ECONOMIST IMPACT

Powering progress:

measuring the benefits of investing in energy resilience for healthcare, education and water

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Contents

About the report

This report, supported by UNICEF, presents findings from research conducted by Economist Impact to assess the social and economic costs and benefits of investing in energy resilience in three priority sectors: healthcare, education and water. The findings are based on insights gathered from a literature review, expert interviews and three sector-specific custom models developed by Economist Impact. Economist Impact bears sole responsibility for the content of this report. The findings and views expressed do not necessarily reflect the views of the sponsor.

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Research objectives and definitions

This research aims to analyse the economic and community benefits of investing in reliable energy access and energy resilience (see definitions in the box below) in three priority social sectors: healthcare, education and water. The analysis is based on three quantitative sector-specific cost-benefit models in two pilot countries–Tanzania and Pakistan–and a qualitative discussion of broader community benefits and barriers to greater investment in the provision of reliable energy (see detailed methodology for each model in the Appendix). It is important to note that the quantitative cost-benefit analysis is agnostic to the type of investment, but our broader analysis stresses the need for these to be targeted towards clean and climate-resilient solutions. The cost-benefit models for each sector have been developed separately, with differing assumptions and parameters. Therefore, the results from each model should be interpreted separately and not in comparison with each other.

This analysis focuses predominantly on energy access and reliability, but it should be noted that the accessed energy needs to be utilised by beneficiaries in practice to fully realise the potential benefits. This might require additional interventions, such as equipping staff with the necessary skills to use and maintain infrastructure, implementing appropriate rules and governance structures within institutions, and building trust and awareness among local communities so they access and utilise the new or additional services.

Defining energy resilience

According to the Intergovernmental Panel on Climate Change (IPCC), an energy system is a system that comprises all components related to the production, conversion, delivery, and use of energy.[1] While there is no clear consensus on its definition in the literature,[2] within this analysis we define resilient energy systems as **systems that are able to withstand and recover quickly from any unanticipated shocks and long-term changes while maintaining essential levels of service, access and functionality**.[3] Energy resilience is a function of three key attributes:

1. **Accessibility:** captures whether the users (households or institutions) are connected to a power source either through a grid or an off-grid solution.[4] The most commonly used indicator for accessibility is the percentage of the population and/or businesses and institutions with access to electricity, or electrification rates. Access is the bedrock of energy resilience, as the first step of assessing the resilience of an energy system is to understand which groups and institutions are not being served in the first place.

2. **Reliability:** captures whether users have continuous and interrupted access to power supply.[5] The most commonly used indicator is the average number and duration of power outages, in hours, that establishments experience in a typical month. Energy reliability—the ability of a power system to withstand instability, uncontrolled events, cascading failures or the unanticipated loss of system components[6]—is a key part of energy resilience, reflecting the state and recovery capacity of physical infrastructure. Unreliable power supply, which makes providing essential services a struggle, is especially vulnerable to additional stresses and shocks.[7]

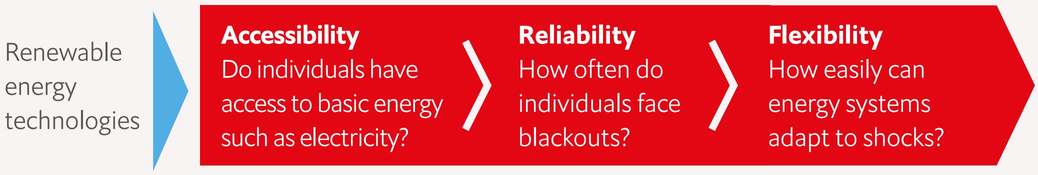
3. **Flexibility:** captures the ability of the system to use resources like storage, demand-side management and responsive generation to manage fluctuating generation and consumption of power, especially in response to shocks.[8] This is essential in contributing towards energy resilience, especially as climate change shocks, such as extreme weather events, become more pervasive. Due to the lack of comprehensive empirical data, this element of energy resilience is not captured in our quantitative modelling analysis.

While these three components form the cornerstone of energy resilience, there are different tools that can be used to improve each component. Renewable energy solutions can play an important role in improving each of these attributes while contributing to communities' broader climate resilience.[9] Decentralised renewable energy systems can be distributed at a local level, making them less vulnerable to climate-related failures of transmission infrastructure and insulated from disruptions to the wider grid.[10] Renewable energy sources are also less exposed to global market fluctuations, unlike fossil fuels, which are subject to vulnerable supply chains and price shocks.[11] Besides energy generation, energy-efficient appliances, heating, ventilation and air conditioning systems, and backup and storage systems play a vital role in developing energy resilience.

In our cost-benefit models, we have derived the costs of investment in energy resilience by assessing the electricity needs for healthcare facilities, schools and water utilities, based on the proportion of facilities in the country that currently have unreliable or no electricity connection (see detailed methodology and definitions in the Appendix). Based on the least cost electrification estimates provided by the Global Electrification Platform database,[12] we calculated capital and operating expenditure requirements for the new on-grid and off-grid connections and backup connections needed for providing reliable electricity access for all facilities in the sector in the country.

Figure 1. The core factors of energy resilience

Energy resilience
Energy systems able to withstand and recover quickly from any unanticipated shocks, driven by three core factors:



Finally, **affordability** is a crucial consideration, particularly in developing countries. People facing **energy poverty** are forced to reduce or avoid energy consumption to a degree that negatively impacts their health and wellbeing, driven by affordability, insufficient disposable income, high energy expenditure and poor energy efficiency of homes.[13]

Executive summary

Last year was another record-breaking year, with July being the hottest month ever documented.[14] In November global temperatures momentarily reached 2°C above the pre-industrial average, a threshold that scientists have been warning will bring catastrophic impacts.[15,16] We are already witnessing some of these impacts. Extreme weather events have significantly affected every continent on the planet.[17] Besides the direct loss of life and livelihoods, these climate-driven impacts threaten the provision of essential social services, starting with energy. Energy systems that struggle to cope with and recover from shocks (such as extreme weather) risk causing knock-on effects in healthcare, education, and water, sanitation and hygiene (WASH)—imposing long-term social and economic costs on some of the most vulnerable communities in the world. Adapting energy systems to withstand and recover quickly from shocks while maintaining essential levels of service and functionality is a critical challenge. It is also an essential element of communities' path towards overall climate resilience, particularly in developing countries. But essential levels of energy provision must exist in the first place.

3.5 billion
people are estimated to be living without reliable power

745 million
people worldwide lacked basic access to electricity in 2023

In 2023 about 745 million people worldwide lacked basic access to electricity, including hundreds of millions of children.[18] This gap in access is most prevalent among vulnerable communities. Sub-Saharan Africa makes up more than 80% of this electricity access chasm, with developing parts of Asia making up almost 15%.[19] The real gap in ***adequate*** electricity access is even greater, with some 3.5 billion people estimated to be living without reliable power.[20] Access to affordable, reliable, sustainable and modern energy for all (SDG7) is crucial for people's wellbeing and quality of life. Those without electricity experience higher morbidity and mortality through exposure to inadequate indoor heating and cooling, and poor housing, water, and air conditions.[21] The lack of reliable power also leads to the financial burden of purchasing costly energy from alternative sources (like diesel generators) and creates poorer mental health, educational and economic outcomes.[22] Inadequate energy access by businesses undermines employment opportunities due to disruption to business activity, reduced productivity and potentially higher operational costs.[23] This is particularly damaging in low-income countries, where 75% of firms experience power outages.[24]

Reliable energy is essential for ensuring that key services can be delivered despite the damaging impacts of climate change—including healthcare, education and WASH. Reliable power is necessary for operating theatres, diagnostic equipment, cold storage for medicines and vaccines, heating and cooling systems in classrooms, water pumps and wastewater treatment plans, and many other pieces of equipment to function properly. The UN Sustainable Development Goals (SDGs) cannot be achieved without reliable electricity access for schools, healthcare facilities and water utilities.

One billion
people in LICs and LMICs were served by healthcare facilities with unreliable or no access to electricity between 2015 and 2022

Yet, an estimated one billion people in low- and middle-income countries, making up an eighth of the global population, were served by healthcare facilities with unreliable or no access to electricity between 2015 and 2022.[25] In 2022 over 186 million children globally attended primary schools that were not connected to any power supply.[26] In sub-Saharan Africa, this affected 68% of children.[27]

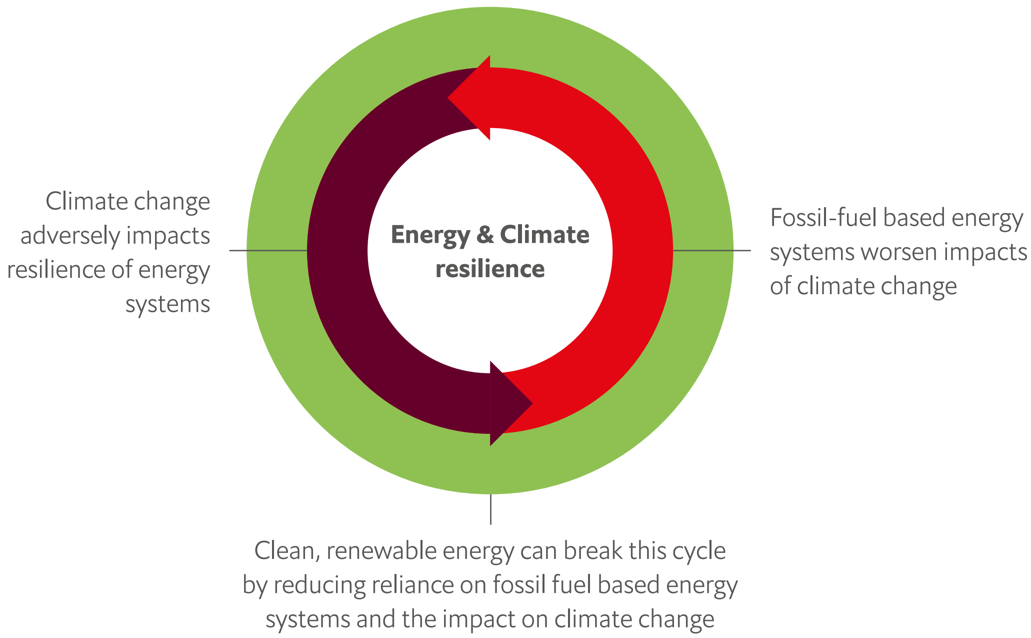
While improving the supply of reliable energy to these services is an essential component of increasing access and uptake, it is not the only one. Issues such as local conflict and violence, the scarcity of facilities such as hospitals and schools, household access to energy, and the general cost of attaining these services, for example, can all prevent uptake. Climate change is making

186 million children
attended primary schools that were not connected to any power supply around the world

it harder to deliver the reliable energy access that underpins such services. In recent years, some of the most notable disruptions to energy systems were due to extreme weather events or shocks related to climate change. For example, the 2022 Pakistan floods severely damaged the country's primary river system, responsible for 25% of its energy supply.[28] In Chile, the El Niño weather pattern caused severe drought and hampered hydroelectric power generation, which contributes 27% of the national electricity mix. To cover this hydroelectric deficit, the Chilean government had to pivot to importing oil and gas.[29] The impact of such natural events on energy systems, including reduced power usage, loss of livelihood and increased mortality, is estimated at US$120bn annually in low- and middle-income countries.[30] Prolonged hot or cold temperatures also cause a substantial increase in demand for heating, cooling, refrigeration, and energy-intensive supply of drinking and irrigation water.[31]

The kinds of energy systems that are most resilient to such challenges are often also marked by lower emissions. Investing in diversified and low-carbon energy sources and storage can support the capacity of local energy systems to withstand, recover and adapt to shocks and disruptions. Decarbonised grids and off-grid renewable solutions increase reliable electricity distribution[32] by making it more decentralised and removing dependence on fuel deliveries.[33] However, there are some considerations that need to be factored in. Each renewable technology comes with its own carbon footprint. Investments will need to factor in long-term operating and maintenance such that these technologies produce clean energy for long enough to offset their own emissions.[34]

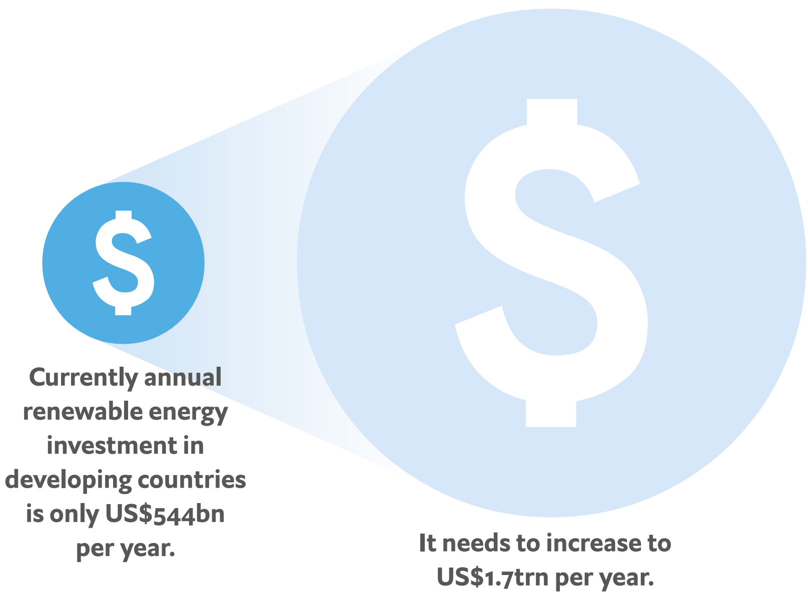
Figure 2. The climate change – energy resilience nexus



Source: Economist Impact (2024)

In some cases, this could take as little as four to eight months. Since the adoption of the Paris agreement in 2015, total investment in renewable energy has increased three-fold.[35] However, most of this was concentrated in developed countries.

Figure 3. Renewable energy investment needs in developing countries



Source: UNCTAD (2023)

In order to achieve the SDG targets by 2030 and contribute to greater energy resilience, renewable energy investment in developing countries needs to reach about US$1.7trn each year, up from only US$544bn currently.[36] Given the constraints on public resources in developing economies, greater private sector investment is needed.

To further understand this critical energy resilience investment gap and how to mobilise greater public and private resources, this Economist Impact report, supported by UNICEF, examines the economic and community benefits of initiatives aimed at alleviating energy poverty and bolstering energy resilience in three social sectors—healthcare, education and water. The findings draw from a blend of quantitative and qualitative evaluations of the economic gains and expenditure associated with investments in energy resilience, along with their impacts on local communities. To explore these payoffs, Economist Impact has developed three separate bespoke cost-benefit models for the healthcare, education and water sectors, focusing on two pilot countries: Pakistan and Tanzania.

Key findings:

1. Developing countries' energy systems are increasingly vulnerable to climate change-related disruptions and need greater investments to become resilient.

Investments in renewable energy—which can often enhance resilience—were four times lower in developing countries than in developed ones.[37] Based on our analysis, this imposes significant medium- and long-term social and economic costs, particularly for children and vulnerable communities.

2. Investing in resilient energy for healthcare, education and water systems in developing countries can deliver significant net benefits.

Our pilot country analysis of Pakistan and Tanzania found positive net-present value returns on investment in the electrification of services in all three sectors. We found that a US$1 investment in energy resilience could return between US$1.5 and US$3 through positive impacts on adult, infant and maternal mortality, immunisation rates, educational attainment, students' earnings, and water provision for households and agriculture. It is important to note that these estimates are conservative, suggesting that our analysis underestimates the true economic benefit of energy resilience investments and that, in reality, this is likely to be notably higher.

US$1 investment in energy resilience could return between US$1.5 and US$3

3. Resilient energy provision is essential to the availability of quality healthcare and could save millions of lives, particularly among children and mothers.

Better energy access and reliability improve health outcomes and are crucial for attaining universal healthcare (SDG3.8), yet one billion people globally still face unreliable or no electricity access in healthcare facilities.[38] Our analysis found that improved access to resilient energy in healthcare facilities could avert over

175,000 deaths could be averted through improved access to resilient energy in healthcare facilities in Pakistan

111,000 deaths could be averted through improved access to resilient energy in healthcare facilities in Tanzania

175,000 deaths in Pakistan and almost 111,000 deaths in Tanzania.[39] Alongside additional benefits from higher immunisation rates and a reduced burden of disease, this could contribute an estimated US$296m and US$360m to the economies of Pakistan and Tanzania respectively by 2044.[40]

4. Ensuring reliable energy access in schools could significantly increase students' educational outcomes and earnings in lower- and middle-income countries.

