy-water-food nexus and sustainable development at large [98]. Thus, community-run microgrids serve as a social enterprise: overcoming the major obstacle of affordable energy [102], engaging local actors in public initiatives, and promoting sustainability. Microgrid social innovation can serve to diversify local income, promote villages' resource independence, and subsequently contribute to broader regional growth, creating cross-sector collaborations based on local culture and ties. Moreover, advances in microgrid technology create local business opportunities, often called peer-to-peer trading. For example, financially capable villagers can install home-based PV systems and sell surplus energy to the local grid—simultaneously turning a profit and avoiding installing hazardous chemical-energy storage systems [103].

Obtaining funding for projects in remote regions poses a major challenge. On the other hand, government commitment to long-term initiatives for rural development can provide a solution by assuring financial assistance and insurance coverage for smaller-scale projects [104]. Equally important is support from non-governmental groups in ensuring the long-term durability of resources for rural endeavors. Most importantly, exploring alternatives to traditional financial support, such as incorporating small investors and local communities in co-financing efforts, can significantly speed up social projects. Rather than investing just in climate-sensitive resources like cattle and farms, for example, local citizens can be encouraged to contribute funds to critical community initiatives such as microgrid projects [105].

Regulation is another hurdle for community enterprises in Sub-Saharan Africa and requires new institutional arrangements and inclusive governance—ones that will also account for the political ambitions of local leaders, the participation level of various civic actors, and the issues that matter most to the rural population [106]. Public policies related to socio-geographical peripheries should integrate social innovation models to draft laws and legal frameworks better and better attract funding for social entrepreneurship in rural areas [98].

4. Case Study: Namibia

The country of Namibia in southwestern Africa is dominated by the Namib desert along its Atlantic coast and part of the Kalahari Desert inland. Considered one of the most waterless regions in Sub-Saharan Africa, it is rich in minerals such as diamonds and uranium [107]. Despite its vast size, Namibia has a population of about 2.5 million as of 2021 [108]. Its abundant mineral resources and political stability have helped the country to count among Sub-Saharan Africa's upper-middle-income nations, with a GDP of USD 12.31 billion and an annual growth rate of 2.7%, driven mainly by the mining sector [109].

Despite its positive macroeconomic outlook, Namibia remains one of the most unequal countries in the world, mainly due to its history of colonial apartheid [110]. With a Gini coefficient of 59.1 and 17.4% of the population below the poverty line in 2015 [111], only a fraction of Namibian society controls the economy, while the vast majority struggles to survive [112]. Access to basic services, economic participation, and economic opportunity vary significantly between social segments and geographic regions. Furthermore, rural agrarian communities make up over 70% of Namibia's population, and most of the country's renewable natural resources—including 90% of 36 million hectares of arable land—remain in the hands of a few wealthy Namibians [113].

Similarly, as in many Sub-Saharan countries, most of Namibia's rural population subsists on agriculture and, as such, is acutely vulnerable to climate change. Average annual rainfall varies dramatically from <25 mm in desert regions to 700 mm in certain semiarid regions [114], and some of the country's rivers, key sources of its freshwater supply, have dried up due to climate change and upstream diverting by neighboring countries [115]. In 2016, Namibia declared a state of emergency that included water rationing to deal with severe drought [116]. Communities often lose crops to flooding and livestock to starvation and thirst, making villagers highly dependent on government aid [117]. Trapped in a poverty cycle [118], many Namibians cut their food consumption, travel long distances to the ocean for fishing, emigrate to other villages or cities for work, or resort to begging [112]. 70% of the rural population cannot afford to go to school.

Energy is vital for addressing Namibia's water-related challenges, yet the country also grapples with a significant electricity shortage [119]. It imports 60% of its power from neighboring countries, including South Africa and Zambia [120]. The remaining 40% of domestically generated electricity comes from various power sources. These include the Ruacana hydropower plants (330 MW capacity), the Van Eck coal-based power plant (120 MW capacity), the Van Eck Power station, and the Anixas diesel-based power stations (24 MW and 22.5 MW capacity, respectively) [121,122]. According to the US Department of Commerce, Namibia installed a 20 MW solar power station in 2022 [121]. Despite having significant renewable energy potential, such as daily averages of 5 kWh/m^2 of solar radiation and wind speeds of 4–15 m/s, the main source of electricity generated by renewable energy sources are solar (5%) and hydroelectricity (89%). The energy market in Namibia is vulnerable due to its heavy reliance on imported electricity and fossil fuels for operating domestic power stations [107]. Furthermore, the country's single hydroelectricity station is not sustainable either, as the country is prone to extreme droughts.

Although national grid-connected renewable energy projects contribute to cleaner energy and increased energy supply, they require substantial investment in infrastructure upgrades. These projects might not be economically viable for developing countries like Namibia, as they require significant amounts of public funds and can hinder efforts to expedite rural electrification [119]. The country's size and sparse population pattern mean that expanding the public grid to remote regions is extremely costly, leaving over 45% of Namibians without access to electricity: rural access to electricity is roughly 35%, while urban access is roughly 75% [119]—another example of extreme inequality.

Namibia utilizes a well-established decentralized governance approach characterized by local councils responsible for regions, constituencies, townships, and villages [113]. These councils play a crucial role in directing services to Namibians with limited access to government resources and in fostering improved land and water management practices [123]. The effectiveness of these efforts, however, has been constrained by the prevailing political culture and the challenges of climate change, a problem that becomes particularly evident when potable water availability depends on electricity.

To address this issue, this study suggests the novel concept of autonomous renewable energy microgrids. In addition, it advocates for a bottom-up coordination approach based on the social innovation model, engaging diverse stakeholders, such as the private sector, civil nonprofits, the international community, and local government. This approach can potentially improve water availability and food security not only in rural Namibia but also across Sub-Saharan Africa. Specifically, the proposal involves implementing community-based micro-agrivoltaics in conjunction with desalination plants while also creating incentives for local small-scale investors to participate in rural water and energy projects.

To test this proposed scenario, the village of Bukalo (Figure 1) in Namibia was selected as a case study. Situated in the Zambezi region in the northeast of Namibia. Bukalo is 112 km from the Namibian capital, Windhoek [124], with the smallest population in Namibia. Bukalo relies on the country's water corporation, which supplies water to the village from four boreholes equipped with pumping stations and three plastic tank reservoirs [125]. The energy powering these water pumping stations is derived from the local grid, which predominantly relies on non-renewable sources and thus lacks sustainability. To ensure consistent electricity supply for the water stations and to maintain the quality of the water produced, this paper proposes the adoption of off-grid agrivoltaics systems for energy generation, coupled with the integration of small-scale desalination plants for water production.

Figure 1. The location of Bukalo village in Namibia [126].

Social Innovation in Namibia

Social innovation (SI) in Africa has recently gained momentum as a dynamic, cross-sectorial effort in response to the challenges posed by the continent's changing economic, urbanization, and population landscape [127]—with initiatives spanning education, agriculture, health, and more demonstrating the impactful application of SI strategies [128]. SI provides technical expertise, human resource training, and legal and administrative reinforcement. Development agencies play a pivotal role in championing SI across the African continent as they provide financial assistance and expertise [105].