The lack of reliable energy access undermines the everyday experience of students and teachers alike, through reduced quality of learning (and teaching) environments, yet nearly 200 million children still attend schools without any electricity.[41,42] Based on our analysis, Pakistan and Tanzania could contribute some US$2.3bn and US$500m to their respective economies by 2040 thanks to decreased dropout rates and the higher future expected incomes of students attending electrified schools.

Pakistan and Tanzania could contribute some US$2.3bn and US$500m to their respective economies by 2040 thanks to energy resilience investments in schools

5. Improved energy reliability for accessing water could boost developing economies by increasing household savings and farms' productivity.

Failures in the energy system can disrupt the provision of essential water services to households and farmers. A lack of resilient energy supply negatively affects water quality, as seen in South Africa[43] and Taiwan,[44] resulting in higher mortality rates and disease incidence. In addition to the impact on municipal water services, interruptions in power supply have been shown to reduce agricultural output. Our analysis suggests that Tanzania and Pakistan could increase their respective economic output by US$5m and US$150m by 2030 through household savings and increased agricultural production.[45]

Tanzania and Pakistan could increase their respective economic output by US$5m and US$150m by 2030 through household savings and increased agricultural production

6. The need to invest in energy resilience is reflected in the cost of inaction: particularly the impact of climate change if no action is taken.

According to a hypothetical scenario in our analysis, failing to improve energy resilience for Tanzania's and Pakistan's healthcare, education and water sectors could lead to an additional loss of hundreds of millions of dollars through fewer essential facilities having access to energy, and more disruptions and blackouts. While these figures are indicative, they stress the need for urgent action to invest in energy systems that can withstand the impacts of climate change, including extreme weather events.

7. Public sector resources alone will be insufficient to achieve resilient energy for healthcare, water and education—the private sector needs to play a bigger role.

Trends in renewable energy financing are revealing, particularly since renewables can be a key component of bolstering energy resilience. Before renewables can be scaled up, there is a financing gap, equivalent to 60% of current global requirements, that will have to come from private sources.[46] While the cost of providing resilient energy for essential services is relatively small compared with the benefits, scaling up private investment in developing countries faces obstacles. These include inadequate regulatory and fiscal environments[47] and the perception of lower returns relative to alternative investments in more developed markets.[48] This gap in private investment is wider in social sectors such as healthcare, education and water owing to limited revenue generation opportunities. Mobilising private finance requires concerted efforts to overcome these obstacles and establish a virtuous cycle of energy investment, including policy to improve the enabling environment, and blended finance models that include de-risking from development banks.

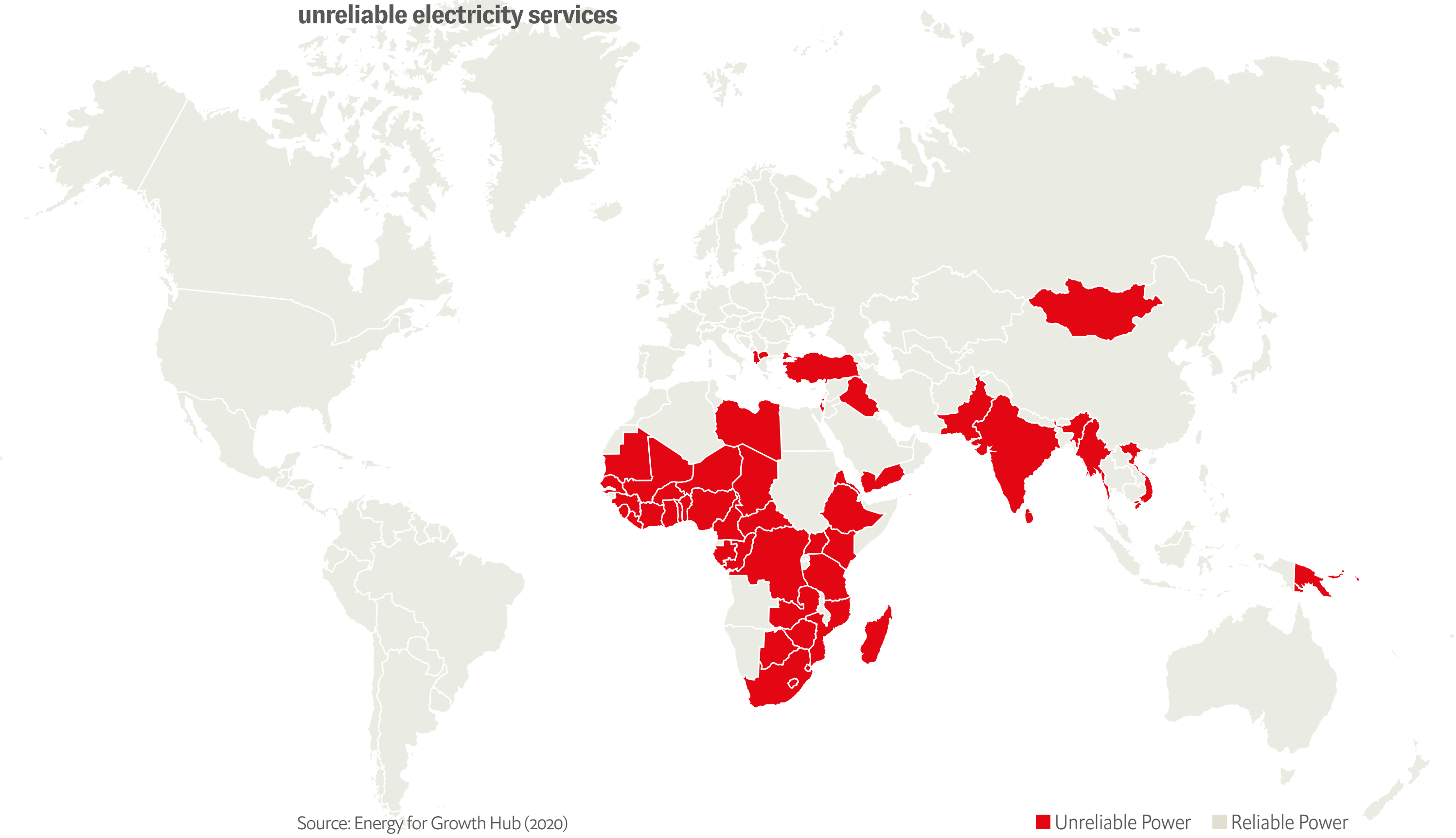
8. Scaled-up private sector investment should be targeted towards increasing resilience at the community level.

While it is essential to bridge the gap in resilient energy supply in developing countries, a just transition will also require investing in skills and capacity building, as well as empowering local communities.[49] Building sustainable local knowledge and capacity, ensuring energy affordability, and creating energy systems that can be sustained over the long term by local communities will be key.[50] This will involve encouraging collective responsibility where communities are well equipped to collectively tackle energy challenges and adopt clean technological solutions. Children and young people are the key beneficiaries of resilient energy systems, and will provide the future talent and skills to ensure the ongoing resilience of local communities.[51]

Introduction: the what, why and how of energy resilience

Energy resilience is a multifaceted problem. As a function of access, reliability and flexibility, system resiliency should ensure that people have **access** to **reliable** energy that is able to **respond to shocks** and maintain essential services. However, in developing countries these three components are falling behind. The International Energy Agency (IEA) estimates that 760 million people lack access to electricity, out of which 600 million live in sub-Saharan Africa.[52] The number of people who live without reliable energy, and who lack power in times of crisis, is many times larger. The Energy for Growth Hub, a think-tank, argues that a reasonably reliable supply constitutes no more than one power outage or one hour of outage per month over a year. With this threshold applied, the number of people living without reliable power is 3.5 billion, mostly concentrated in developing regions.[53] Taking into account the impact of occasional shocks, the number without resilient energy is higher still. This is seriously holding back progress towards SDG7, which aims to ensure affordable, reliable, sustainable and modern energy for all.

Figure 4. Map of countries with reliable and unreliable electricity services



Source: Energy for Growth Hub (2020)

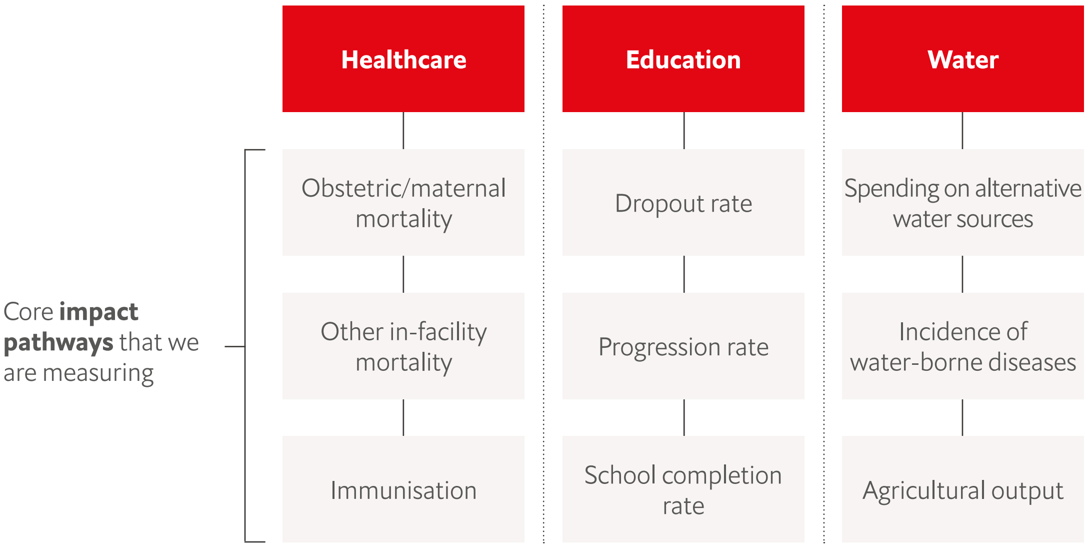
The increasingly visible impacts of climate change are making a bad situation worse. Climate change impacts energy systems by disrupting generation, transmission and distribution. For example, the ability of hydropower systems to generate electricity is compromised by lower levels of rainfall and increased risk of flooding. The IPCC estimates that hydropower generation in the Zambezi river basin in sub-Saharan Africa could fall by as much as 35% from current levels by 2050 as a result of lower rainfall and higher temperatures.[54] Those living in California in the second half of the 2010s had reliable access to power, but PG&E's antiquated equipment still lacked the resilience needed to face the devastating wildfires. Infrastructure in low-lying coastal regions around the world is at risk from rising sea levels. Climate change also alters demand for power: the IEA has stated that prolonged hot or cold temperatures have been shown to cause a substantial increase in electricity use for heating, cooling, refrigeration and supplying water for drinking and irrigation.[55] This creates a vicious cycle of energy vulnerability and highlights the urgent need for resilient energy solutions for mitigating climate-related risks, especially in developing countries.

Disrupted power supplies affect the provision of every sort of public service. It can interrupt surgeries; result in insufficient lighting, temperature control and internet access, ultimately impeding learning; and cause water-purification systems to fail. Across these sectors, children are some of the most adversely impacted. Without safe and reliable energy, children lack adequate learning environments, cannot access necessary health interventions such as vaccinations and may have to travel long distances to healthcare and education facilities with electricity. Poorer health and educational outcomes also have a direct impact on economic performance. Academic researchers estimated that a single storm in Sweden in 2005, which left some without power for almost three weeks, cost the economy 1% of annual GDP.[56] Similarly, in 2017 Hurricane Maria struck Puerto Rico, causing widespread power outages and significant damage, costing around US$73.4bn.[57]

The IEA argues that the construction of climate-resilient energy infrastructure overlaps with energy security and climate-change adaptation while aligning with the low-carbon transition. Further scaling of renewables will be an essential step towards energy resilience, since solar and wind energy is often less vulnerable to shocks. Diversifying energy sources contributes to energy security, which enhances the system's robustness against climate-driven disruptions.[58] Studies have found that electricity grids designed with renewables in mind—for instance, when rooftop solar panels and small wind turbines can feed back into the grid—increase the reliability of electricity distribution by increasing the number of sources and reducing the dependence on fuel deliveries.[59,60]

Importantly, investing in energy resilience is vital, but context matters. In order to reap the benefits of resilient energy for essential services, people need to be able to access and use these services in the first place. People in fragile regions impacted by conflict and violence may be unable to access schools, hospitals and even water sources due to safety reasons.[61,62,63] If households themselves do not

Figure 5. Core impact pathways explored across the three sector-specific models



have access to resilient and reliable energy, it is likely that children may struggle to keep up with schoolwork, impacting educational attainment.[64] Ensuring these contexts and enabling factors are considered when making these investments will be essential to bring about sufficient economic and community benefits.

These investments hold immense potential for bolstering communities in developing countries. By delivering resilient low carbon energy, sources such as solar, wind and hydroelectric power bring access to communities and reduce their dependence on erratic and costly traditional energy sources.[65] Decentralised energy solutions may provide insulation from grid failures, but they also empower local economies and create jobs.[66] Access to resilient energy not only improves living standards by powering essential services, but also catalyses economic growth by attracting investment and facilitating entrepreneurship. In essence, investing in energy resilience serves as a catalyst for holistic community development in developing countries.

While these societal and community benefits are profound, this report aims to understand the potential benefits relative to the costs required to provide reliable energy in developing countries. As part of this research, we have developed three custom economic models to quantitatively assess the economic output and costs of energy resilience investments in three sectors: healthcare, education and water. The analysis is focused on two pilot countries, Pakistan and Tanzania, which are referred to as examples throughout this report. The quantitative analysis in this report adopts a conservative approach, meaning that our analysis likely vastly underestimates the true economic benefit of energy resilience investments. The report builds on the models to identify tangible actions targeted towards boosting private-sector engagement and investment, which are needed to make progress towards energy resilience.

Energy resilience in the healthcare sector

The availability of resilient energy is an essential part of providing universal healthcare, as targeted by the UN's SDG3.[67] The World Health Organization (WHO) estimates that one billion people in low- and lower-middle-income countries rely on healthcare facilities with either unreliable or no access to electricity.[68] Resolving these gaps supports healthcare provision in two main ways: energy resilience improves the capacity of facilities and raises the quality of care delivered.

effective cold storage for medicines and vaccines, and enable the use of digital and electrical equipment. This is particularly clear in obstetric[69] and paediatric care. In Uganda, researchers found that healthcare facilities with access to electricity were more likely to provide emergency obstetric care services, which led to a 61% drop in the maternal mortality rate.[70] Similarly, following the electrification of health facilities in Gujarat, India, the likelihood of receiving a health check-up in the first semester of pregnancy rose by 9.5%.[71] Researchers in Rwanda found that the electrification of hospitals enabled improvements in lighting, the use of electrical medical devices, medicine storage in fridges and the sterilisation of utensils, boosting the quality of primary care delivered.[72]

Reliable energy is also an important factor in delivering vaccinations, many of which require ongoing refrigeration to remain effective. Connecting healthcare centres in Gujarat to reliable electricity raised the proportion of children completing immunisations against common diseases by 3.6%.[73] In Sierra Leone, in the six months after introducing solar-powered back-up electricity in a district hospital, the under-five child mortality rate among in-patients fell from 3.7% to 1.8%.[74] Further research found that healthcare facilities subject to power outages in Ethiopia led to incorrect diagnoses, as the lack of electricity prevented laboratory tests from taking place, forcing doctors to attempt diagnoses based solely on patients' medical histories.[75]

Community impact: Nairobi, Kenya

In 2023 Kenya faced a nationwide blackout lasting more than 24 hours—the longest in its history. It caused immediate and widespread chaos. Flights were delayed or cancelled, perishable goods had to be thrown away due to the lack of refrigeration, and small businesses lost revenue from closures. The effects were most concerning in hospitals and medical centres that required a continuous supply of stable electricity to run ventilators and other life-saving devices. While many facilities remained operational using back-up diesel generators, which require expensive fuel and emit pollutants, one hospital used a renewable energy source to continue its operation.

Top Care Nursing Home, located on the outskirts of Nairobi, managed to keep the lights on throughout the blackout owing to its on-site solar photovoltaic system. Not only did this keep critical operations running, it attracted people from nearby communities to charge their phones, which can be vital during times of crisis. All hospitals and medical centres require a stable power source, making backups essential for countries where power cuts are frequent occurrences, as is the case in Kenya.[76] Off-grid renewable energy solutions, as installed at Top Care Nursing Home, could be a life-saving solution.

Energy resilience in healthcare also enables a wider use of medical equipment. For example, Mother Theresa Hospital in Warrap State in South Sudan is now powered entirely by solar energy.[77] Prior to a World Bank-funded project to install solar panels, the hospital was entirely reliant on diesel generators, which are costly to run and prone to breaking down. Doctors and midwives in the maternity unit often used to deliver babies by torchlight and complicated births frequently became fatal because of the absence of neonatal oxygen. For outpatients, conducting simple laboratory tests was impossible without power to run testing equipment. Improving the hospital's performance means that more women want to give birth in hospital rather than at home, which is saving lives. This intervention has also resulted in fewer outbreaks of measles and a higher proportion of children completing their immunisations, which are attributed to the greater convenience that the hospital offers its patients, all because of its reliable power supply.

The case for investment

The benefits of improving energy access, reliability and flexibility in healthcare facilities translate into broader positive economic and community impacts. Targeted energy investments into healthcare facilities can improve the health and wellbeing of women and children, boosting a country's human capital, female labour-force participation and fertility rates.[78] The same can be said about reducing the prevalence of chronic disease. A study of South African women found that those suffering from long-term illnesses, such as diabetes, were much less capable of working. Similarly, researchers in Kenya found that a 1% increase in the incidence of HIV led to a 5.4% fall in labour-force participation.[79] As energy resilience allows for improved capacity and quality of care from healthcare facilities, these health outcomes stand to improve further too.

Case in point: Investing in energy resilience in Tanzania and Pakistan's healthcare facilities

Tanzania and Pakistan's healthcare sectors are currently facing notable energy obstacles. In Tanzania, an estimated 15% of healthcare facilities have no access to electricity.[80] Meanwhile in Pakistan, 12% either don't have an electricity connection or have an unreliable supply.[81]

Our analysis finds that ensuring full access to energy without disruption in all healthcare facilities could return substantial economic benefits in both Tanzania and Pakistan. In Tanzania, investing in energy resilience gives an annual average economic return of **US$18m** between 2024 and 2044, adding up to US$360m in total by 2044. In Pakistan, the annual return amounts to almost **US$15m,** with the aggregated total by 2044 amounting to US$297m (see Appendix for the full breakdown of benefits and costs). This return is driven by the reduced maternal, adult and infant mortality, as well as a lower disease burden as a result of greater energy resilience. In the longer term, higher immunisation rates propel the economic benefits of these energy investments in both countries (see figure below).

The total investment required to ensure energy resilience in Tanzania and Pakistan's healthcare sectors would be **US$170m** and **US$128m** by 2044, respectively. This represents approximately 6% and 1.2% of the yearly total health expenditure for each country, respectively.[82] While significant, these investments deliver far higher returns and capture both the capital and the operating expenditure of running the systems.

Our analysis shows that a US$1 investment in energy resilience in healthcare facilities could return US$2.1 and US$2.3 by 2044 in Tanzania and Pakistan, respectively

Snapshot:
Tanzania's healthcare sector by 2044

US$18m gained per year

US$360m gained in total

US$170m investment cost

US$2.11 return for every $ invested

Snapshot:
Pakistan's healthcare sector by 2044

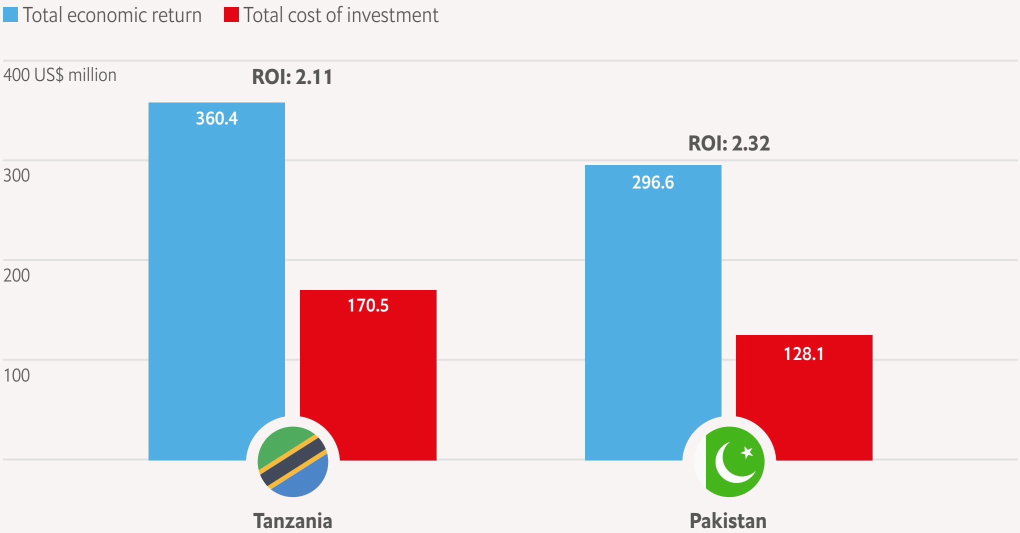
US$15m gained per year

US$297m gained in total

US$128m investment cost

US$2.32 return for every $ invested

Figure 6. Total economic benefits and costs of investing in healthcare energy resilience by 2044 (US$ m)



Source: Economist Impact (2024)

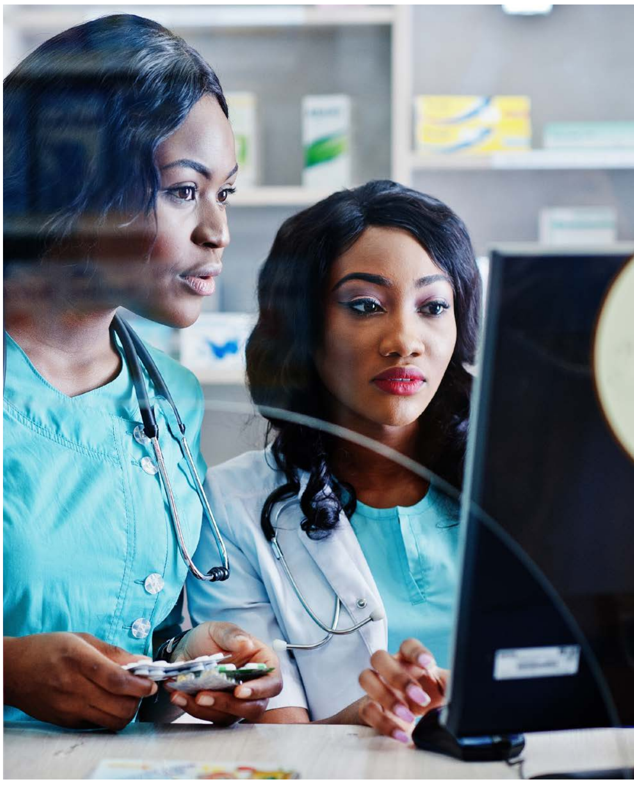
Improved quality of care

In addition to the impact pathways quantified in the cost-benefit model, there are additional pathways through which resilient energy investments could contribute to economic benefits. Better energy supplies improve patients' perceptions of care. In Uganda and Ghana, following the electrification of rural hospitals through the UN Foundation's 'Powering healthcare' programme, hospitals were able to run at night. Patients' perceptions around safety, cleanliness and the overall quality of care improved. In particular, community approval increased from 10% to 95% in Ghana and from 34% to 96% in Uganda.[83] And, as a result of local health facilities being able to function during the night, pride and trust towards the health facility increased. Improved perceptions around healthcare facilities may therefore draw more communities to seek medical attention.

Alongside patients' perceptions, resilient energy supply in healthcare facilities positively impacts staff motivation and retention. Following the Powering Healthcare programme, healthcare workers in rural Uganda and Ghana stated that they were equipped with adequate lighting, which allowed them to do their job more effectively.[84] Specifically, they were able to conduct tasks in the maternity department both during the day and at night. Moreover, electrification enhanced the overall quality of life for hospital staff, which is essential for retaining much-needed healthcare staff in rural areas. A study in Burkina Faso and Tanzania illustrated that maternity health workers prefer to serve in urban areas, in part owing to availability of electricity.[85] Moreover, retention of staff has a reinforcing effect on the quality of healthcare delivered.

Moving forward

Our model emphasises the importance of investing in energy resilient solutions in the healthcare sector, uncovering the positive economic benefits through a set of impact pathways, namely improved mortality, higher immunisation rates and a lower disease burden. However, as laid out above, there are additional pathways that we have not quantified, whereby further benefits could be realised. This suggests that our analysis underestimates the true economic benefit of energy resilience investments. However, while acknowledging this is the first step, time is running out for action. With one billion people in the poorest parts of the world relying on insufficiently electrified healthcare facilities, which makes them more vulnerable to the health-related impacts of climate change, there is a clear mismatch of priorities and financing. Bringing this number down will require a concerted effort to ensure that healthcare facilities are able to improve health outcomes and local communities' wellbeing.



Energy resilience in the education sector

The UN's SDG4—inclusive, equitable and quality education for all—requires resilient energy. Access is a crucial obstacle—close to 186 million children around the world attend schools without any electricity at all.[86] The number in schools without reliable supply is much higher still. Some pupils try to overcome this: children in Guinea often study under streetlights, while others in Uganda work at home by candlelight, causing a fire risk.[87] Access to resilient energy improves the accessibility and quality of education, delivering an economic boost when they enter the workforce.

The return on energy and education

Solving the access gap is essential for improving educational outcomes, starting with attendance. A study conducted in Argentina found that installing electrical lighting raised attendance by creating a more comfortable environment.[88] In Malawi, teachers reported that solar-powered lights increased school attendance and improved pupils' concentration in class.[89] The positive link between school electrification and student enrolment is somewhat tenuous. A nationwide electrification programme in Uruguay saw approximately two extra students enrolled per school, but other studies have been less conclusive. Electrification is likely to make the school environment a more positive place, but that does not necessarily mean more children will sign up.[90]

When it comes to educational results, however, the benefits are very clear. Children at schools with electricity tend to have significantly higher educational attainment than those without it.[91] Researchers in Ghana demonstrated that access to electricity in schools was a factor that contributed to increases of 30% and 40% on the pass rate for national tests in English and mathematics, respectively.[92] As part of its response to the covid-19 pandemic, the government in Zambia installed solar panels in 19 schools across five provinces, benefitting 6,000 students. This meant that lighting could be provided—allowing school to extend into evenings—as well as offering reliable power for computers.[93]

Access to energy also attracts and retains better teachers.[94] Approximately 85% of teachers in Ghana consider access to potable water and electricity to be key factors when assessing whether to work in rural areas, highlighting the importance of such utilities in keeping teachers.[95] Similar data from Zimbabwe shows that 94% of trainee teachers identify the availability of electricity as an important factor in choosing where to work.[96] Access to energy, especially when it is reliable, in schools enables teachers to prepare lessons or receive training, ultimately improving their quality of life.

186 billion children
around the world attend schools without any electricity at all

The next priority is ensuring that the energy systems are stable, reliable and resilient to shocks. Without such systems, schools and their students are subject to insufficient lighting, disruptions to ICT equipment, and an overall loss in educational hours.[97] Preventing this takes targeted investments. In South Africa in 2019, an automobile manufacturer, Nissan, partnered with a boarding school in Pretoria for disabled children to improve energy reliability and resilience.[98] Prior to this, the school was subject to several blackouts a month, with some lasting the full day, causing disruptions to computer use, cooking for students and printing braille for visually impaired students. Using second-life batteries from cars and solar panels, Nissan equipped the school with a back-up solution to ensure energy access during power outages.[99] Investing in energy resilience in schools is clearly beneficial, but it is important to note that household access to electricity also matters. However, this aspect is not quantified in the models used in this report.[100]

As a result of such investments into energy resilience for schools, additional years of schooling, better qualifications and heightened teacher retention can lead to a more productive labour force who draw higher salaries in the long term. Evidence from rural communities in India highlights that those with a secondary school certificate who have access to electricity earn, on average, 55% more than those without.[101] Another study across 72 developing countries estimated that an additional year of schooling resulted in an 18% increase in labour productivity, while an improvement in school quality (as measured by stronger test scores) pushed up productivity by 24%.[102]

Community impact: Punjab and Khyber Pakhtunkhwa (KPK), Pakistan

In two Pakistani provinces, Punjab and KPK, approximately 20% of schools are off-grid. This has a profound impact on learning experiences and outcomes for students. Being connected to the grid doesn't bring notable improvements, with power outages in Pakistan lasting up to ten hours a day in rural areas and four hours in urban areas due to inefficient transmission and distribution networks. In Punjab, where temperatures often exceed 40°C during summer, teachers and students rely on fans to keep classroom conditions manageable. However, with regular power outages, students struggle to attend class, and maintain concentration if they do attend, due to the excessive heat.[103]

In 2016, through its Access to Clean Energy Investment Program, the Asian Development Bank invested US$325m in the form of a loan in these two provinces, with the aim of supporting the government in installing solar powered facilities. Since then, rooftop solar panels have been fitted into over 10,700 schools in Punjab and more than 2,000 in KPK. This has allowed more than 1.4 million students to receive reliable electricity in their schools and access opportunities that they otherwise would not be able to.

Case in point: Investing in energy resilience in Tanzania and Pakistan's education facilities

Almost a quarter of secondary education facilities in Tanzania have no access to electricity. The situation is worse still for primary schools, with over 50% lacking access.[104] Meanwhile, 30% of schools delivering primary education in Pakistan do not have access to electricity.[105] This has implications on school attendance and attainment, educational performance, and school absenteeism and progression through to secondary education.

Our cost-benefit analysis highlights that investing in energy resilience in education facilities results in an average economic benefit of **US$31m** per year through to 2040 in Tanzania, amounting to a total benefit of US$500m by 2040. In Pakistan, the annual return is significantly higher—**US$142million** per year through to 2040—with the cumulative total amounting to US$2.3bn by 2040. This is driven by the positive impacts of providing resilient energy to schools on dropout rates, and subsequently graduation rates, for students already enrolled in primary and secondary schools, the productivity and wage benefits of completing education, and the impact on the construction sector of installing the new power infrastructure.

The combined capital and operating expenditure of providing resilient energy to schools is well below the benefit, amounting to a total of **US$209m** in Tanzania and **US$945m** in Pakistan. This represents 8.5% and 2.8% of the yearly total government expenditure on education for each country, respectively.[106]

Our analysis shows that a US$1 investment in energy resilience in education facilities could return, on average, US$2.4 by 2040 in both countries

Snapshot:
Tanzania's education sector by 2040

US$31m gained per year

US$500m gained in total

US$209m investment cost

US$2.39 return for every $ invested

Snapshot:
Pakistan's education sector by 2040

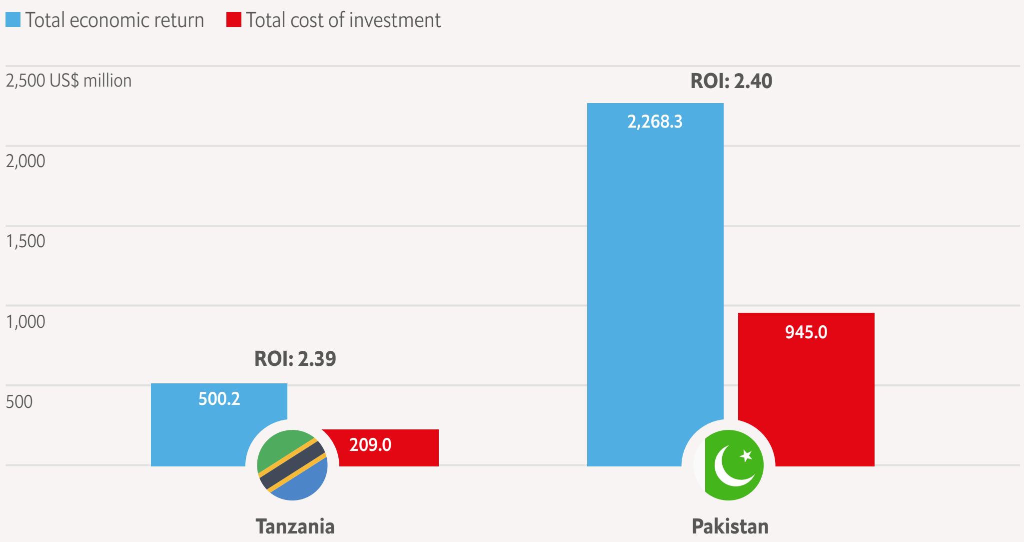
US$142m gained per year

US$2.3bn gained in total

US$945m investment cost

US$2.40 return for every $ invested

Figure 7. Total economic benefits and costs of investing in energy resilience in education facilities by 2040 (US$ m)



Source: Economist Impact (2024)

More inclusive education

While the benefits of implementing energy resilience solutions in schools outlined above are quantified in the education cost-benefit model, there are additional education-related benefits that rely on community electrification, which includes schools. As these effects are difficult to untangle and cannot be easily quantified, they have not been investigated in the model. For example, community energy access and resilience has shown to contribute towards gender equity in education. In a study in Bhutan, rural electrification contributed to 0.65 years of additional schooling for girls (and 0.41 years for boys).[107] Similarly, bringing electricity to other facilities in the community in Mali also spurs higher school attendance among girls. When the government in Mali partnered with the UN Development Programme to distribute so-called multi-functional platforms (MFPs), which are small diesel engines attached to a variety of end-use equipment, to rural villages, more girls began to attend school.[108] This is most likely because daily tasks that tended to be assigned to girls and women, such as milling cereals, suddenly became much faster to complete, freeing up time that could be devoted to education. In the region of Balanfina, for example, the girl-to-boy ratio rose from 0.3 to 0.6 in primary schools in villages that received the MFPs.