Namibia's extensive and sparsely populated geography, tribal barriers, small GDP, and limited research and development all pose challenges to the development of SI. Fortunately, the country's public sector recognizes SI as a crucial factor and recognizes indigenous knowledge as a key driver—particularly in the tourism and food sectors, with the government incorporating it into innovation-related strategies [129].

The Harambee Plan Policy (HPP II) program, spanning from 2021 to 2035, aims to drive inclusive economic growth in Namibia—by improving public services, encouraging citizen participation in decision-making, and enhancing energy, food, and water security [130]. The Namibian government has forged agreements with international agencies from different countries such as Germany and Finland, actively fostering SI [130–132]. This commitment has positioned Namibia as a hub for local and regional policy innovation, achieving a global ranking of 107 and 13 in Sub-Saharan Africa in the 2015 Global Innovation Index [133].

5. Materials and Methods

The research design adopts a mixed-method approach, combining both quantitative and qualitative analyses to comprehensively evaluate the feasibility of implementing community agrivoltaics with flywheel energy storage in Namibia. Within the quantitative analysis, the focus is on capital budgeting for a small-scale agrovoltaic-based water desalination plant [108,123,124,134,135]. Utilizing existing data on Namibia's population, water consumption patterns Table 1, and water prices Table 2, a small-scale desalination plant is selected for examination [108,115,134]. Simultaneously, data are gathered on the cost, energy requirements, and water production capacity of a small-scale Reverse Osmosis system [136]. Additionally, a Bukalo village in Namibia was chosen, and data on its population and water consumption pattern were gathered. See Table 3 for a detailed analysis [124]. Comprehensive data are collected on the global average installed photovoltaic (PV) cost for micro-agrovoltaic systems' cost estimation [137]. Data on solar radiation in Namibia are examined [138]. This information contributes to the overall capital budgeting analysis, providing a more comprehensive assessment of the feasibility. The capital budgeting analysis employs Net Present Value (NPV) and Payback Period methods.

The qualitative analysis involved designing a comprehensive questionnaire aimed at surveying prominent flywheel manufacturers, with eight open-ended questions designed to gain insights into the contemporary status of flywheel technology and its potential contribution to sustainable rural electrification. The extensive answers to this questionnaire enabled us to explore the technological advancements and capabilities of flywheel energy storage systems, providing valuable qualitative data to enhance the understanding of the feasibility of incorporating flywheel technology in the context of rural electrification in Namibia.

Literature reviews play a crucial role in shaping the research context. An extensive exploration of social innovation models in rural Africa informs the theoretical foundation for promoting the food-water-energy nexus in Africa. A specific literature review on Namibia is conducted to understand contextual factors influencing the feasibility of community agrivoltaics and flywheel energy storage. The integration and synthesis of findings from the capital budgeting analysis, survey, and literature reviews allow for a comprehensive feasibility assessment. Ethical considerations were paramount throughout the research, with measures taken to ensure participant privacy and obtain informed consent. Limitations, particularly those associated with survey data, are transparently acknowledged to enhance the credibility of the overall feasibility assessment.

Table 1. Namibian population distribution and water consumption pattern.

Namibia	Urban	Rural	Total
Population (2022)	1,403,099	1,137,806	2,540,905 [108,123]
Water for domestic use (m^3/month/capita)	5.41	0.80	6.21 [134]

Table 2. Water prices in Namibia (1 Namibian dollar = USD 0.053) [139–141].

Amount of Water Consumed in m^3	Tariff, $USD per m^3 [139]
0–6	0.36
6–36	4.04
>36	81.81

Table 3. Total water consumption in Bukalo village, Namibia.

Sample Village	Bukalo [124]
Population	600
Monthly domestic water demand per capita in m^3	0.8 [134]
Monthly total domestic water demand in m^3	480

Equation (1) is used to calculate the NPV of the project, while Equation (2) is used to calculate the number of years needed to recover the initial investment.

$$\mathbf{NPV} = \sum_{t=0}^{n} \frac{\mathbf{Ct}}{(\mathbf{1+i})^{\mathbf{t}}} \tag{1}$$

Equation (1): Net Present Value equation.
t = number of years; Ct = net cash flow over a single period; i = discount rate

$$PP = initial\ project \frac{initial\ project\ cost}{annual\ cash\ flows} \tag{2}$$

Equation (2): Payback Period Equation.

6. Results

In assessing the overall cost of the 3 kW agrivoltaics energy system required to power the Okiana desalination system, we had an option between two approaches for calculating the cost of the 3-kW system. The first alternative required us to take a detailed approach in which we methodically developed the agrivoltaics system and assessed the cost of each individual component [137]. Alternatively, we have chosen to use an existing statistics database that has a thorough record of installed PV system pricing globally. In this technique, we used average installation costs to compute the system's overall energy cost, which currently stands around 0.879 $/kWh. In addition, we calculated the interest rate for this analysis using both the loan rate and interest rate provided by the Namibian Central Bank [140]. We have chosen to utilize the average of these two rates for the analysis in this research. This research adopts a social innovation model involving collaboration among the private and public sectors, as well as the local community, for the implementation of the water project. As a result, our analysis assumes that the necessary land will be contributed by the local community, with labor costs covered by the local government. Therefore, our calculations exclude both land and labor costs from consideration. Lastly, due to data limitations, certain assumptions were made regarding shipping, installation, and maintenance costs (Table 4). Factoring in all the above, we calculated the total cost of solar-driven desalination plants and the annual revenue from water and then estimated the NPV and payback period for the Okiana desalination system. NPV is a capital budgeting tool for determining the worthwhileness of new investments, while the payback period is the time required to recover the initial investment [142]. Table 5 presents these calculations.

Table 4. Small-scale desalination plant.

Desalination plant information table [136]	
Model	Okiana desalination system
Energy Input (kWh)	3
Production capacity (m^3/h)	1
Optimal daily output in m^3	20
System cost details [136]	
Initial cost	$22,069
Installation cost	$6621
Energy cost	$2571
Total cost	**$31,260**
Annual O&M cost	$3310
Additional information based on assumptions	
Shipping & Installation (with respect to initial cost)	30%
Operation & Maintenance (with respect to initial cost)	15%
AVG. Installed PV price	$0.879
Days in month	30
Revenue information	
Water tariff per m^3	$1.01
Annual interest rate	7.75%
Monthly interest rate	0.65%
Project lifetime in year	20
Annual Revenue	**$6976**

Table 5. Okaina System Capital budgeting.