Moreover, geography is a crucial factor in determining the benefits of bringing resilient energy to schools. There is a limit to how far children can travel to school each day. At the same time, connecting remote communities to national power grids to reduce that distance can be expensive and technically challenging. The One Meralco Foundation, the charitable arm of Meralco, the largest power distributor in the Philippines, has been running an electrification programme for rural schools since 2011. So far it has installed solar power units in around 250 schools.[109] The pilot schools for the project, located on Isla Verde in Batangas province, recorded stronger educational outcomes as well as greater resilience to shocks. Prior to the arrival of solar power, lessons were regularly cancelled during the rainy season, as there was insufficient light for pupils to read comfortably. Another issue was that teachers had no way to duplicate resources like exam papers, meaning they would have to take a boat to the nearest city to use printers.[110] Other schools that have benefited from the programme are able to run electric fans during summer to keep classrooms at a temperature conducive to learning.[111]

What next?

Driven by improvements in school attendance, performance and dropout rates, our model clearly sets out the case for investment in energy resilience in schools. Factoring in potential improvements to gender equality and access to education, these potential benefits could be even greater. Moreover, in the face of worsening climate impacts, vulnerable developing countries stand to benefit from a well-equipped future workforce, given that implementing more innovative mitigation and adaptation solutions will require a wide range of skill sets.[112] Prioritising the resilient electrification of schools in developing countries will be essential to achieve both short- and long-term goals, but mobilising capital from a wide range of sources, including the private sector, is essential.

Resilient energy in the water sector

The water sector is energy intensive. The IEA splits electricity demand from the sector into six sub-components. In descending order by electricity demand, these are: supply, waste-water treatment, distribution, transfer, desalination and reuse.[113] Moving water around vast networks requires electric machinery such as pumps, aerators and anaerobic digesters, which demand a substantial amount of energy.[114] The absence of a resilient energy supply halts essential functions, leading to a cascade of direct and indirect impacts. Direct impacts could include the failure of distribution machinery, leading to interruptions in water supply, which has downstream impacts on households and industries. Consequent indirect impacts might be an increase in water-borne diseases or a decline in agricultural output.[115]

The case for resilient energy

Unreliable energy supply has negative impacts on the quality of municipal water supply. Power outages cause water pumps to fail.[116] In South Africa, a single daily water outage is strongly correlated with higher mortality and morbidity rates.[117] Similarly, in Taiwan, incidences of gastroenteritis and skin and eye diseases have been found to be higher during periods with an interrupted water supply.[118] A lack of access to clean and safe drinking water owing to unreliable electricity leads to a greater incidence of waterborne diseases. These diseases have steep costs at the macroeconomic level and for households. The World Bank estimated that around 20% of communicable diseases in India are water-related and in 2017 resulted in the loss of 73 million days of labour.[119]

Community Impact: Tanzania

Resilient energy systems ensure a consistent supply of water free from contamination. In 2019 a programme supported by the UN Development Programme saw 12 off-grid boxes installed around the Lake Victoria region of Tanzania. They contained a solar panel at the top of a shipping container that housed all of the hardware needed to produce electricity and clean water. In addition to providing electricity to pump and treat water, the boxes also allowed residents to charge battery packs for household use and other productive use cases.[120] The UNDP reports tangible financial benefits from installing these boxes, which serve approximately 24,000 residents. For example, households that were previously spending around US$1.3 on bottled water per day saw this amount drop to only 43 cents a week.[121]

Agriculture is the thirstiest economic sector in terms of freshwater withdrawals and consumption, accounting for around 70% globally.[122] However, this figure can reach as much as 95% in some developing countries.[123] As such, resilient energy is essential for ensuring that water is supplied adequately and regularly to agriculture. In irrigated systems that are designed to be efficient in their use of water, a resilient and reliable supply of electricity is essential to ensure that crops remain healthy. Studies from countries as diverse as Zimbabwe and Australia have shown that power interruptions reduce agricultural output.[124,125] The losses resulting from a lack of access to reliable electricity could also, under extreme scenarios, lead to seasonal crop failures. In 2019 smallholder farmers in the Zaka district of Zimbabwe reported concerns over the potential loss of cultivated seasonal crops due to lack of water for irrigation caused by intermittent power supply and the high cost of alternative energy sources.[126] The opposite is also true. Introducing small-scale pressurised irrigation into three countries in East Africa significantly increased the yields for horticulture crops, as well as maize and potato.[127]

The challenge of bringing resilient energy to the water sector in developing countries is to do so cheaply and efficiently, enabling an increase in economic output but, essentially, without promoting excessive water use. A programme in Cambodia conducted by the UN Development Programme and funded by the South Korean government highlights one potential solution for small-scale agricultural producers.[128] The Tonle Sap Lake Basin occupies much of the country's North-West and is vulnerable to cycles of flooding and drought. Growing crops, particularly rice, is becoming more challenging for farmers, partly because of the impact of climate change on meteorological patterns. Many farmers lack the funds to afford a diesel generator and are therefore reliant on hand-pumped water for domestic consumption and their smallholding. Others that can afford a generator are then committed to servicing it, buying diesel and accepting noise and air pollution. The UNDP programme installed solar water pumps, which are less labour intensive than manual pumps and cheaper to run than generators. Their reliability means that farmers can commit to a second growing season in a year, while the greater availability of water has reduced conflict in the community. However, it is important to keep in mind that there are potential unintended consequences of increased water access. For example, increased power in the farming industry could result in inefficient water use and excessive waste.[129]

Agriculture is the thirstiest economic sector in terms of freshwater withdrawals and consumption, accounting for around 70% globally

Case in point: Investing in energy resilience in Tanzania and Pakistan's water facilities

Firms in Tanzania faced an estimated 0.7 power outages per month lasting for an average of 6.4 hours in 2022, causing notable disruption.[130] The case is similar for Pakistan, where firms faced, on average, 22 power outages in a month for 1.8 hours.[131] Water utilities in both of these countries bear the brunt of unreliable electricity supply. In 2022 frequent power cuts and unannounced load-shedding disrupted the water supply, leading to severe water shortages in urban areas such as Rawalpindi in Pakistan.[132] This will only worsen without investment.

Our analysis shows that the economic return of investing in complete energy resilience in the water facilities averages **US$750,000** per year through 2030 in Tanzania, adding up to US$5.2m by 2030. This amounts to, on average, **US$21m** per year in Pakistan, and an aggregate of US$149m by 2030. In Pakistan, this amounts to potential spending on alternative water sources falling by an average of US$3.6m a year. In addition, when water utilities have access to resilient energy, around 70,000 cases of diarrhoea could potentially be prevented in Pakistan annually. The same investment would also add around US$2.5m annually to agricultural output.

The overall investment needed to eliminate power outages in the water sector is **US$1.7m** by 2030 in Tanzania and **US$95m** in Pakistan, covering both the initial capital expenditure as well as the operating costs.[133]

Our analysis shows that a US$1 investment in energy resilience in water facilities could return US$3.2 and US$1.6 by 2030 in Tanzania and Pakistan, respectively

Snapshot: Tanzania's water sector by 2030

US$0.75m gained per year

US$5.2m gained in total

US$1.7m investment cost

US$3.18 return for every $ invested

Snapshot: Pakistan's water sector by 2030

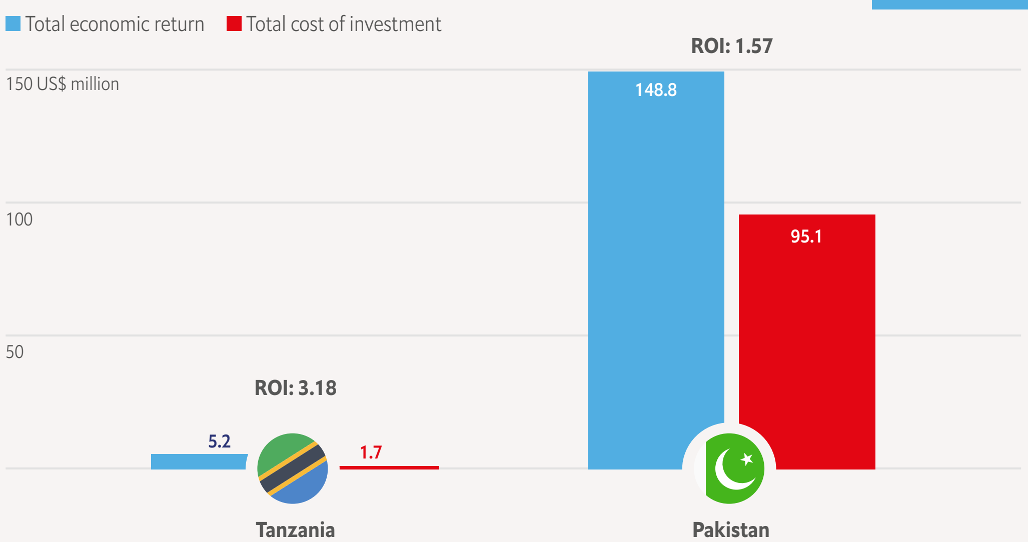
US$21m gained per year

US$149m gained in total

US$95m investment cost

US$1.57 return for every $ invested

Figure 8. Total economic benefits and costs of investing in energy resilience in water facilities by 2030 (US$ m)



Source: Economist Impact (2024)

The water sector is closely linked to others, including healthcare and agriculture—as explored in our model—as well as manufacturing and food production. Ensuring that energy access for the water sector is resilient will be essential, especially in the face of growing climate change shocks that threaten the availability of clean water and food security.[134] While our analysis is focused specifically on how electrifying municipal water services reduces spending on alternative water sources and the incidence of water-borne diseases while having a positive impact on agricultural output, the water sector's proliferation through numerous sectors underscores the need for greater investment in energy resilient infrastructure for water utilities. This is of particular importance, as it stands to affect household health, livelihoods and income.

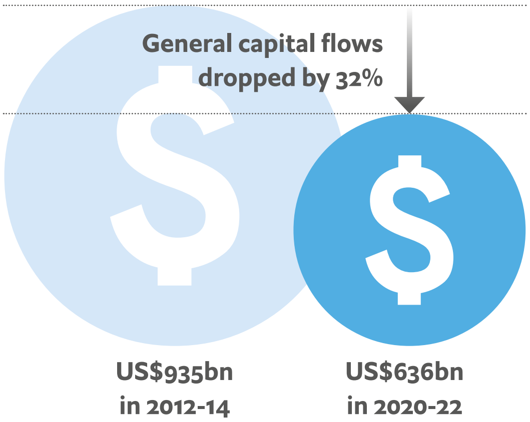
A pathway to the future

Energy resilience in critical sectors such as healthcare, water and education is a paramount endeavour and will not happen with public resources alone. In 2022 about half of clean energy spending in developing countries, with its positive contribution to greater resilience, came from public financing. That figure stands at less than 20% in advanced economies.[135] Yet the IEA estimates that around 60% of financing will potentially need to come from the private sector to ensure climate resilient energy at scale, due to constraints on public finances.

This report highlights that the cost of providing universal resilient energy to the healthcare, education and water sectors is relatively small compared with the potential benefits. According to Angela Homsi, founder of Ignite Power, "the cost of universal access to resilient electricity in the global South is a lot lower than people think. For a few tens of dollars, you can get a family equipped with solar. For just a few dollars, you can get a school of children connected with electricity and internet access." According to the IEA, US$45bn in investment is needed per year to achieve universal access to electricity and clean cooking fuels by 2030, which contributes to greater energy resilience. This amounts to less than 2% of overall spending on clean energy.[136]

Although there are signs of growth in private sector investment in the SDGs, persistent barriers undermine private investment in projects in developing countries. This is evident from the decline in general private capital flows to developing countries, which dropped by 32% from its peak of US$935bn in 2012-14 to US$636bn in 2020-22.[137] This current immobility in private investment is detrimental to energy and community resilience, especially as climate change impacts worsen.

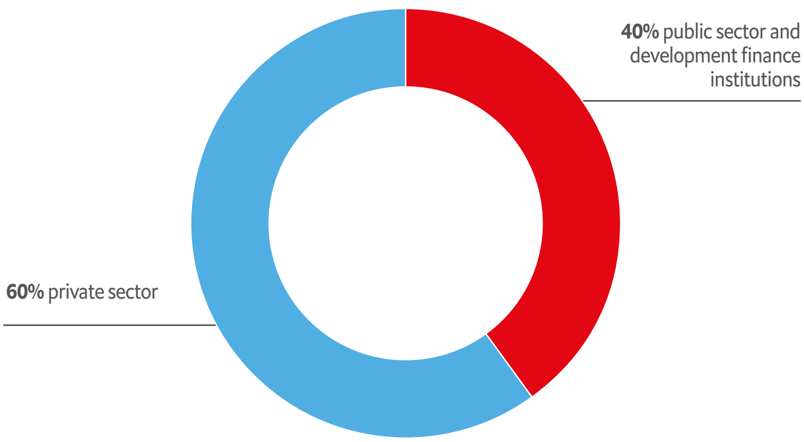
Figure 10. A decline in general private capital flows to developing countries



Source: World Bank (2023)

In 2022 about half of clean energy spending in developing countries, with its positive contribution to greater resilience, came from public financing

Figure 9. Breakdown of funding needed to scale up climate resilient energy (%)



Source: IEA (2023)

Navigating the complexities of investment in developing countries presents formidable challenges to scaling up private sector investment in energy resilience. Overcoming these barriers will require a suite of multistakeholder actions, primarily with three core objectives: **building an enabling environment for private sector investment; incentivising this investment into social sectors; and leveraging and strengthening local knowledge and value chains to ensure a just energy transition.**

1. Starting broad: building an enabling environment

The complex, and sometimes prohibitive, regulatory landscape in developing countries is a notable barrier to private sector investment. The often-unstable policy environment in developing countries raises the reputational risk of investing due to the risks associated with poor governance and institutional capacity. For example, research conducted by Network for Greening the Financial System (NGFS) shows that a lack of regulatory clarity related to blended finance mechanisms for climate mitigation, adaptation and resilience solutions is a particular hurdle for both private and public investors. Issues driving this include the treatment of risk capital and liquidity requirements, risk-retention rules and the treatment of credit insurance.[138] Coupled with difficulty in conducting business, this makes the investing environment less attractive to external private sector actors.[139]

Moreover, policy and regulation in advanced countries, including EU members and the US, are making new investments in clean energy solutions in these regions more attractive to private sector investors. However, this is proving detrimental to the attractiveness of investments in developing countries.[140] In particular, in the face of growth in strict environmental, social and governance regulations in advanced economies, investors are facing a greater risk of non-compliance with investments in developing countries, which may have comparatively less stringent requirements.[141]

Furthermore, government-led policies, commitments and instruments targeted towards the energy transition will be crucial to crowd-in private investment. For example, in 2016 India committed to generate approximately 40% of its electricity through resilient and renewable sources by 2030. To fulfil this commitment, the government has made efforts to improve its regulatory and fiscal environment. One example is its Solar Parks policy, which aims to scale up the establishment of solar parks and reduce barriers to private investment in large projects.[142] One of India's flagship solar projects, the Rewa solar park in Madhya Pradesh, powers the New Delhi metro rail system and resulted in a record low tariff equivalent to US$0.44 per kilowatt hour, making it more attractive than coal-fired plants across the country.[143] The World Bank's US$18m investment into the project spurred a further US$575m in private investment.[144] The government's role in facilitating this 'virtuous cycle' of successful projects and private investment cannot be understated.[145]

Local governments will need to cultivate a suitable enabling environment for private investment. "Developing countries' policymakers will need to start exploring the establishment of local sustainable finance standards, which may not be easy due to limited accountability mechanisms", explains Bernadette Victorio, programme lead at Oxfam's Fair Finance Asia. For example, in the Philippines, the central bank has issued its Philippine Sustainable Taxonomy Guidelines (STFG), which helps investors identify whether an economic activity is environmentally and socially sustainable, guiding their funding appropriately.[146] Establishing science-based taxonomies that are comparable with others can play a crucial role in attracting private sector investment to a country by bringing credibility, integrity and transparency to the local market.[147]

2. Homing in: creating sectoral incentives

In the three social sectors prioritised in this report, there is a dearth of private sector investment. Private investment into social infrastructure fell from US$19bn globally in 2010 to less than US$3bn in 2019, mostly concentrated in advanced economies. "Health, education and water are very much public-sector driven", explains Kenta Usui, senior energy specialist at the World Bank. "Unlike households and businesses they do not create their own revenue. For private-sector investors there is no guarantee that the public sector will pay to keep the systems operating." This uncertainty is one of the biggest challenges for potential private-sector investors. The perceived risk profiles of investments in developing countries are a particular concern. These are often not in line with institutional investors' risk bearing capacity, enhancing their aversion. Most developing countries lack an investment-grade sovereign credit rating—according to the International Monetary Fund, this figure is only 8%.[148] Investments in social sectors' infrastructure are typically localised, meaning investors may have to face different laws and customs across states and municipalities. Moreover, such investments can be too small, overly complicated, illiquid and subject to political risks.[149]

This is driven by the low government prioritisation of energy resilience in these sectors in many developing countries, which discourages private sector investment. Vaqar Ahmed, joint executive director of the Sustainable Development Policy Institute, explains that "in the everyday political discourse, health, education and water get left behind. There are all sorts of innovative incentives for resilient, reliable and renewable energy solutions going into the manufacturing sector, but not in these social sectors." The private sector is ready, Mr Ahmed argues, to make the transition to clean and green as early as possible, but governments are currently directing firms to invest elsewhere in their economies.

Overcoming this will require two crucial steps by policymakers. First, governments and development finance institutions can join forces with otherwise reluctant private sector investors through blended finance mechanisms. This will be important to scale up the financing needed to achieve climate goals, and more specifically energy resilience, while bringing discipline and long-term planning.[150] Blended finance is a structuring approach that brings together organisations to invest alongside each other while allowing them to still achieve their own distinct objectives.[151] Blended financing approaches involve public funds that are usually offered on concessional and more attractive terms and are used to share the risks of investment projects to mobilise additional private capital. Moreover, the public sector can reduce risk further by implementing, for example, guarantees that limit the risk of non-payment.[152] Such approaches can come in different shapes and forms, ranging from sizable sovereign bonds supported by global public finance to more localised initiatives focused on expanding lending to marginalised communities by sharing risks.[153]

Second, and more broadly, policymakers in developing countries will need to work on ensuring stability and predictability in the local policy environment.[154,155] Overly complex and bureaucratic policies and laws that lack clarity, efficiency and transparency are major obstacles to the growth of private sector investment in any industry.[156] Therefore, in order to attract private sector investment, governments will need to make conscious efforts to ensure policies affecting the business and investment ecosystem, ranging from taxation to trade, are stable and resilient to changes to administrations.

This will be essential, especially since energy resilience investments, as with other infrastructure investments, have a relatively long life-span. Investors need reassurance that their investments are safe from volatile policy-driven shocks.

3. Going local: building capacity and knowledge

Ms Homsi questions whether existing ideas of what sort of investments are required are correct. "A large power plant will only help a certain percentage of the population, because others are off the grid and even those on the grid will struggle for access because grids fail." She continues, "in the future the world will be powered by decentralised infrastructures, which are better suited to resilience and adaptation." The private sector should ensure that investments are targeted towards localised solutions. For example, decentralised mini-grids in Africa are estimated to provide low-cost access to at least 30% of the continent's population that currently have no electricity.[157] However, to ensure the financial sustainability of such investments, certain barriers will need to be mitigated. Governments will need to ensure tariffs are appropriate while investors will need to effectively manage cash flow problems and management deficits. This is evident in a case study of a private for-profit mini-grid business model in Tanzania.[158]

Decentralised electricity provision means that there is a larger number of much smaller systems, which creates huge demand for local knowledge and skills to manage and repair them. According to Gilles Vermot-Desroches, the chief citizenship officer at Schneider Electric, a worldwide company specialised in solutions to accelerate the energy transition: "Empowering rural populations in emerging markets with skills training is pivotal to ensuring a just transition towards clean and resilient energy. By strategically directing capital towards capacity-building training and education, we can cultivate the essential skill sets needed to attract future investment and fulfil upcoming demands, notably on electrification and digitisation. Based on past experiences, we know that collaboration among governments, industry, educational institutions, and trade unions/NGOs is essential in driving this transformative effort." For example, the RES4Africa Foundation leveraged private sector capacity from partners including Enel Green Power, Siemens, Gamesa, Schneider Electric and PwC to deliver the Micro-Grid Academy in 2018, a vocational capacity-building programme in sub-Saharan Africa. It aimed to build a skilled workforce to deploy decentralised renewable energy solutions in East Africa, specifically focusing on cultivating skills, innovation and empowerment among young people.[159] Moreover, as energy systems change, local industries will need to adapt and will need support in doing this.

Beyond local skills, integration with local value chains is essential in ensuring the long-term sustainability of investments. Where projects are available to private investors, longevity matters, emphasises Dr Nicolas Jarraud, senior specialist engagement and partnerships development at the Global Water Partnership (GWP). The positive returns on investment are generally sustainable for as long as the systems are operational. However, Dr Jarraud stresses that some projects do not fully meet the definition of resilience, as many countries lack the ability to manufacture replacement parts. "If a photovoltaic system lasts 15 years but you then have to import replacement parts from abroad, you are not creating a resilient system," he explains. In countries with difficult financial conditions, it is crucial to invest in open innovation and a whole value chain rather than simply importing the technology. "Resilience is also usually a function of simplicity," says Dr Jarraud. "For example, you can invest in a concentrated solar power system that is more mechanical than electronic and which can be maintained using an existing value chain. If you think that way you can create more than just an investment, you are creating a value chain that is sustainable in the long term."

Finally, even with the most appropriate financing scheme in place, achieving universal resilient energy in health, education and water will only be effective if it is affordable to local communities. This affects both facilities within these three social sectors, as well as the individuals utilising them. With the recent energy crisis, hospitals, schools and water utility companies alike are facing significantly higher running costs. While data on the affordability of energy in these facilities is limited, household energy bills reflect a similar concern. The IEA forecasts that household energy bills are set to rise by 80% between 2045 and 2050,[160] highlighting the need to ensure that resilient energy solutions and supplies are affordable. Policymakers should look towards a combination of supply-side and demand-side funding mechanisms to ensure that risks and costs are managed while boosting affordability. While supply-side funding mechanisms including grants and tax exemptions for clean, resilient energy providers could be effective, they may be less accessible for countries with overburdened public budgets. Similarly, demand-side instruments, such as end-user subsidies, may improve the uptake of such solutions. However, they may not be financially sustainable for developing countries, as they could strain public finances.[161] One mechanism that could be impactful in this context is concessional consumer financing, which is increasingly showing promise in developing countries.[162] This product is offered to end-users with a lower interest rate than its commercial equivalent, often with the goal of boosting the uptake of products or services that deliver on desirable social, economic and/or environmental outcomes.

Conclusion

As we approach 2030, climate change-induced threats to our energy systems are becoming increasingly palpable. With constrained public budgets in developing countries and insufficient energy infrastructure, mobilising private sector financing will be a critical step towards achieving SDG7—ensuring access to affordable, reliable, sustainable and modern energy for all, especially in the most vulnerable parts of the world. This is even more pertinent since energy underpins key social sectors such as healthcare, education and water, which are vital to the economic and physical wellbeing of local communities, specifically children, but are often overlooked as attractive investments.

In this report, we have laid out the case for investing in these sectors, highlighting significant positive benefits in two forms. First, in Pakistan and Tanzania—the countries assessed in the cost-benefit analysis—our research uncovers economic returns across all three sectors. Second, but equally important, the social and community impact is also evident in the case studies. By ensuring energy systems in these three sectors are resilient to shocks, local communities are likely to be healthier, able to learn more, have access to water, and maintain their livelihoods. Within these communities, children and young people in particular stand to benefit from better learning environments, health and wellbeing, and earning potential, all culminating in improved quality of life.

Underscoring the need for investments in energy resilience is the importance of ensuring local communities are kept at the forefront of such interventions. By bringing local communities along on the transition to energy resilience, investors can deploy technical expertise and knowledge, which will ultimately make affected communities more self-sufficient and resilient while maintaining the fruitfulness of their investments. Implementing new clean energy technologies will only be effective if local communities are well equipped to use and benefit from them in the long term.

As illustrated in this report, investment from a wide range of sources is necessary to build energy resilience in developing countries and private sector investment is a crucial untapped resource. However, crowding in private sector investment is no easy feat. Current barriers to private sector investment include insufficient regulatory and fiscal environments and perceived lower returns relative to investments in more developed markets. Overcoming these barriers will require a suite of actions, from policy levers to risk-sharing funding mechanisms. But no one stakeholder is responsible. Regulators and policymakers need to cultivate a stable policy environment to incentivise private sector investors, while partnering up with development finance institutions to offer blended finance solutions. Private sector actors should ensure that their investments include provisions for local capacity- and knowledge-building. Only with coordinated efforts involving these different groups can such barriers be meaningfully overcome.

Energy services that are stable, affordable and resilient to shocks underpin an entire suite of essential human services across society. If incentives are aligned and mechanisms are put in place to realise the necessary investments into energy resilience, those investments will pay off handsomely—especially in the form of healthier, happier and better educated children to comprise future societies.

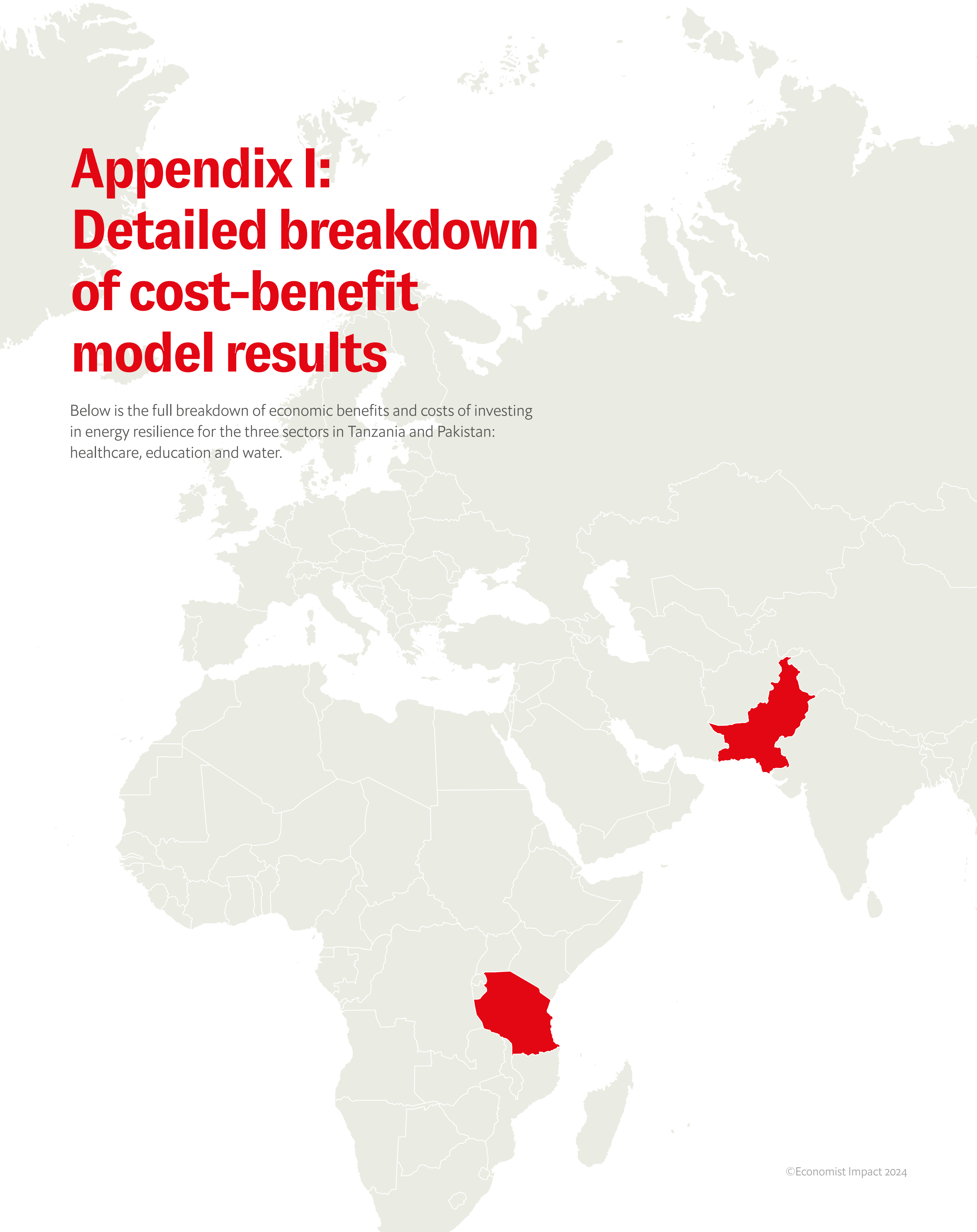
Appendix

Appendix I: Detailed breakdown of cost-benefit model results

Appendix II: Methodology

Appendix I: Detailed breakdown of cost-benefit model results

Below is the full breakdown of economic benefits and costs of investing in energy resilience for the three sectors in Tanzania and Pakistan: healthcare, education and water.