Year	**Initial Cost**	**OPEX**	**Revenue**	**Gross Income**	**PV**
1	$(28,691.95)	$(3310.31)	$6838.26	$(25,164.00)	$(22,954.61)
2	0	$(3310.31)	$6838.26	$3527.96	$2935.65
3	0	$(3310.31)	$6838.26	$3527.96	$2677.90
4	0	$(3310.31)	$6838.26	$3527.96	$2442.78
5	0	$(3310.31)	$6838.26	$3527.96	$2228.31
6	0	$(3310.31)	$6838.26	$3527.96	$2032.66
7	0	$(3310.31)	$6838.26	$3527.96	$1854.20
8	0	$(3310.31)	$6838.26	$3527.96	$1691.40
9	0	$(3310.31)	$6838.26	$3527.96	$1542.90
10	0	$(3310.31)	$6838.26	$3527.96	$1407.43
11	0	$(3310.31)	$6838.26	$3527.96	$1283.86
12	0	$(3310.31)	$6838.26	$3527.96	$1171.14
13	0	$(3310.31)	$6838.26	$3527.96	$1068.31
14	0	$(3310.31)	$6838.26	$3527.96	$974.52
15	0	$(3310.31)	$6838.26	$3527.96	$888.95
16	0	$(3310.31)	$6838.26	$3527.96	$810.90
17	0	$(3310.31)	$6838.26	$3527.96	$739.71
18	0	$(3310.31)	$6838.26	$3527.96	$674.76
19	0	$(3310.31)	$6838.26	$3527.96	$615.52
20	0	$(3310.31)	$6838.26	$3527.96	$561.48
NPV					**$4647.77**
Payback period (in year)					**4.20**

7. Discussion

In this section, we explored our findings on the three key subjects of flywheel storage, the Net Present Value (NPV) of solar-powered desalination, and the significance of social innovation in Namibia.

Flywheel Energy Storage System (FESS) has emerged as a pivotal solution in contemporary energy systems, particularly within microgrid applications. It effectively addresses challenges associated with Renewable Energy Sources (RES) and autonomous microgrids, offering a reliable means to stabilize frequency, control voltage, and manage intermittent energy output. Categorized under mechanical energy storage technology, FESS distinguishes itself with its environmental friendliness, minimal maintenance requirements, and extended lifecycle. Our analysis revealed that, despite certain limitations such as the potential for rotor failure and standby power loss, FESS boasts high energy density, efficiency, and suitability for isolated microgrid applications. Considering the unique challenges of autonomous stand-alone grids based on renewable energy, we found that FESS holds promise in addressing issues related to low inertia and intermittent nature. Unlike conventional solutions like diesel generators or battery systems, FESS stands out as an environmentally friendly alternative with quick response times and the ability to provide smoother frequency management. In the broader context of the global energy transition, FESS emerges as a valuable player. Its potential applications go beyond microgrids, making it a suitable choice for various grid applications as materials improve and upfront costs decrease.

ZOOZ was chosen as the only flywheel storage developer company in Israel. The outcome of the interview with ZOOZ's representatives shows that today's development of flywheel answers mainly the need for quick-charging electric cars rather than off-grid energy storage systems. The result of the interviews shows the global significance of the flywheel storage market. It was emphasized that, unlike lithium-ion batteries, flywheel energy storage is currently not capable of running off-grid, but there is hope that technological developments may make it a viable option soon [143].

In assessing the economic feasibility of off-grid desalination, we used data from the description of Okiana's solar-powered desalination plants. The results revealed a positive NPV, providing evidence for the project's overall feasibility. Additionally, based on the project's 20-year lifespan, our payback period estimation showed that the initial investment cost might be recovered within the first five years of the project. It is crucial to stress, however, that our study was based on the premise of a social innovation model supporting a public-private partnership, which would entail the provision of land and labor for the project. As a result, our calculations excluded land and labor expenditures. In addition to these issues, it is worth mentioning the complexity of desalination plants, which rely on advanced technology and require professional operation and maintenance. As a result, selecting a dependable water filtration system is critical, especially when addressing the demands of rural populations.

Finally, in leveraging social innovation in Namibia, funds should be effectively allocated towards developing an extensive list of bottom-up, community-oriented initiatives. These include sustainable agriculture, improving access to energy and water, promoting a local sustainable energy transition, democratizing the energy system, and closing the gender gap, developing community—based sustainable business models, installing water taps in public places such as schools and clinics, and much more—including supportive policies related to all the above.

8. Conclusions and Recommendations

The importance of rural electrification lies in the fact that access to clean water and improved agriculture depend equally on energy. Freshwater supplies have been severely impacted by climate change and population growth, resulting in the loss of livelihoods in rural parts of developing countries. While they provide some limited support, current strategies for coping are insufficient to ensure sustainability over the long term. Therefore, effective adaptation policies should prioritize reducing the vulnerability of rural communities to climate change and increasing their resilience. One strategy to accomplish this is to leverage social innovation business models, which can aid in the formulation and execution of rural sustainable development initiatives. Social Innovation is a powerful platform that leverages institutions and technology to tackle pressing issues. Communities should utilize these models to enhance their capabilities and gain scientific insights into climate change [9].

Community-based APV systems provide a dependable and affordable alternative for accessing clean water, irrigation, lighting, and farming equipment. By integrating agrivoltaics with energy storage, rural farmers can confidently enhance their agricultural production and quality of life. If social innovation is integrated into the community energy system, there will be a potential positive outlook. This convergence will allow these communities to overcome longstanding challenges and finally reach their fullest potential. An integrated off-grid water filtration plant based on social innovation in a community microgrid has the potential to offer long-lasting solutions to water scarcity in Namibia and Sub-Saharan Africa, which can lead to a brighter tomorrow for rural communities [52]. In closing, while this research did not explicitly undertake experimental studies into social innovation, it did rely heavily on the previous literature to explain its results and suggestions. As a result, we advocate a more in-depth investigation of Flywheel Energy Storage System (FESS) development and investment, which is in line with the significant potential given by the notion of social innovation. This study emphasizes the importance of multidisciplinary methods and collaborations in advancing rural electrification and sustainable energy solutions, underlining the importance of ongoing research and action in this critical domain.

Lastly, social innovation can play a pivotal role in empowering rural communities to become more climate resilient. By offering specialized training in renewable energy and water desalination systems, these communities can equip their personnel with the knowledge and skills required to harness sustainable technologies. This training not only fosters energy self-sufficiency but also holds the potential to ensure a consistent energy-water-food nexus. Through social innovation initiatives, they can effectively address climate challenges, mitigate environmental risks, and enhance their overall adaptability to the ever-evolving demands of a changing climate.

Author Contributions: Conceptualization, J.K., O.A., T.Z. and T.A.H.; methodology, J.K., O.A., T.Z. and T.A.H.; software, J.K. and O.A.; analysis, J.K., O.A., T.Z. and T.A.H.; writing—original draft preparation, J.K., O.A., T.Z. and T.A.H.; writing—review and editing, J.K., O.A., T.Z. and T.A.H.; supervision, T.Z. and T.A.H. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The data presented in this study are available on request from the corresponding authors.

Acknowledgments: We are grateful to Martina Pilloni for her professional guidance and encouragement. Also, thanks to the Haifa Center for German and European Studies, the University of Haifa, the FS Foundation, and the Isadore and Bertha Gudelsky Family Foundation for supporting this research.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Serdeczny, O.; Adams, S.; Baarsch, F.; Coumou, D.; Robinson, A.; Hare, W.; Schaeffer, M.; Perrette, M.; Reinhardt, J. Climate change impacts in Sub-Saharan Africa: From physical changes to their social repercussions. *Reg. Environ. Change* **2017**, *17*, 1585–1600. [CrossRef]
2. The World Bank. Sub-Saharan Africa | Data. Available online: https://data.worldbank.org/country/ZG (accessed on 4 June 2023).
3. Statista. Sub-Saharan Africa—Total Population 2011–2022 | Statista. Available online: https://www.statista.com/statistics/805605/total-population-sub-saharan-africa/ (accessed on 3 September 2023).

4. Calzadilla, A.; Zhu, T.; Rehdanz, K.; Tol, R.S.J.; Ringler, C. Economywide impacts of climate change on agriculture in Sub-Saharan Africa. *Ecol. Econ.* **2013**, *93*, 150–165. [CrossRef]
5. Cattaneo, C.; Beine, M.; Fröhlich, C.J.; Kniveton, D.; Martinez-Zarzoso, I.; Mastrorillo, M.; Millock, K.; Piguet, E.; Schraven, B. Human Migration in the Era of Climate Change. *Rev. Environ. Econ. Policy* **2019**, *13*, 189–206. [CrossRef]
6. Schilling, J.; Hertig, E.; Tramblay, Y.; Scheffran, J. Climate change vulnerability, water resources and social implications in North Africa. *Reg. Environ. Change* **2020**, *20*, 15. [CrossRef]
7. Gosling, S.N.; Arnell, N.W. A global assessment of the impact of climate change on water scarcity. *Clim. Change* **2013**, *134*, 371–385. [CrossRef]
8. Derrick Ngoran, S.; Etornam Dogah, K.; Wang, Y. Assessing the Impacts of Climate Change on Water Resources: The Sub-Saharan Africa Perspective. 2015. Available online: www.iiste.org (accessed on 13 September 2023).
9. Fischer, G.; Shah, M.; Van Velthuizen, H. Climate Change and Agricultural Vulnerability; Laxenburg, Austria. 2002; Available online: https://pure.iiasa.ac.at/id/eprint/6670/1/XO-02-001.pdf (accessed on 10 December 2023).
10. Jankowska, M.M.; Lopez-Carr, D.; Funk, C.; Husak, G.J.; Chafe, Z.A. Climate change and human health: Spatial modeling of water availability, malnutrition, and livelihoods in Mali, Africa. *Appl. Geogr.* **2012**, *33*, 4–15. [CrossRef]
11. Blanc, E. The Impact of Climate Change on Crop Yields in Sub-Saharan Africa. *Am. J. Clim. Change* **2012**, *1*, 1–13. [CrossRef]
12. Stringer, L.C.; Mirzabaev, A.; Benjaminsen, T.A.; Harris, R.M.B.; Jafari, M.; Lissner, T.K.; Stevens, N.; der Pahlen, C.T.-V. Climate change impacts on water security in global drylands. *One Earth* **2021**, *4*, 851–864. [CrossRef]
13. Mancosu, N.; Snyder, R.; Kyriakakis, G.; Spano, D. Water Scarcity and Future Challenges for Food Production. *Water* **2015**, *7*, 975–992. [CrossRef]
14. Mutono, N.; Wright, J.A.; Mutembei, H.; Muema, J.; Thomas, M.L.H.; Mutunga, M.; Thumbi, S.M. The nexus between improved water supply and water-borne diseases in urban areas in Africa: A scoping review. *AAS Open Res.* **2021**, *4*, 27. [CrossRef]
15. The World Bank. Rural Population (% of Total Population)—Sub-Saharan Africa | Data. Available online: https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS?locations=ZG (accessed on 29 August 2023).
16. Progress on Household Drinking Water, Sanitation, and Hygiene 2000–2017. Special Focus on Inequalities. New York: United Nations Children's Fund (UNICEF) and World Health Organization. Available online: https://www.who.int/publications-detail-redirect/9789241516235 (accessed on 29 August 2023).
17. Adhikari, U.; Nejadhashemi, A.P.; Woznicki, S.A. Climate change and eastern Africa: A review of impact on major crops. *Food and Energy Secur.* **2015**, *4*, 110–132. [CrossRef]
18. Abedin, M.A.; Collins, A.E.; Habiba, U.; Shaw, R. Climate Change, Water Scarcity, and Health Adaptation in Southwestern Coastal Bangladesh. *Int. J. Disaster Risk Sci.* **2019**, *10*, 28–42. [CrossRef]
19. Delpla, I.; Jung, A.-V.; Baures, E.; Clement, M.; Thomas, O. Impacts of climate change on surface water quality in relation to drinking water production. *Environ. Int.* **2009**, *35*, 1225–1233. [CrossRef] [PubMed]
20. UNICEF. Africa to Drastically Accelerate Progress on Water, Sanitation and Hygiene—Report. Available online: https://www.unicef.org/media/117731/file/Press%20Release.pdf (accessed on 22 March 2022).
21. Coates, S.J.; Enbiale, W.; Davis, M.D.P.; Andersen, L.K. The effects of climate change on human health in Africa, a dermatologic perspective: A report from the International Society of Dermatology Climate Change Committee. *Int. J. Dermatol.* **2020**, *59*, 265–278. [CrossRef]
22. Sunga, L.S. Does climate change kill people in Darfur? *J. Hum. Rights Environ.* **2011**, *2*, 64–85. [CrossRef]
23. Burke, M.B.; Miguel, E.; Satyanath, S.; Dykema, J.A.; Lobell, D.B. Warming increases the risk of civil war in Africa. *Proc. Natl. Acad. Sci. USA* **2009**, *106*, 20670–20674. [CrossRef]
24. Nordås, R.; Gleditsch, N.P. Climate Change and Conflict. In *Competition and Conflicts on Resource Use*; Springer International Publishing: Cham, Switzerland, 2015; pp. 21–38. [CrossRef]
25. Scheffran, J.; Ide, T.; Schilling, J. Violent climate or climate of violence? Concepts and relations with focus on Kenya and Sudan. *Int. J. Hum. Rights* **2014**, *18*, 369–390. [CrossRef]
26. Maystadt, J.-F.; Calderone, M.; You, L. Local warming and violent conflict in North and South Sudan. *J. Econ. Geogr.* **2015**, *15*, 649–671. [CrossRef]
27. Olsson, O. Climate Change and Market Collapse: A Model Applied to Darfur. *Games* **2016**, *7*, 9. [CrossRef]
28. De Juan, A. Long-term environmental change and geographical patterns of violence in Darfur, 2003–2005. *Political Geogr.* **2015**, *45*, 22–33. [CrossRef]
29. Koubi, V. Climate Change and Conflict. *Annu. Rev. Political Sci.* **2019**, *22*, 343–360. [CrossRef]
30. Mazo, J. Chapter Three: Darfur: The First Modern Climate-Change Conflict. *Adelphi Pap.* **2009**, *49*, 73–86. [CrossRef]
31. Buhaug, H.; A Benjaminsen, T.; Sjaastad, E.; Theisen, O.M. Climate variability, food production shocks, and violent conflict in Sub-Saharan Africa. *Environ. Res. Lett.* **2015**, *10*, 125015. [CrossRef]
32. Owusu, P.A.; Asumadu-Sarkodie, S. A review of renewable energy sources, sustainability issues and climate change mitigation. *Cogent Eng.* **2016**, *3*, 1167990. [CrossRef]
33. Aslam, A.; Coelli, F.; Eugster, J.; Ho, G.; Juamotte, F.; Buitron, O.C.; Piazza, R. Chapter 4: Is Productivity Growth Shared in a Global Economy? In World Economic Outlook (pp. 1–42). 2018. Available online: https://www.imf.org/en/Publications/WEO/Issues/2018/03/20/world-economic-outlook--2018#Chapter%204 (accessed on 10 February 2024).