Tanzania

Investing in energy resilience in the healthcare sector

Net costs and benefits (net present value, US$)

	Short Term (2024-30)		Total (2024-44)	
	Optimistic	Climate impact	Optimistic	Climate impact
Total benefits	259,444,359	-130,901,411	360,369,111	-314,517,124
Total costs	170,481,437		170,481,437	
Net benefits	88,962,923	-130,901,411	189,887,675	-314,517,124
Benefit cost ratio	1.52		2.11	

Optimistic scenario (US$ m)

		2024	2025	2026	2027	2028	2029	2030	2044	Total
Short-term output	Maternal mortality	0.23	0.47	0.73	1.02	1.34	1.70	2.09		7.56
	Adult and infant mortality	0.85	1.56	2.13	2.62	3.04	3.41	3.73		17.34
	Disease burden	3.66	3.84	4.03	4.21	4.39	4.56	4.72		29.42
	Multiplier effects	140.04	12.17	11.63	11.10	10.57	10.05	9.56		205.12
	Total short-term incremental output	144.77	18.04	18.52	18.94	19.35	19.72	20.10		259.44
Long-term output	Immunisation impacts								100.92	100.92
Total output		144.77	18.04	18.52	18.94	19.35	19.72	20.10	100.92	**360.37**

Climate impact scenario (US$ m)

		2024	2025	2026	2027	2028	2029	2030	2044	Total
Short-term output	Maternal mortality	-0.01	-0.02	-0.05	-0.09	-0.14	-0.21	-0.30		-0.83
	Adult and infant mortality	-0.50	-1.56	-3.23	-5.63	-8.99	-13.49	-19.40		-52.79
	Disease burden	-0.96	-2.46	-4.73	-8.05	-12.83	-19.61	-28.64		-77.28
	Multiplier effects									
	Total short term incremental output	-1.47	-4.05	-8.00	-13.77	-21.96	-33.31	-48.34		-130.90
Long-term output	Immunisation impacts								-183.62	-183.62
Total output		-1.47	-4.05	-8.00	-13.77	-21.96	-33.31	-48.34	-183.62	**-314.52**

Total costs (US$ m)

		2024	2025	2026	2027	2028	2029	2030	2044	Total
New connections	Capex	41.54	1.43	1.35	1.27	1.18	1.10	1.02		48.90
	Opex	2.17	2.18	2.10	2.03	1.96	1.89	1.82		14.14
	Sub total	43.71	3.61	3.45	3.29	3.14	2.99	2.85		63.04
Backup connections	Capex	68.40	2.80	2.64	2.48	2.32	2.15	2.00		82.78
	Opex	3.77	3.80	3.67	3.54	3.41	3.29	3.18		24.66
	Sub total	72.17	6.60	6.30	6.02	5.73	5.45	5.18		107.44
Total cost of investment		115.88	10.20	9.75	9.31	8.87	8.44	8.03		**170.48**

Investing in energy resilience in the education sector

Net costs and benefits (net present value, US$)

	2024-40	
	Optimistic	Climate impact
Total benefits	500,178,428	-174,326,292
Total costs	208,958,019	
Net benefits	291,220,409	-174,326,292
Benefit cost ratio	2.39	

Optimistic scenario (US$)

	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	Total
Existing enrolment: primary education	113,504	320,829	605,043	979,856	1,436,245	1,971,951	2,568,114	3,094,601	3,539,218	3,897,416	4,177,296	4,387,028	4,536,944	4,641,723	4,718,504	4,787,186	4,861,756	50,637,214
Existing enrolment: secondary education	256,589	690,255	1,924,286	3,667,243	5,875,825	8,466,391	10,372,799	11,598,342	12,277,523	12,567,623	12,697,780	12,841,857	13,000,295	13,173,586	13,362,270	13,566,942	13,788,250	160,127,855
Productivity impact	5,473,207	8,830,563	9,888,508	8,475,547	4,226,329	0	0	0	0	0	0	0	0	0	0	0	0	36,894,154
Indirect economic impacts: construction	228,449,754	2,774,628	2,375,774	1,972,044	1,563,051	1,186,398	865,501	538,981	206,443	0	0	0	0	0	0	0	0	239,932,575
Indirect economic impacts: O&M	11,984,252	145,554	124,631	103,452	81,996	62,237	45,403	28,274	10,830	0	0	0	0	0	0	0	0	12,586,630
Total benefits	246,277,306	12,761,830	14,918,242	15,198,141	13,183,447	11,686,977	13,851,816	15,260,198	16,034,014	16,465,038	16,875,076	17,228,885	17,537,239	17,815,309	18,080,774	18,354,128	18,650,006	**500,178,428**

Climate impact scenario (US$)

	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	Total
Impact of higher dropout rates: primary	-5,957	-20,835	-47,882	-92,430	-160,063	-258,635	-395,305	-573,579	-800,194	-1,074,865	-1,383,777	-1,712,058	-2,041,528	-2,348,326	-2,618,015	-2,837,653	-3,000,383	-19,371,486
Impact of higher drop-out rates: secondary	-24,845	-90,701	-290,531	-697,794	-1,430,669	-2,582,345	-4,028,298	-5,716,561	-7,420,660	-8,918,632	-9,993,788	-10,593,856	-10,862,395	-11,007,188	-11,164,843	-11,335,857	-11,520,771	-107,679,734
Productivity loss	-571,470	-1,770,150	-3,661,252	-6,360,414	-9,988,270	-12,105,789	-9,006,972	-3,810,755	0	0	0	0	0	0	0	0	0	-47,275,072
Total disbenefits	-602,273	-1,881,686	-3,999,665	-7,150,638	-11,579,001	-14,946,770	-13,430,574	-10,100,895	-8,220,854	-9,993,497	-11,377,565	-12,305,914	-12,903,924	-13,355,515	-13,782,858	-14,173,510	-14,521,154	**-174,326,292**

Total costs (US$)

	2024	2025	2026	2027	2,028	2,029	2,030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	Total
Grid connections: capex	88,875,167	1,079,430	924,262	767,196	608,083	461,551	336,711	209,683	80,314	0	0	0	0	0	0	0	0	93,342,397
Grid connections: opex	4,647,048	56,441	48,327	40,115	31,795	24,133	17,606	10,964	4,199	0	0	0	0	0	0	0	0	4,880,628
Grid connections: off-grid backup	18,606,244	225,981	193,497	160,614	127,304	96,627	70,491	43,898	16,814	0	0	0	0	0	0	0	0	19,541,470
Off-grid connections: capex	82,292,233	999,477	855,802	710,370	563,043	427,365	311,771	194,152	74,365	0	0	0	0	0	0	0	0	86,428,578
Off-grid connections: opex	4,536,904	55,103	47,182	39,164	31,041	23,561	17,188	10,704	4,100	0	0	0	0	0	0	0	0	4,764,947
Total cost of investment	198,957,595	2,416,432	2,069,069	1,717,460	1,361,266	1,033,238	753,767	469,400	179,792	0	0	0	0	0	0	0	0	**208,958,019**
Cost per school	22,308																	

Investing in energy resilience in the water sector

Net costs and benefits (net present value, US$)

	2024-40	
	Optimistic	Climate impact
Total benefits	5,249,617	-624,825
Total costs	1,652,978	
Net benefits	3,596,639	-624,825
Benefit cost ratio	3.18	

Optimistic scenario (US$)

	2024	2025	2026	2027	2028	2029	2030	Total
Spending on alternative water sources	-97,163	-70,435	-51,543	-38,306	-28,675	-22,683	-17,937	-326,743
Incidence of water-borne diseases	144,919	116,078	93,042	75,610	59,862	47,398	37,532	574,441
Agriculture sector impact pathway	505,927	369,155	269,357	196,539	143,407	104,638	76,350	1,665,373
Agriculture Multiplier	473,582	333,868	235,372	165,934	116,981	82,470	58,140	1,466,348
Indirect economic impacts	557,785	411,106	302,970	223,298	164,536	121,217	89,286	1,870,197
Total output	1,585,050	1,159,772	849,199	623,076	456,110	333,040	243,370	**5,249,617**

Climate impact scenario (US$)

	2024	2025	2026	2027	2028	2029	2030	Total
Spending on alternative water sources	16,426	11,862	8,648	6,403	4,775	3,763	2,964	54,840
Incidence of water-borne diseases	-39,059	-31,195	-24,927	-20,190	-15,930	-12,569	-9,917	-153,787
Agriculture sector impact pathway	-85,527	-62,172	-45,193	-32,851	-23,879	-17,357	-12,617	-279,597
Agriculture multiplier	-80,060	-56,229	-39,491	-27,736	-19,479	-13,680	-9,608	-246,282
Indirect economic impacts	0	0	0	0	0	0	0	0
Total output	-188,220	-137,733	-100,963	-74,374	-54,514	-39,844	-29,177	-624,825

Total costs (US$)

		2024	2025	2026	2027	2028	2029	2030	Total
New connections	Capex	367,492	280,333	213,826	163,112	124,395	94,852	72,311	1,316,321
	Opex	16,113	12,292	9,376	7,152	5,454	4,159	3,171	57,717
	Sub total	383,605	292,625	223,202	170,264	129,849	99,011	75,482	1,374,038
Backup connections	Capex	73,806	56,301	42,944	32,759	24,983	19,050	14,523	264,365
	Opex	4,069	3,104	2,368	1,806	1,377	1,050	801	14,575
	Sub total	77,875	59,405	45,312	34,565	26,360	20,100	15,323	278,940
Total cost of investment		461,480	352,030	268,514	204,829	156,210	119,111	90,805	**1,652,978**

Pakistan

Investing in energy resilience in the healthcare sector

Net costs and benefits (net present value, US$)

	Short term (2024-30)		Total (2024-44)	
	Optimistic	Climate impact	Optimistic	Climate impact
Total benefits	170,231,536	-25,777,545	296,609,892	-484,987,888
Total costs	128,124,282		128,124,282	
Net benefits	42,107,255	-25,777,545	168,485,610	-484,987,888
Benefit cost ratio	1.33		2.32	

Optimistic scenario (US$ m)

		2024	2025	2026	2027	2028	2029	2030	2044	Total
Short-term output	Maternal mortality	0.04	0.07	0.09	0.10	0.10	0.11	0.11		0.61
	Adult and infant mortality	0.32	0.57	0.73	0.81	0.87	0.91	0.93		5.13
	Disease burden	0.30	0.33	0.37	0.55	0.28	0.00	0.00		1.84
	Multiplier effects	44.32	21.53	20.77	20.03	19.32	18.66	18.02		162.65
	Total short-term incremental output	44.99	22.50	21.95	21.49	20.57	19.67	19.06		170.23
Long-term output	Immunisation impacts								126.38	126.38
	Total output	44.99	22.50	21.95	21.49	20.57	19.67	19.06	126.38	**296.61**

Climate impact scenario (US$ m)

		2024	2025	2026	2027	2028	2029	2030	2044	Total
Short-term output	Maternal mortality	-0.01	-0.03	-0.05	-0.08	-0.12	-0.15	-0.18		-0.62
	Adult and infant mortality	-0.14	-0.39	-0.72	-1.07	-1.45	-1.85	-2.26		-7.88
	Disease burden	-0.07	-0.21	-0.51	-1.77	-4.89	-5.00	-4.82		-17.27
	Multiplier effects									
	Total short-term incremental output	-0.22	-0.62	-1.28	-2.93	-6.46	-7.00	-7.27		-25.78
Long-term output	Immunisation impacts								-459.21	-459.21
Total output		-0.22	-0.62	-1.28	-2.93	-6.46	-7.00	-7.27	-459.21	**-484.99**

Total costs (US$ m)

		2024	2025	2026	2027	2028	2029	2030	2044	Total
New connections	Capex	14.37	0.04	0.03	0.02	0.00	0.00	0.00		14.46
	Opex	6.09	5.90	5.70	5.50	5.31	5.13	4.95		38.57
	Sub total	20.45	5.94	5.72	5.51	5.31	5.13	4.95		53.03
Backup connections	Capex	13.34	0.04	0.02	0.01	0.00	0.00	0.00		13.42
	Opex	9.74	9.43	9.11	8.79	8.49	8.20	7.92		61.68
	Sub total	23.08	9.47	9.13	8.81	8.49	8.20	7.92		75.10
Total cost of investment		43.53	15.41	14.86	14.32	13.80	13.33	12.87		**128.12**

Investing in energy resilience in the education sector

Net costs and benefits (net present value, US$)

	2024-40	
	Optimistic	Climate impact
Total benefits	2,268,255,625	-571,865,118
Total costs	945,010,506	
Net benefits	1,323,245,119	-571,865,118
Benefit cost ratio	2.40	

Optimistic scenario (US$)

	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	Total
Existing enrolment: primary education	245,217	747,574	1,503,063	2,512,372	3,783,297	4,863,698	5,819,700	6,496,310	7,019,889	7,398,574	7,640,085	7,751,747	7,740,506	7,612,956	7,387,566	7,093,211	6,757,363	92,373,127
Existing enrolment: secondary education	228,417	694,519	1,493,268	2,632,037	4,167,042	5,920,946	7,925,513	9,541,783	10,926,829	12,093,787	13,055,128	13,822,698	14,407,746	14,820,956	15,072,478	15,171,951	15,128,530	157,103,629
Productivity impact	16,176,262	31,374,899	45,193,507	57,667,133	69,170,892	77,038,195	82,897,098	84,788,522	84,742,481	82,912,330	79,441,465	74,463,946	68,105,074	60,481,941	51,703,934	41,873,221	31,085,200	1,039,116,101
Indirect economic impacts: construction	415,323,685	6,036,883	5,535,981	5,043,670	4,559,768	4,084,100	3,616,490	3,156,769	2,704,769	2,260,326	1,823,278	1,393,468	970,741	554,944	319,319	245,181	173,214	457,802,587
Indirect economic impacts: O&M	473,437,459	6,881,589	6,310,598	5,749,400	5,197,789	4,655,563	4,122,524	3,598,477	3,083,231	2,576,600	2,078,399	1,588,448	1,106,571	632,594	364,000	279,488	197,451	521,860,182
Total benefits	905,411,041	45,735,464	60,036,417	73,604,612	86,878,789	96,562,503	104,381,325	107,581,861	108,477,200	107,241,616	104,038,355	99,020,306	92,330,638	84,103,390	74,847,297	64,663,052	53,341,758	**2,268,255,625**

Climate impact scenario (US$)

	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	Total
Impact of higher dropout rates: primary	-10,234	-37,490	-89,001	-173,222	-301,002	-457,271	-647,870	-853,803	-1,085,321	-1,341,664	-1,622,110	-1,925,979	-2,252,625	-2,601,437	-2,959,619	-3,303,696	-3,611,335	-23,273,678
Impact of higher dropout rates: secondary	-7,730	-28,076	-69,478	-139,958	-250,905	-401,285	-602,004	-827,662	-1,086,197	-1,375,927	-1,695,243	-2,042,607	-2,416,544	-2,815,645	-3,238,561	-3,683,999	-4,150,723	-24,832,542
Productivity loss	-586,191	-1,803,235	-3,673,809	-6,238,799	-9,600,668	-13,400,300	-17,799,136	-22,262,789	-27,077,330	-32,206,934	-37,618,292	-43,280,448	-49,164,643	-55,244,177	-61,494,274	-67,891,954	-74,415,920	-523,758,898
Total disbenefits	-604,154	-1,868,801	-3,832,287	-6,551,979	-10,152,576	-14,258,855	-19,049,011	-23,944,254	-29,248,847	-34,924,524	-40,935,646	-47,249,033	-53,833,811	-60,661,259	-67,692,453	-74,879,649	-82,177,977	**-571,865,118**

Total costs (US$)

	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	Total
Grid connections: capex	132,429,343	1,924,910	1,765,193	1,608,215	1,453,919	1,302,248	1,153,147	1,006,562	862,438	720,723	581,367	444,319	309,529	176,948	101,818	78,178	55,231	145,974,087
Grid connections: opex	55,878,493	812,215	744,822	678,586	613,480	549,483	486,570	424,718	363,905	304,109	245,308	187,480	130,605	74,663	42,962	32,987	23,305	61,593,691
Grid connections: off-grid backup	118,061,715	1,716,071	1,573,682	1,433,735	1,296,179	1,160,964	1,028,039	897,357	768,869	642,530	518,293	396,113	275,947	157,751	90,771	69,696	49,239	130,136,952
Off-grid connections: capex	318,479,629	4,629,219	4,245,116	3,867,600	3,496,534	3,131,780	2,773,207	2,420,682	2,074,078	1,733,269	1,398,131	1,068,543	744,386	425,544	244,861	188,010	132,825	351,053,415
Off-grid connections: opex	232,475,040	3,379,111	3,098,734	2,823,165	2,552,304	2,286,051	2,024,310	1,766,983	1,513,979	1,265,204	1,020,569	779,986	543,367	310,627	178,737	137,239	96,956	256,252,361
Total cost of investment	857,324,220	12,461,525	11,427,546	10,411,301	9,412,417	8,430,527	7,465,273	6,516,302	5,583,269	4,665,836	3,763,668	2,876,441	2,003,834	1,145,533	659,149	506,111	357,554	**945,010,506**
Cost per school	25,056																	

Investing in energy resilience in the water sector

Net costs and benefits (net present value, US$)

	2024-40	
	Optimistic	Climate impact
Total benefits	148,836,301	-27,832,324
Total costs	95,062,079	
Net benefits	53,774,221	-27,832,324
Benefit cost ratio	1.57	

Optimistic scenario (US$)

	2024	2025	2026	2027	2028	2029	2030	Total
Spending on alternative water sources	7,731,096	5,620,994	4,052,309	2,923,144	2,103,893	1,525,838	1,101,659	25,058,933
Incidence of water-borne diseases	2,549,014	1,791,455	1,281,042	906,257	651,410	458,365	323,947	7,961,490
Agriculture sector impact pathway	6,519,822	4,294,526	2,828,751	1,863,263	1,227,309	808,413	532,492	18,074,576
Agriculture Multiplier	2,180,950	1,387,986	883,332	562,164	357,769	227,689	144,904	5,744,795
Indirect economic impacts	34,335,145	22,007,317	14,182,618	9,169,959	5,941,461	3,856,175	2,503,833	91,996,508
Total output	53,316,027	35,102,278	23,228,052	15,424,788	10,281,841	6,876,480	4,606,835	**148,836,301**

Climate impact scenario (US$)

	2024	2025	2026	2027	2028	2029	2030	Total
Spending on alternative water sources	-1,418,459	-1,615,007	-1,622,022	-1,529,202	-1,381,798	-1,223,957	-1,057,903	-9,848,348
Incidence of water-borne diseases	-1,420,610	-1,576,542	-1,579,411	-1,465,869	-1,326,246	-1,141,769	-967,157	-9,477,602
Agriculture sector impact pathway	-1,196,221	-1,233,890	-1,132,267	-974,740	-806,074	-648,472	-511,342	-6,503,006
Agriculture Multiplier	-400,149	-398,792	-353,572	-294,088	-234,976	-182,641	-139,149	-2,003,368
Indirect economic impacts	0	0	0	0	0	0	0	0
Total output	-4,435,440	-4,824,232	-4,687,271	-4,263,899	-3,749,094	-3,196,838	-2,675,550	**-27,832,324**

Total costs (US$)

		2024	2025	2026	2027	2028	2029	2030	Total
New connections	Capex	14,113,609	9,362,820	6,245,056	4,179,147	2,802,553	1,882,598	1,265,164	39,850,946
	Opex	7,066,937	4,688,131	3,127,011	2,092,574	1,403,289	942,651	633,490	19,954,082
	Sub total	21,180,546	14,050,951	9,372,067	6,271,721	4,205,842	2,825,249	1,898,654	59,805,028
Backup connections	Capex	7,217,906	4,788,283	3,193,813	2,137,277	1,433,267	962,788	647,023	20,380,357
	Opex	5,268,729	3,495,220	2,331,332	1,560,111	1,046,217	702,790	472,296	14,876,695
	Sub total	12,486,636	8,283,502	5,525,145	3,697,388	2,479,483	1,665,578	1,119,319	35,257,051
Total cost of investment		33,667,181	22,334,453	14,897,211	9,969,108	6,685,325	4,490,827	3,017,973	**95,062,079**

Appendix II: Methodology

Methodology Note

The findings from this research are based on analysis conducted by Economist Impact, supported by UNICEF, to quantify the costs and benefits of alternative investment pathways towards providing resilient energy to three key public services: healthcare, education and water utilities. The findings are based on insights gathered from a literature review, expert interviews and a custom model developed by Economist Impact. The technical annex details the methodology used in conducting the analysis.

Developing the methodology

The methodology was developed based on the research conducted through a literature review, expert interviews and a data audit. Combined, this research has informed a methodology that is robust and relevant to the research question, while also feasible based on the availability of data.

Literature review

Our methodological framework, theoretical underpinnings and selection of impact pathways were informed by the insights of an extensive literature review. This review encompassed a diverse range of sources including global, regional and country-specific studies authored by academic institutions, governmental bodies, international organisations and private sector entities. The literature covered diverse aspects, including, but not limited to, the prevailing status of electricity provision within healthcare facilities, educational institutions, and water utilities. Furthermore, it delved into the indirect societal benefits associated with each model, such as reductions in maternal mortality rates, mitigated school dropout rates, and improved household and agricultural water supply. Additionally, attention was directed towards comprehensively understanding the costs entailed in the construction, operation and maintenance of energy-resilient infrastructure.

Expert interviews and consultations

In formulating our methodology and conducting the subsequent analysis, we engaged in a series of one-on-one interviews with 12 individuals. These experts, drawn from a diverse array of professional backgrounds, spanning academia, governmental agencies, international organisations and non-profits, contributed valuable insights and validation to our theory of change and model methodology. Furthermore, their expertise in energy provision, healthcare, education and water proved instrumental in directing us towards pertinent datasets essential for our research.

Moreover, we convened an advisory board session comprising nine esteemed experts to further refine our methodology and validate our findings. During this session, we also delved into discussions regarding the fundamental barriers and constraints encountered by private sector investors when contemplating investments in energy and climate resilience solutions within developing nations.

Data audit

A comprehensive data audit of available datasets on healthcare, education and water utilities contributed to shaping our model methodology and guiding our selection of countries. In conducting this data audit, we analysed key databases and tools. These include:

- The World Bank Enterprises Survey, providing comprehensive global data on energy access, usage patterns and outage frequencies.[163]
- The Institute for Health Metrics and Evaluation (IHME), for most healthcare statistics.[164]
- UNESCO, particularly for datasets aligning with SDG 4.0, focusing on education.[165]
- WHO/UNICEF Joint Monitoring Programme (JMP), offering global data on water utilisation patterns.[166]

Defining resilient energy systems and its impacts

The two common threads in otherwise diverging definitions of resilience in the literature are: 1) extreme, unexpected or unknown threats regardless of the likelihood of their occurrence; and 2) the ability and capacity to bounce back. Therefore, for the purpose of this research, we define resilience as the ability of the energy system to survive and quickly recover from extreme and unexpected disruptions in ways that maintain its essential functionality. Energy resilience is our independent variable.

The essential functionality depends on a narrower definition of "energy".[167] For instance, a continuous, reliable, stable and flexible supply of ***electricity*** keeps the lights on, appliances running, and heating, ventilation, and air conditioning (HVAC) operating. For ***oil and gas***, it means that the manufacturing industry keeps producing, vehicles continue moving and the aviation industry keeps operating. For biofuel, it means that homes are kept continually warm and power turbines running.

The analysis conducted for this report estimates the costs of inaction in resilient energy systems, specifically for electricity, using a cost-benefit analysis. It quantitatively measures the costs of investments in resilient energy systems and its impacts on the economy through three sectors: 1) healthcare in public hospitals and non-hospitals; 2) education in primary and secondary schools; and 3) water utilities in municipal services and irrigated agriculture.

Analysis scope

Country selection

The objective of this research was to estimate the cost of inaction in resilient energy systems in two selected countries: Tanzania and Pakistan. The selection of these countries was based on several key criteria:

- **Geographic representation**: we aimed to capture a diverse representation of the developing world by selecting one country from Africa (Tanzania) and one from Asia (Pakistan).
- **Availability of data**: this was a pivotal criterion in country selection. Both Tanzania and Pakistan boast the most recent data available for the metrics covered in this analysis, ensuring robustness and reliability across our analysis.

Scenarios

We estimate the total socioeconomic benefits of energy resilience across three distinct scenarios, each tailored to specific needs and challenges from the healthcare, education and water sectors:

1. **Baseline scenario:** this scenario represents the steady state of energy resilience in the sector in which we assume that electrification rates and power outages are projected using their historical levels or the historical rate of growth for the period under consideration. Moreover, all the available outcome indicators, such as mortality rates, productivity, attendance rates, water withdrawals, are also projected without any intervention in energy resilience.
2. **Optimistic scenario:** under this scenario, we assume that the sectors under consideration reach 100% energy resilience by 2024 through a combination of investments in resilient energy systems. Crucially, we are not distinguishing between the type of energy system (green vs fossil-fuel based), although the need for green energy systems is qualitatively discussed throughout the report. Quantitative estimation of the resulting benefits on all the outcome indicators is based on data availability. The difference between baseline and optimistic scenarios represents the potential benefits derived from investing in resilient energy systems.
3. **Climate impact scenario:** this scenario incorporates the negative impacts of climate change on the wider economy through the lens of energy resilience within each of the three sectors. First, we estimate the percentage decline in energy resilience that is associated with climate change based on existing literature. Second, we assess the impact of reduced energy resilience on all the outcome indicators. Finally, the difference between baseline and climate impact scenarios is estimated as the lost benefit to the economy due to energy resilience.

Detailed methodology and assumptions

We devised three distinct cost-benefit models to evaluate the repercussions of inaction in resilient energy systems across three critical sectors: healthcare, education and water supply. Specifically, our approach involved quantifying the financial outlays associated with investments in resilient energy systems and their resultant economic impacts within these sectors. This encompassed:

- Healthcare: focusing on public hospitals and healthcare facilities.
- Education: targeting primary and secondary schools.
- Water: spanning municipal services and the agriculture sector

These models were designed for the specific contexts of Tanzania and Pakistan. Inputs into the models comprised various investments aimed at bolstering energy system resilience, while outputs were delineated to define electricity resilience in quantitative terms. Outcome and impact assessments were sector specific. To measure the benefits of resilient energy systems on the economy, we considered the three distinct scenarios detailed above.

Furthermore, we operationalise energy resilience as: a) the percentage of the population with access to electricity (E); and b) the total hours of power outages in a typical month (N*D), where N denotes the average number of power outages and D signifies the duration in hours.

Figure 2: Modelling framework

Inputs	Outputs	Outcomes	Impacts
Measure the costs of investments in resilient energy systems	Measure the change in energy resilience resulting from investments	Measure the sector-specific outcomes defined in the impact pathways	Measure the total benefit to the economy in monetary terms

Education model

We draw on literature to develop distinct pathways that identify the impact of increased energy resilience on the education sector. We begin by building a country-level energy resilience baseline drawing on the following data points, after which we quantify the impacts of increased resilience across each pathway.

Baseline data:

Measure	Source
Proportion of government and non-government schools with access to electricity, primary education (%)	UN Statistics - SDG4
Proportion of government and non-government schools with access to electricity, secondary education (upper and lower) (%)	UN Statistics - SDG4
Number of government and non-government schools, primary education	National Education Statistics
Number of government and non-government schools, secondary education	National Education Statistics
Number of schools (primary and secondary) with no access to electricity	Economist Impact calculation

For the education model, we estimate impacts between 2024 and 2040 and discount future costs and benefits to present terms using a 3.5% discount rate.

Key impact pathways

School graduation pathway

This pathway captures the impact of resilient energy provision on the dropout and graduation rates of primary and secondary enrolled pupils, and the subsequent impact of higher graduation rates on overall labour market earnings.

We define dropout rates as the number of enrolled students that don't complete the school year over the total number of enrolled students. Where available we used dropout rates provided by national education statistics. And where those statistics are not available, we used historical enrolment data.

As increased primary/secondary school electrification reduces the dropout rates of enrolled pupils, more pupils will graduate at each level of education. Our model quantifies the difference in total earnings by comparing the graduation rates of primary/secondary education relative to the baseline and the wage differences between these levels of education. In other words, with more children completing higher levels of education, the average wage in the economy will increase.

The first step in deriving the impacts of the school graduation pathway is to calculate the baseline dropout rates of primary and secondary schools (where these are not given by national education statistics) based on historical enrolment data. We then calculate the optimistic dropout rates based on a literature-based parameter, ΔDROP, which identifies the difference in dropout rates between electrified and non-electrified schools.

The number of averted dropouts at each level of education is calculated by subtracting the number of dropouts in the baseline by the number of dropouts in the optimistic scenario.

Of the children who remain in education who would have previously dropped out, we then calculate the additional number who eventually enter the labour force with different levels of qualifications. By multiplying by the equilibrium wages, estimated based on country-specific data, we calculate the total change in labour market earnings over the modelled time period.

Parameters	Definition	Value	Primary source
ΔDROP	Impact of electrification on primary/secondary school dropout rates (% change)	27%	https://publications.iadb.org/en/brighter-future-impact-rural-school-electrification-programs-dropout-rate-primary-education-brazil

Labour market productivity pathway

This pathway captures the additional wage benefits across secondary school cohorts resulting from improvements in energy resilience. Students in secondary schools that have resilient energy are able to develop more robust IT and digital skills. This boosts their expected earnings when entering the labour market, implying higher productivity in the economy.

We estimate the impact of this pathway by first calculating the wage differential for school cohorts that are graduating from non-electrified schools and electrified schools in the baseline case. We derive the wages for both types of schools using a weighted average formula based on the equilibrium market wage in a country (w) and ΔEARN, the percentage difference in earnings between cohorts graduating from electrified schools versus those graduating from non-electrified schools:

$$w=((w_{ne} * n_v) + ((1+x_{par})* w_{ne} * n_n))/ (n_v + n_n)$$

Where:

- w: Equilibrium market wage of all graduates of secondary school
- w_{ne}: Equilibrium wages of graduates of secondary school with no access to electricity
- n_v: Number of secondary school children enrolled in school with no access to electricity
- n_n: Number of secondary school children enrolled in schools with access to electricity
- ΔEARN: percentage difference between earnings of secondary school attendees with electrified schools vs non-electrified schools

As our optimistic case assumes 100% secondary school electrification, we calculate the difference between our equilibrium wage in our baseline and the full electrification equilibrium wage. This gives us the wage differential that we apply to our graduating secondary cohorts entering the labour market to estimate the additional wage earnings of secondary school graduates due to electrification.

Parameters	Definition	Value	Primary source
ΔDROP	% difference between earnings in children attending schools with and without electricity	55%	https://www.annualreviews.org/doi/full/10.1146/annurev.energy.30.050504.144228

Indirect economic pathway

This pathway measures the indirect economic impact of spending (costs) on the electrification of schools on other economic sectors, namely construction and electricity. Impacts on the construction sector are captured through the additional capital expenditure in electrifying schools while electricity sector impacts are captured through the operational and maintenance expenditure running electrified schools.

The indirect economic impacts of construction and maintenance of electrified school infrastructure is calculated as follows where CAPEX is the capital expenditure and OPEX is the operational expenditure of investment in resilient energy systems for school infrastructure.

- Economic impact, construction (US$) = $(CAPEX_{grid} + CAPEX_{off\text{-}grid} + \text{Backup costs}_{capex}) * (MULTc\text{-}1)$
- Economic impact, O&M (US$) = $(OPEX_{grid} + OPEX_{off\text{-}grid} + \text{Backup costs}_{opex}) * (MULT_e\text{ -}1)$

Where:

- $MULT_c$: Construction multiplier
- $MULT_e$: Operations and maintenance multiplier

Parameters	Definition	Value	Primary source
$MULT_c$ Construction multiplier: Tanzania	Total economic impact (direct, indirect and induced) for every additional dollar of investment in the construction sector	2.21	https://set.odi.org/wp-content/uploads/2015/08/Using-a-Social-Accounting-Matrix-to-Calculate-Output-and-Employment-Effects-in-Tanzania.pdf
$MULT_c$ Construction multiplier: Pakistan	Total economic impact (direct, indirect and induced) for every additional dollar of investment in the construction sector	1.80	https://www.adb.org/what-we-do/data/regional-input-output-tables
$MULT_e$ Operation and maintenance multiplier: Tanzania	Total economic impact (direct, indirect and induced) for every additional dollar of investment in the electricity sector	2.18	https://set.odi.org/wp-content/uploads/2015/08/Using-a-Social-Accounting-Matrix-to-Calculate-Output-and-Employment-Effects-in-Tanzania.pdf
$MULT_e$ Operation and maintenance multiplier: Pakistan	Total economic impact (direct, indirect and induced) for every additional dollar of investment in the electricity sector	2.40	https://www.adb.org/what-we-do/data/regional-input-output-tables

Calculating investment costs

We quantify the costs of electrifying all schools, both primary and secondary. These costs include the capital expenditure costs of connecting schools to the grid or installing an off-grid PV system, as well as the operational costs associated with ensuring electricity access to the school 100% of the time. The costs of installing backup systems are also quantified for grid-based connections. The calculation methodology is based on the World Health Organization's Energising health: accelerating electricity access in health-care facilities publication, with integration of assumptions relevant to the education sector.

Parameters	Definition	Value	Primary source
ELE_{NH}	Estimated daily electricity requirement (non-hospital) (kWh)	15	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023
ELE_{H}	Estimated daily electricity requirement (hospital) (kWh)	1500	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023
LF_{NH}	Load factor (non-hospital)	0.15	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023
LF_{H}	Load factor (hospital)	0.21	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023
GRID	% of grid-based coverage of the country	0.93	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023
NGRID	% of off-grid-based coverage of the country	0.07	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023
$CAPEX_{GRID}$	Grid capital expenditure ($/kW)	7,199.10	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023
$CAPEX_{NGRID}$	Off-grid capital expenditure ($/kW)	2,856.80	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023
$OPEX_{NGRID}$	Off-grid operating expenditure ($/kW)	157.50	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023
$OPEX_{GRID}$	Grid operating expenditure ($/kW)	376.42	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023
ALTPEAK	Backup peak load (a combined PV–battery–diesel off-grid backup system was considered, based on assumptions developed by the WHO)	0.5	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023

Water model

We draw on literature to develop distinct pathways that identify the impact of increased energy resilience on the water sector. We begin by building a country-level energy resilience baseline drawing on the following data points, after which we quantify the impacts of increased resilience across each pathway.

For the water model, we estimate impacts between 2024 and 2030 and discount future costs and benefits to present terms using a 3.5% discount rate.