34. Konstantinos, K. Introducing Microgrids & Local Energy Communities. Available online: https://www.incite-itn.eu/blog/introducing-microgrids-local-energy-communities/ (accessed on 4 June 2023).
35. Nicolli, F.; Vona, F. Energy market liberalization and renewable energy policies in OECD countries. *Energy Policy* **2019**, *128*, 853–867. [CrossRef]
36. Necoechea-Porras, P.D.; López, A.; Salazar-Elena, J.C. Deregulation in the Energy Sector and Its Economic Effects on the Power Sector: A Literature Review. *Sustainability* **2021**, *13*, 3429. [CrossRef]
37. Nosakhale, O.S.; Mwaniki, C.; Akorede, M.F. Optimal Sizing and Analysis of a Hybrid Energy System for a Community Microgrid in Nigeria. *J. Eng. Appl. Sci.* **2019**, *14*, 8769–8778. [CrossRef]
38. Hirsch, A.; Parag, Y.; Guerrero, J. Microgrids: A review of technologies, key drivers, and outstanding issues. *Renew. Sustain. Energy Rev.* **2018**, *90*, 402–411. [CrossRef]
39. Roosa, S.A. Community and Local Microgrids. Taylor & Francis Group, 2020; pp. 141–156. Available online: https://www.taylorfrancis.com/books/edit/10.1201/9781003082408/fundamentals-microgrids-stephen-roosa?refId=f5cee991-6551-4739-b073-97dcff28af42&context=ubx (accessed on 10 February 2024).
40. Warneryd, M.; Håkansson, M.; Karltorp, K. Unpacking the complexity of community microgrids: A review of institutions' roles for development of microgrids. *Renew. Sustain. Energy Rev.* **2020**, *121*, 109690. [CrossRef]
41. Trivedi, R.; Patra, S.; Sidqi, Y.; Bowler, B.; Zimmermann, F.; Deconinck, G.; Papaemmanouil, A.; Khadem, S. Community-Based Microgrids: Literature Review and Pathways to Decarbonise the Local Electricity Network. *Energies* **2022**, *15*, 918. [CrossRef]
42. Kojonsaari, A.-R.; Palm, J. Distributed Energy Systems and Energy Communities Under Negotiation. *Technol. Econ. Smart Grids Sustain. Energy* **2021**, *6*, 17. [CrossRef]
43. Karthikeyan, R.; Parvathy, A.K.; Priyadarshini, S. Community Energy Sharing in a Microgrid Architecture with Energy Storage and Renewable Energy Support. *IOP Conf. Ser. Earth Environ. Sci.* **2020**, *573*, 012023. [CrossRef]
44. Gui, E.M.; Diesendorf, M.; MacGill, I. Distributed energy infrastructure paradigm: Community microgrids in a new institutional economics context. *Renew. Sustain. Energy Rev.* **2017**, *72*, 1355–1365. [CrossRef]
45. Warneryd, M.; Karltorp, K. Microgrid communities: Disclosing the path to future system-active communities. *Sustain. Futures* **2022**, *4*, 100079. [CrossRef]
46. Scott, N. Microgrids: A Guide to Their Issues and Value. 2016. Available online: https://www.hie.co.uk/media/5957/a-guide-to-microgrids.pdf (accessed on 10 January 2024).
47. Gorjian, S.; Ebadi, H.; Jathar, L.D.; Savoldi, L. Solar energy for sustainable food and agriculture: Development, barriers, and policies. In *Solar Energy Advancements in Agriculture and Food Production System*, 1st ed.; Gorjian, S., Campana, P.E., Eds.; Elsevier: Amsterdam, The Netherlands, 2022; pp. 1–29.
48. van de Ven, D.-J.; Capellan-Peréz, I.; Arto, I.; Cazcarro, I.; de Castro, C.; Patel, P.; Gonzalez-Eguino, M. The potential land requirements and related land use change emissions of solar energy. *Sci. Rep.* **2021**, *11*, 2907. [CrossRef] [PubMed]
49. Toledo, C.; Scognamiglio, A. Agrivoltaic Systems Design and Assessment: A Critical Review, and a Descriptive Model towards a Sustainable Landscape Vision (Three-Dimensional Agrivoltaic Patterns). *Sustainability* **2021**, *13*, 6871. [CrossRef]
50. Agostini, A.; Colauzzi, M.; Amaducci, S. Innovative agrivoltaic systems to produce sustainable energy: An economic and environmental assessment. *Appl. Energy* **2020**, *281*, 116102. [CrossRef]
51. Sreekar, V.S.; Gaikwad, N.A.; Sathe, T. A Case Study on Agrovoltaic: Technology for Rural Infrastructure Development. In *Infrastructure Development—Theory, Practice and Policy—Sustainability and Resilience*; Gangwar, R., Agarwalla, A., Sreekumar, S., Eds.; Routledge: London, UK, 2023; pp. 45–51. [CrossRef]
52. Campana, P.E.; Stridh, B.; Amaducci, S.; Colauzzi, M. Optimisation of vertically mounted agrivoltaic systems. *J. Clean. Prod.* **2021**, *325*, 129091. [CrossRef]
53. Weselek, A.; Ehmann, A.; Zikeli, S.; Lewandowski, I.; Schindele, S.; Högy, P. Agrophotovoltaic systems: Applications, challenges, and opportunities. A review. *Agron. Sustain. Dev.* **2019**, *39*, 35. [CrossRef]
54. Jain, P.; Raina, G.; Sinha, S.; Malik, P.; Mathur, S. Agrovoltaics: Step towards sustainable energy-food combination. *Bioresour. Technol. Rep.* **2021**, *15*, 100766. [CrossRef]
55. Dinesh, H.; Pearce, J.M. The potential of agrivoltaic systems. *Renew. Sustain. Energy Rev.* **2016**, *54*, 299–308. [CrossRef]
56. Trommsdorff, M.; Kang, J.; Reise, C.; Schindele, S.; Bopp, G.; Ehmann, A.; Weselek, A.; Högy, P.; Obergfell, T. Combining food and energy production: Design of an agrivoltaic system applied in arable and vegetable farming in Germany. *Renew. Sustain. Energy Rev.* **2021**, *140*, 110694. [CrossRef]
57. Giri, N.C.; Mohanty, R.C. Design of agrivoltaic system to optimize land use for clean energy-food production: A socio-economic and environmental assessment. *Clean Technol. Environ. Policy* **2022**, *24*, 2595–2606. [CrossRef]
58. Olabi, A.G.; Wilberforce, T.; Abdelkareem, M.A.; Ramadan, M. Critical Review of Flywheel Energy Storage System. *Energies* **2021**, *14*, 2159. [CrossRef]
59. Okou, R.; Sebitosi, A.; Pillay, P. Flywheel rotor manufacture for rural energy storage in sub-Saharan Africa. *Energy* **2011**, *36*, 6138–6145. [CrossRef]
60. Pullen, K.R. The Status and Future of Flywheel Energy Storage. *Joule* **2019**, *3*, 1394–1399. [CrossRef]
61. Hebner, R.; Beno, J.; Walls, A. Flywheel batteries come around again. *IEEE Spectr.* **2002**, *39*, 46–51. [CrossRef]
62. Esparcia, E.A.; Castro, M.T.; Buendia, R.E.; Ocon, J.D. Long-Discharge Flywheel Versus Battery Energy Storage for Microgrids: A Techno-Economic Comparison. *Chem. Eng. Trans.* **2019**, *76*, 949–954. [CrossRef]

63. Esparcia, E.A.; Castro, M.T.; Odulio, C.M.F.; Ocon, J.D. A stochastic techno-economic comparison of generation-integrated long duration flywheel, lithium-ion battery, and lead-acid battery energy storage technologies for isolated microgrid applications. *J. Energy Storage* **2022**, *52*, 104681. [CrossRef]
64. Mousavi, G.S.M.; Faraji, F.; Majazi, A.; Al-Haddad, K. A comprehensive review of Flywheel Energy Storage System technology. *Renew. Sustain. Energy Rev.* **2017**, *67*, 477–490. [CrossRef]
65. Bamisile, O.; Zheng, Z.; Adun, H.; Cai, D.; Ting, N.; Huang, Q. Development and prospect of flywheel energy storage technology: A citespace-based visual analysis. *Energy Rep.* **2023**, *9*, 494–505. [CrossRef]
66. Amiryar, M.E.; Pullen, K.R. A Review of Flywheel Energy Storage System Technologies and Their Applications. *Appl. Sci.* **2017**, *7*, 286. [CrossRef]
67. Choudhury, S. Flywheel energy storage systems: A critical review on technologies, applications, and future prospects. *Int. Trans. Electr. Energy Syst.* **2021**, *31*, e13024. [CrossRef]
68. Faisal, M.; Hannan, M.A.; Ker, P.J.; Hussain, A.; Mansor, M.B.; Blaabjerg, F. Review of Energy Storage System Technologies in Microgrid Applications: Issues and Challenges. *IEEE Access* **2018**, *6*, 35143–35164. [CrossRef]
69. Palizban, O.; Kauhaniemi, K. Energy storage systems in modern grids—Matrix of technologies and applications. *J. Energy Storage* **2016**, *6*, 248–259. [CrossRef]
70. Kikusato, H.; Ustun, T.S.; Suzuki, M.; Sugahara, S.; Hashimoto, J.; Otani, K.; Ikeda, N.; Komuro, I.; Yokoi, H.; Takahashi, K. Flywheel energy storage system based microgrid controller design and PHIL testing. *Energy Rep.* **2022**, *8*, 470–475. [CrossRef]
71. Arani, A.K.; Karami, H.; Gharehpetian, G.; Hejazi, M. Review of Flywheel Energy Storage Systems structures and applications in power systems and microgrids. *Renew. Sustain. Energy Rev.* **2017**, *69*, 9–18. [CrossRef]
72. Li, X.; Palazzolo, A. A review of flywheel energy storage systems: State of the art and opportunities. *J. Energy Storage* **2022**, *46*, 103576. [CrossRef]
73. Amber Kinetic. The Industry's Only Long-Duration Kinetic Energy Storage System (KESS)—Enabling Highly Efficient Industrial and Commercial Applications. Available online: https://www.amberkinetics.com/wp-content/uploads/2020/05/Amber-Kinetics-DataSheet.pdf (accessed on 10 January 2024).
74. Jiangmen Greenfall Water Treatment Technology Co., Ltd. Sea Water Treatment Equipment/Seawater Desalination System. Available online: https://jmglf.en.alibaba.com/index.html?spm=a2700.details.0.0.5dd95a06f633ev&from=detail&productId= (accessed on 10 December 2023).
75. Alkaisi, A.; Mossad, R.; Sharifian-Barforoush, A. A Review of the Water Desalination Systems Integrated with Renewable Energy. *Energy Procedia* **2017**, *110*, 268–274. [CrossRef]
76. Boden, K.; Subban, C. A Road Map for Small Scale Desalination: An Overview of Existing and Emerging Technology Solutions for Cost-Efficient and Low-Energy Desalination in South and Southeast Asia. 2018. Available online: https://policy-practice.oxfam.org/resources/a-desalination-road-map-for-asia-an-overview-of-existing-and-emerging-desalinat-620448/ (accessed on 10 January 2024).
77. Liponi, A.; Tempesti, C.; Baccioli, A.; Ferrari, L. Small-Scale Desalination Plant Driven by Solar Energy for Isolated Communities. *Energies* **2020**, *13*, 3864. [CrossRef]
78. Wang, J.; Huo, E. Opportunities and Challenges of Seawater Desalination Technology. *Front. Energy Res.* **2022**, *10*, 960537. [CrossRef]
79. Cosín, C. The Evolution of Rates in Desalination (Part I). Available online: https://smartwatermagazine.com/blogs/carlos-cosin/evolution-rates-desalination-part-i (accessed on 4 June 2023).
80. Antonyan, M. Energy Footprint of Water Desalination. Master's Thesis, University of Twente, Enschede, The Netherlands, 2019.
81. Gorjian, S.; Ghobadian, B.; Ebadi, H.; Ketabchi, F.; Khanmohammadi, S. Chapter 8—Applications of solar PV systems in desalination technologies. In *Photovoltaic Solar Energy Conversion: Technologies, Applications and Environmental Impacts*; Gorjian, S., Shukla, A., Eds.; Academic Press: Cambridge, MA, USA, 2020; pp. 237–275. [CrossRef]
82. Mansour, T.M.; Ismail, T.M.; Ramzy, K.; El-Salam, M.A. Energy recovery system in small reverse osmosis desalination plant: Experimental and theoretical investigations. *Alex. Eng. J.* **2020**, *59*, 3741–3753. [CrossRef]
83. Cipollina, A.; Tzen, E.; Subiela, V.; Papapetrou, M.; Koschikowski, J.; Schwantes, R.; Wieghaus, M.; Zaragoza, G. Renewable energy desalination: Performance analysis and operating data of existing RES desalination plants. *Desalination Water Treat.* **2015**, *55*, 3120–3140.
84. Andrew, B. No Batteries Needed: Can Low-Cost Solar Desalination System 'Green' Namibia's Desert Coast? No Batteries Needed: Can Low-Cost Solar Desalination System "Green" Namibia's Desert Coast? Available online: https://solarmagazine.com/no-batteries-needed-low-cost-solar-desalination-system-green-namibia-desert-coast/ (accessed on 4 June 2023).
85. Shatat, M.; Worall, M.; Riffat, S. Economic study for an affordable small scale solar water desalination system in remote and semi-arid region. *Renew. Sustain. Energy Rev.* **2013**, *25*, 543–551. [CrossRef]
86. Kyriakarakos, G.; Papadakis, G. Is Small Scale Desalination Coupled with Renewable Energy a Cost-Effective Solution? *Appl. Sci.* **2021**, *11*, 5419. [CrossRef]
87. Mohammed, R.A.; Alkhafaja, R.J.M. Review: Water Desalination Cost. University of Thi-Qar Journal for Engineering Science. Available online: https://www.researchgate.net/publication/367450886_Review_Water_Desalination_Cost (accessed on 17 October 2023).

88. Lattemann, S.; Kennedy, M.D.; Schippers, J.C.; Amy, G. Chapter 2 Global Desalination Situation. *Sustain. Sci. Eng.* **2010**, *2*, 7–39. [CrossRef]
89. Sichuan Zhuoyue Water Treatment Equipment Co., Ltd. Small Desalination Plant RO Water Plant Price For Drinking ZYCJ. Available online: https://zhuoyuescl.en.alibaba.com/search/product?SearchText=Desalination%20Plant%20RO (accessed on 16 January 2024).
90. Ghermandi, A.; Messalem, R. Solar-driven desalination with reverse osmosis: The state of the art. *Desalination Water Treat.* **2009**, *7*, 285–296. [CrossRef]
91. Environmental Investment Fund of Namibia. Press Release on Signing of Moa Mawlr & EIF on Water Softening Project. Available online: https://www.eif.org.na/post/press-release-on-signing-of-moa-mawlr-eif-on-water-softening-project (accessed on 15 December 2023).
92. Hoffmann, J.; Dall, E. Integrating desalination with concentrating solar thermal power: A Namibian case study. *Renew. Energy* **2018**, *115*, 423–432. [CrossRef]
93. Neumeier, S. Social innovation in rural development: Identifying the key factors of success. *Geogr. J.* **2016**, *183*, 34–46. [CrossRef]
94. Kusumastuti, R.; Silalahi, M.; Sambodo, M.T.; Juwono, V. Understanding rural context in the social innovation knowledge structure and its sector implementations. *Manag. Rev. Q.* **2022**, *73*, 1873–1901. [CrossRef]
95. Hoppe, T.; De Vries, G. Social Innovation and Energy Transition. *Sustainability* **2018**, *11*, 141. [CrossRef]
96. Berzin, S.C.; Pitt-Catsouphes, M.; Peterson, C. Role of State-Level Governments in Fostering Social Innovation. *J. Policy Pract.* **2014**, *13*, 135–155. [CrossRef]
97. Steinerowski, A.A.; Steinerowska-Streb, I. Can social enterprise contribute to creating sustainable rural communities? Using the lens of structure theory to analyse the emergence of rural social enterprise. *Local Econ.* **2012**, *27*, 167–182. [CrossRef]
98. Moulaert, F.; MacCallum, D.; Hilier, J. Social Innovation: Institution, Precept, Concept, Theory and Practice. In *The International Handbook on Social Innovation*; 2014; pp. 13–25, ISBN 978 1 78254 559 0. Available online: https://www.e-elgar.com/shop/gbp/the-international-handbook-on-social-innovation-9781782545590.html (accessed on 22 December 2023).
99. McClenaghan, P. Social Capital: Exploring the theoretical foundations of community development education. *Br. Educ. Res. J.* **2020**, *26*, 565–582. [CrossRef]
100. Selvakkumaran, S.; Ahlgren, E.O. Impacts of social innovation on local energy transitions: Diffusion of solar PV and alternative fuel vehicles in Sweden. *Glob. Transit.* **2020**, *2*, 98–115. [CrossRef]
101. Chatfield, A.T.; Reddick, C.G. Smart City Implementation Through Shared Vision of Social Innovation for Environmental Sustainability. *Soc. Sci. Comput. Rev.* **2016**, *34*, 757–773. [CrossRef]
102. Dall-Orsoletta, A.; Cunha, J.; Araújo, M.; Ferreira, P. A systematic review of social innovation and community energy transitions. *Energy Res. Soc. Sci.* **2022**, *88*, 102625. [CrossRef]
103. Steiner, A.; Calò, F.; Shucksmith, M. Rurality and social innovation processes and outcomes: A realist evaluation of rural social enterprise activities. *J. Rural Stud.* **2023**, *99*, 284–292. [CrossRef] [PubMed]
104. Pilloni, M.; Hamed, T.A.; Pilloni, M.; Hamed, T.A. Small-Size Biogas Technology Applications for Rural Areas in the Context of Developing Countries. In *Anaerobic Digestion in Built Environments*; IntechOpen: London, UK, 2021; ISBN 978-1-83969-224-6. [CrossRef]
105. Spitzer, H.; Twikirize, J. Social innovations in rural communities in Africa's Great Lakes region. A social work perspective. *J. Rural Stud.* **2021**, *99*, 262–271. [CrossRef]
106. Berka, A.L.; MacArthur, J.L.; Gonnelli, C. Explaining inclusivity in energy transitions: Local and community energy in Aotearoa New Zealand. *Environ. Innov. Soc. Transit.* **2020**, *34*, 165–182. [CrossRef]
107. The World Factbook. Namibia—The World Factbook. Available online: https://www.cia.gov/the-world-factbook/countries/namibia/summaries (accessed on 4 June 2023).
108. Woldometer. Namibia Population (2023)—Worldometer. Available online: https://www.worldometers.info/world-population/namibia-population/ (accessed on 4 June 2023).
109. The World Bank. GDP Growth (Annual %)—Namibia | Data. Available online: https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=NA (accessed on 4 June 2023).
110. Wilhelm, M. Impact of Climate Change in Namibia—A Case Study of Omusati Region. Polytechnic of Namibia, Windhoek, Namibia. 2012. Available online: https://ir.nust.na/server/api/core/bitstreams/00d6195c-a7af-4a86-926c-05b60193d932/content (accessed on 16 February 2024).
111. World Bank. The World Bank in Namibia. Available online: https://www.worldbank.org/en/country/namibia/overview (accessed on 4 June 2023).
112. Forrest, J.B. Water policy and environmental sustainability: The case of post-colonial Namibia. *Public Adm. Dev.* **2001**, *21*, 393–400. [CrossRef]
113. Hossain, F.; Helao, T. Local governance and water resource management: Experiences from Northern Namibia. *Public Adm. Dev.* **2008**, *28*, 200–211. [CrossRef]
114. Montle, B.P.; Teweldemedhin, M.Y. Assessment of farmers perceptions and the economic impact of climate change in Namibia: Case study on small-scale irrigation farmers (SSIFs) of Ndonga Linena irrigation project. *J. Dev. Agric. Econ.* **2014**, *6*, 443–454. [CrossRef]

115. Chisanga, C.B.; Mubanga, K.H.; Sichigabula, H.; Banda, K.; Muchanga, M.; Ncube, L.; van Niekerk, H.J.; Zhao, B.; Mkonde, A.A.; Rasmeni, S.K. Modelling climatic trends for the Zambezi and Orange River Basins: Implications on water security. *J. Water Clim. Chang.* **2022**, *13*, 1275–1296. [CrossRef]
116. John, G. Extreme Measures Are Needed: Namibia's Battle with Drought Comes to Its Cities. *The Guardian*, 13 July 2016. Available online: https://www.theguardian.com/sustainable-business/2016/jul/13/namibia-drought-coca-cola-meat-construction-industry-water-crisis-climate-change(accessed on 4 June 2023).
117. Inman, E.N.; Hobbs, R.J.; Tsvuura, Z. No safety net in the face of climate change: The case of pastoralists in Kunene Region, Namibia. *PLoS ONE* **2020**, *15*, e0238982. [CrossRef] [PubMed]
118. Liu, X.; Zhou, J. Assessment of the Continuous Extreme Drought Events in Namibia during the Last Decade. *Water* **2021**, *13*, 2942. [CrossRef]
119. Amupolo, A.; Nambundunga, S.; Chowdhury, D.S.P.; Grün, G. Techno-Economic Feasibility of Off-Grid Renewable Energy Electrification Schemes: A Case Study of an Informal Settlement in Namibia. *Energies* **2022**, *15*, 4235. [CrossRef]
120. Amesho, K.T.; Edoun, E.I. Financing Renewable Energy in Namibia—A Fundamental Key Challenge to the Sustainable Development Goal 7: Ensuring Access to Affordable, Reliable, Sustainable and Modern Energy for All. *Int. J. Energy Econ. Policy* **2019**, *9*, 442–450. [CrossRef]
121. US Department of Commerce. Namibia—Energy. Available online: https://www.trade.gov/country-commercial-guides/namibia-energy (accessed on 23 August 2023).
122. Database Earth. Hydro Power Plants in NA Namibia (Map) | Database Earth. Available online: https://database.earth/energy/power-plants/hydro-power/namibia (accessed on 21 August 2023).
123. Permanent Mission of the Republic of Namibia to the United Nations. Chapter 12—Regional And Local Government. Available online: https://www.un.int/namibia/namibia/chapter-12-regional-and-local-government (accessed on 4 June 2023).
124. Brinkhoff, T. City Population. Available online: http://citypopulation.de/en/namibia/cities/ (accessed on 4 June 2023).
125. NamWater. Bukalo water supply scheme—Environmental Management Plan. Windhoek, Namibia, April 2021. Available online: http://the-eis.com/elibrary/sites/default/files/downloads/literature/2554_EMP_Bukalo%20Water%20Supply%20Scheme%20and%20maintenance%20to%20infrastructure_Zambezi%20Region.pdf (accessed on 16 January 2024).
126. Bukalo, Namibia—Google Map. Available online: https://www.google.com/maps/d/u/1/edit?mid=1rLKjsFY7FxdH8Lk2VXdCSOPnL652VXQ&usp=sharing (accessed on 21 March 2024).
127. Matthews, J.R. Understanding Indigenous Innovation in Rural West Africa: Challenges to Diffusion of Innovations Theory and Current Social Innovation Practice. *J. Hum. Dev. Capab.* **2017**, *18*, 223–238. [CrossRef]
128. International Labor Organization. Social and Solidarity Economy: Social Innovation Catalyst in Africa? 2022. Available online: https://www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/---coop/documents/publication/wcms_856431.pdf (accessed on 18 December 2023).
129. Jauhiainen, J.S.; Hooli, L. Indigenous Knowledge and Developing Countries' Innovation Systems: The Case of Namibia. *Int. J. Innov. Stud.* **2017**, *1*, 89–106. [CrossRef]
130. Russmann, N. The Harambee Prosperity Plan II (2021–2025). Available online: https://www.kas.de/documents/279052/279101/Der+Harambee+Prosperity+Plan+II.pdf/7691d89b-2e35-20e9-86d4-cd9779a40f61?version=1.0&t=1624954438275 (accessed on 21 December 2023).
131. Hooli, L.J.; Jauhiainen, J.S. *Development Aid 2.0—Towards Innovation-Centric Development Co-Operation: The Case of Finland in Southern Africa*; Cunningham, P., Cunningham, M., Eds.; Windhoek, Namibia, 2017; pp. 1–9. Available online: https://www.researchgate.net/profile/Lauri-Hooli/publication/316035261_Development_Aid_20_-_Towards_Innovation-Centric_Development_Co-operation_The_Case_of_Finland_in_Southern_Africa/links/59b2a670aca2728472d5056b/Development-Aid-20-Towards-Innovation-Centric-Development-Co-operation-The-Case-of-Finland-in-Southern-Africa.pdf (accessed on 19 January 2024).
132. Wach, D.; Kruse, P.; Costa, S.; Antonio Moriano, J. Exploring Social and Commercial Entrepreneurial Intentions from Theory of Planned Behaviour Perspective: A Cross-Country Study among Namibian and German Students. *J. Soc. Entrep.* **2023**, *14*, 226–247. [CrossRef]
133. Cornell University; INSEAD; WIPO. The Global Innovation Index 2015: Effective Innovation Policies for Development. Fontainebleau, Ithaca, and Geneva. 2015. Available online: https://www.wipo.int/edocs/pubdocs/en/wipo_gii_2015.pdf (accessed on 16 November 2023).
134. Diergaardt, G. National Experience on Water Statistics. Windhoek. December 2019. Available online: https://unstats.un.org/unsd/envstats/meetings/2019-Namibia/documents/Session%205.1.1%20Water%20Statistics%20Namibia.pdf (accessed on 16 December 2023).
135. Commonwealth Local Government Forum. Namibia. Available online: https://www.clgf.org.uk/default/assets/File/Country_profiles/Namibia.pdf (accessed on 16 December 2023).
136. Okiana—Water Solutions. *Water Treatment System (1 m3/h) Description*; Okiana: Haifa, Israel, 2020; pp. 1–9.
137. STATISTA. Average Installed Cost for Solar Photovoltaics Worldwide from 2010 to 2022 (in U.S. Dollars Per Kilowatt). Available online: https://www.statista.com/statistics/809796/global-solar-power-installation-cost-per-kilowatt/ (accessed on 4 June 2023).
138. Global Solar Atlas. Namibia. Available online: https://globalsolaratlas.info/map?c=6.402648,-12.480469,3&s=-23.241346,13.710938&m=site (accessed on 4 June 2023).

139. Uhlendahl, T.; Ziegelmayer, D.; Wienecke, A.; Mawisa, M.L.; du Pisani, P. Water Consumption at Household Level in Windhoek, Namibia Survey about Water Consumption at Household Level in Different Areas of Windhoek Depending on Income Level and Water Access in 2010. 2010. Available online: https://freidok.uni-freiburg.de/dnb/download/7937 (accessed on 5 November 2023).
140. Trading Economics. Namibia Prime Lending Rate. Available online: https://tradingeconomics.com/namibia/lending-rate (accessed on 13 September 2023).
141. NamWater. Cost of Water Supply. Available online: https://www.namwater.com.na/index.php/about-us?start=7 (accessed on 4 June 2023).
142. FAO. Chapter 6: Investment Decisions—Capital Budgeting. Available online: https://www.fao.org/3/w4343e/w4343e07.htm (accessed on 17 March 2024).
143. ZOOZ. Proprietary Flywheel Technology for EV Charging. Available online: https://www.zoozpower.com/flywheel-technology-ev/#:~:text=The%20flywheel%20passes%20through%203%20main%20phases:&text=Deceleration%20%E2%80%93%20The%20integrated%20motor/generator,system%20through%20the%20local%20grid (accessed on 16 February 2024).