Baseline data:

Measure	Source
Number of power outages in a typical month	World Bank - Enterprise Surveys
Average duration of a typical electrical outage (hours)	World Bank - Enterprise Surveys
Total hours of outages in a typical month	
Number of power outages in a typical month (optimistic scenario)	Assumed to be zero under optimistic scenario
Average duration of a typical electrical outage (hours) (optimistic scenario)	Assumed to be zero under optimistic scenario
Total hours of outages in a typical month (optimistic scenario)	

Key impact pathways

Municipal services pathway

This pathway captures the impact of resilient energy provision on the quality and quantity of water supplied by the municipal water services/water utilities. It also explores the subsequent impacts on household spending on alternative water sources and economic output associated with water-borne diseases.

1. **Impact on spending on alternative water sources**: our model estimates the cost savings that can be generated from additional supplies of piped water for household purposes when power outages in the water sector are reduced, and a subsequent reduction in the usage of water from expensive alternative sources such as tankers. We calculate the cost savings for households accessing water through private sources as a product of the following:

   a) the additional volume of water supplied by the water sector as a result of reduced power outages, calculated based on the population relying on private tanker water (PRI), the additional number of hours of electricity under an optimistic scenario (the reduction in hours of power outage), and the additional volume of water supplied for every additional hour of power (WAT_{Elec})

   b) the difference in per unit price of water from alternative private sources ($PWAT_{Pri}$) and from piped source ($PWAT_{Pipe}$)

   These calculations estimate the reduced spending for households previously substituting piped water for private sources who see a decline in prices. The analysis also accounts for increased spending on piped water for households not previously relying on private water supply.

Parameters	Definition	Value	Primary source
WAT_{Elec}	Increase in volume of water (litres) supplied per capita per day with an additional hour of electricity supplied	0.92	https://www.ochaopt.org/content/increased-electricity-supply-improves-access-water-and-sanitation-gaza
PRI	% of population relying on tanker water (privately sources)	4.9	https://documents1.worldbank.org/curated/en/633471519163338316/pdf/123627-REVISED-W17084.pdf
$PWAT_{Pri}$	Annual cost of tanker water (US$/m3)	9.7 (for 2024)	https://www.researchgate.net/publication/283500874_Services_and_Supply_Chains_The_role_of_the_domestic_private_sector_in_water_service_delivery_in_Tanzania
$PWAT_{Pipe}$	Annual cost of piped water (US$/m3)	0.59 (for 2024)	https://twaweza.org/wp-content/uploads/2021/05/Water-kiosks-in-DSM-Englsih.pdf

2. **Impact on economic output related to water-borne diseases:** our model estimates the additional economic output that can be generated with improved labour productivity resulting from a decline in the incidence of water-borne diarrhoeal diseases when there is a reduction of power outages in the water sector. We calculate additional economic output based on the reduced incidence of diarrhoeal diseases (calculated based on the baseline incidence of disease and INC_{Wat}) among the labour force and the productivity difference between infected and healthy workers ($\Delta PROD_{Disease}$).

   As a first step, we calculate the additional hours of water service provided to households as a result of reduced power outages. We next estimate the reduction in likelihood of the incidence of gastrointestinal diseases (drawing on parameter INC_{Wat} and parameter ΔINC_{Wat}). Based on the estimated change in incidence, we calculate the specific reduction in cases of diarrhoeal disease for those in the labour force with access to piped water.

   Applying a literature-based parameter on the decline in productivity associated with diarrheal disease, we estimate the additional output resulting from averted cases of disease.

Parameters	Definition	Value	Primary source
INC_{Wat}	% likelihood of gastrointestinal diseases in people living in an area with water outage for one hour compared with people living in an area with no water outage	1.9375	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3198703/
$\Delta PROD_{Disease}$	% reduction in output per worker in an individual with gastrointestinal disease compared with a healthy person	20.7	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5310011/
$DUR_{Disease}$	Average duration of a persistent case of diarrhoea (days)	7	https://www.nhsinform.scot/illnesses-and-conditions/stomach-liver-and-gastrointestinal-tract/diarrhoea/
DIS_{Wat}	Proportion of cases of diarrhoea attributable to unsafe water, sanitation and hygiene	94	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9899848/
ΔINC_{Wat}	% reduction in the likelihood of reporting diarrhoeal diseases among those with piped water supply, compared with those without	72	https://bmcpublichealth.biomedcentral.com/articles/10.1186/1471-2458-13-1145

Agriculture output pathway

This pathway captures the impact of resilient energy provision on the quantity of water supplied to the agriculture sector, and its subsequent impact on agricultural output and other economic sectors reliant on agriculture.

1. **Impact on total agricultural output:** our model quantifies the additional agricultural output that can be produced with additional water inputs resulting from reduced power outages in the water sector. We calculate the additional output based on the marginal productivity of water in agricultural production, using the following production function:

   Y = K^(a) * L^(b) * W ^(1-a-b)

   Where:

   - Y: Total agricultural output
   - K: Capital inputs in agriculture (excluding water)
   - L: Labour inputs in agriculture
   - W: Water inputs in agriculture
   - a: share of returns to capital in agriculture (excluding water)
   - b: share of returns to labour in agriculture

   Using this production function, the marginal productivity of water (MPW) is calculated as:

   MPW = (Y/W)* (1-a-b)

where Y/W is the agricultural output per unit of water, and (1-a-b) is the estimated share of water in agricultural production, estimated based on input output tables.

Parameters	Definition	Value	Primary source
Y/W	Agricultural output per unit of water in agriculture (US$/m³)	0.031 (Pakistan); 2.1 (Tanzania)	FAOSTAT
1-a-b	Share of water as an input in agricultural production	0.46% (Pakistan); 1.47% (Tanzania)	Economist Impact estimates based on country input-output tables

It should be noted that in this pathway, we focus on the impact of supplying resilient electricity on water generated for irrigation in agriculture as a whole, and do not distinguish between how and where the water is generated (piped water supply or groundwater pumping).

2. **Impact on other economic sectors:** our model uses type-I multipliers (country and sector specific) to estimate the wider economic activity, measured by output generated, in other sectors of the economy as a result of increased agricultural output.

Parameters	Definition	Value	Primary source
$MULT_{ag}$ Agriculture multiplier: Tanzania	Total economic impact (direct, indirect and induced) for every additional dollar of output in the agricultural sector	1.94	https://set.odi.org/wp-content/uploads/2015/08/Using-a-Social-Accounting-Matrix-to-Calculate-Output-and-Employment-Effects-in-Tanzania.pdf
$MULT_{ag}$ Agriculture multiplier: Pakistan	Total economic impact (direct, indirect and induced) for every additional dollar of output in the agricultural sector	1.33	https://data.adb.org/dataset/economic-insights-input-output-tables-asia-and-pacific

Indirect economic pathway

This pathway measures the indirect economic impact of spending (costs) on the electrification of the water sector on other economic sectors, namely construction and electricity. Impacts on the construction sector are captured through the additional capital expenditure in electrifying the water sector while electricity sector impacts are captured through the operational and maintenance expenditure of providing electricity to the water sector.

The indirect economic impacts of the construction and maintenance of the electrified water sector infrastructure is calculated as follows, where CAPEX is the capital expenditure and OPEX is the operational expenditure.

- Economic impact, construction (US$) = $(CAPEX_{grid} + CAPEX_{off\text{-}grid} + \text{Backup costs}_{capex}) * (MULT_c - 1)$
- Economic impact, O&M (US$) = $(OPEX_{grid} + OPEX_{off\text{-}grid} + \text{Backup costs}_{opex}) * (MULT_e - 1)$

Where:

- $MULT_c$: Construction multiplier
- $MULT_e$: Operations and maintenance multiplier

Parameters	Definition	Value	Primary source
$MULT_c$ Construction multiplier: Tanzania	Total economic impact (direct, indirect and induced) for every additional dollar of investment in the construction sector	2.21	https://set.odi.org/wp-content/uploads/2015/08/Using-a-Social-Accounting-Matrix-to-Calculate-Output-and-Employment-Effects-in-Tanzania.pdf
$MULT_c$ Construction multiplier: Pakistan	Total economic impact (direct, indirect and induced) for every additional dollar of investment in the construction sector	1.80	https://www.adb.org/what-we-do/data/regional-input-output-tables
$MULT_e$ Operation and maintenance multiplier: Tanzania	Total economic impact (direct, indirect and induced) for every additional dollar of investment in the electricity sector	2.18	https://set.odi.org/wp-content/uploads/2015/08/Using-a-Social-Accounting-Matrix-to-Calculate-Output-and-Employment-Effects-in-Tanzania.pdf
$MULT_e$ Operation and maintenance multiplier: Pakistan	Total economic impact (direct, indirect and induced) for every additional dollar of investment in the electricity sector	2.40	https://www.adb.org/what-we-do/data/regional-input-output-tables

Calculating investment costs

We first estimate the additional amount of electricity that would be available for water utilities to use under the optimistic scenario (supply of resilient electricity to all water utilities). We do this by multiplying the energy used to produce water (by water utilities) in an hour (ELE_{WAT}) with the total number of additional hours of electricity supplied to the water utilities when there is no power outage. After estimating the annual amount of additional electricity available under an optimistic scenario with no power outages in the water sector, we calculate the investment cost of developing infrastructure and operation and maintenance to generate this level of electricity. The includes the capital expenditure costs of connecting water utilities to the grid ($CAPEX_{GRID}$) or installing an off-grid PV system ($CAPEX_{NGRID}$), as well as operational costs ($OPEX_{GRID}$ and $OPEX_{NGRID}$) associated with ensuring electricity access to the water utilities 100% of the time. The costs of installing backup systems are also quantified for grid-based connections.

Parameters	Definition	Value	Primary source
TOTELE	Total electricity consumption in country X, annual (kWh)	Varies by country and year	https://data.worldbank.org/indicator/EG.USE.ELEC.KH.PC?locations=TZ
$ELECONS_{WAT}$	Proportion of total electricity consumed by water utilities (%)	1.5	https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2015/4-mobility-transport-and-smart-and-sustainable-cities/energy-efficiency-in-action-giz-tackles-the-water-energy-nexus-in-tanzania/
$ELEHR_{WAT}$	Number of hours of electricity available to water utilities in a day	Varies by country and year	Calculated as: The difference between the total number of hours and total hours of power outage in a month, and divided by 30 (24*30)-power outage hours)/30
ELE_{WAT}	Energy used to produce water (by water utilities) hourly (kWh)	Varies by country and year	Calculated as: $E/(12*30*ELEHR_{wat})$
ALTPEAK	Backup peak load (a combined PV–battery–diesel off-grid backup system was considered, based on assumptions developed by the WHO)	0.5	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023
$CAPEX_{GRID}$	Grid capital expenditure (US$/kW)	7,199.10	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023
$OPEX_{GRID}$	Grid operating expenditure (US$/kW) assumed to be 2x the off-grid operational expenditure	376.2	Assumption
$CAPEX_{NGRID}$	Off-grid capital expenditure (US$/kW)	2856.8	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023
$OPEX_{NGRID}$	Off-grid operating expenditure (US$/kW)	157.5	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023
$GRID_{WAT}$	% of grid-based coverage of the water sector	98.00%	https://www.tanesco.co.tz/attachments/investments/investment_reports/WiYQwYs5IKH-KkgiIEGW8WSowqf_nsG3K_POWER%20SYSTEM%20MASTER%20PLAN%202020%20UPDATE_2023_09_12_07_39_38.pdf
$NGRID_{WAT}$	% of off-grid-based coverage of water sector	2.00%	https://www.tanesco.co.tz/attachments/investments/investment_reports/WiYQwYs5IKH-KkgiIEGW8WSowqf_nsG3K_POWER%20SYSTEM%20MASTER%20PLAN%202020%20UPDATE_2023_09_12_07_39_38.pdf

Healthcare model

We draw on literature to develop distinct pathways that identify the impact of increased energy resilience on the healthcare sector. We begin by building a country-level energy resilience baseline drawing on the following data points, after which we quantify the impacts of increased resilience across each pathway.

For the healthcare model, we estimate impacts between 2024 and 2030 and discount future costs and benefits to present terms using a 3% discount rate.

Key outputs:

Inputs and calculations	Measure	Source
N_{Base}	Number of power outages in a typical month	World Bank - Enterprise Surveys
D_{Base}	Average duration of a typical electrical outage (hours)	World Bank - Enterprise Surveys
$G_{Base} = N_{Base} \times D_{Base}$	Total hours of outages in a typical month	Economist Impact calculation
N_{Opt}	Number of power outages in a typical month (optimistic scenario)	Assumed to be zero under optimistic scenario
D_{Opt}	Average duration of a typical electrical outage (hours) (optimistic scenario)	Assumed to be zero under optimistic scenario
$G_{Opt} = N_{Opt} \times D_{Opt}$	Total hours of outages in a typical month (optimistic scenario)	Economist Impact calculation

Key impact pathways

Maternal mortality pathway

This pathway captures the impact of resilient energy provision on economic output through averting maternal deaths in healthcare facilities. An increase in the number of healthcare facilities with access to electricity reduces maternal mortality and, as a consequence, increases the number of women in the workforce. This, in turn, increases the output due to more people in the workforce.

To estimate this pathway, we first calculate the change in maternal mortality due to electrification. Based on the parameter, $\Delta MATDEATH_{ELE}$, and the change in the healthcare facilities with no access to electricity between the baseline and the optimistic scenario, we derive the change in in-facility maternal mortality due to electrification.

We convert this into the number of maternal deaths averted in the optimistic scenario using the new maternal mortality rate due to 100% electrification. The difference between the maternal deaths in an optimistic scenario and in our baseline is our averted maternal deaths. This number is used to calculate the cumulative benefits to the economy over the modelled period by multiplying the averted maternal deaths by output per worker.

Parameters	Definition	Value	Primary source
$\Delta MATDEATH_{ELE}$	Decrease in the number of maternal deaths in health facilities due to the availability of electricity	61%	https://obgyn.onlinelibrary.wiley.com/doi/pdfdirect/10.1016/j.ijgo.2007.05.019

Adult and infant mortality pathway

This pathway captures the impact of energy resilience on the number of children and adult deaths averted and the subsequent impacts on workforce and economic output, excluding averted maternal deaths captured in the pathway discussed above.

Our model quantifies the impact of electricity outages in healthcare facilities on the number of adult and infant deaths, and the subsequent number of people in the workforce. A decrease in the number of electricity outages in healthcare facilities reduces the number of adult deaths and, as a consequence, increases the number of people in the workforce. This, in turn, increases the output due to more people in the workforce.

To calculate the number of averted deaths and how they increase economic output, we first calculate the difference in power outages between our optimistic (0% power outages) and baseline case. Using this difference, we apply the parameter $\Delta MORT_{ELE}$ to this difference and multiply by the baseline in-facility mortality. This gives us the difference between the optimistic and the baseline in-facility mortality.

We then calculate the total number of deaths averted from the difference in the in-facility mortality rate. This gives us the total number of deaths averted by achieving 100% energy resilience in healthcare facilities. We segment the total deaths by population under and over 14 years of age. This enables us to calculate how many of the averted deaths are providing labour in the economy for each year. Multiplied by the output per worker in the economy, we obtain an estimate of total increase in output.

Parameters	Definition	Value	Primary source
$\Delta MORT_{ELE}$	Increase in in-facility mortality for each day the power was out for over two hours	43%	https://www.researchgate.net/publication/306269348_The_effect_of_power_outages_on_in-facility_mortality_in_healthcare_facilities_Evidence_from_Ghana

Immunisation impact pathway

This pathway captures the impact of energy resilience on the vaccination rates and cold chains. We subsequently measure the impact on child mortality, workforce, output and the costs associated with immunisation strategies. This pathway is divided into two parts. The long-term immunisation impact captures how electrification drives child immunisation and brings about economic benefits in the longer term. The short-term immunisation impact captures the cost savings delivered to the healthcare system by having lower levels of morbidity that can be averted by higher vaccination rates.

1. **Long-term immunisation impact:** our model quantifies the impact of electricity access in healthcare facilities on child immunisation and infant mortality rates, labour force participation, and additional output provided in the long term. An increase in the number of healthcare facilities with energy access leads to a greater rate of child immunisation and lower infant mortality. In turn, there is an increase in the number of people entering the workforce in the long term and an increase in the total output.

   The increase in child immunisation due to electrification is calculated from the difference between the baseline and optimistic electrification rates and the impact of electrification on vaccination rates ($\Delta VACC_{ELE}$). This gives the increase in child immunisation due to higher health facility electrification. We calculate the difference between optimistic and baseline infant mortality rates from the increase in the child immunisation rate using the parameter $\Delta MORT_{VACC}$.

   Next, we use the change in the infant mortality rate to calculate the number of averted deaths in the optimistic scenario from 2024 to 2030. This gives us the number of averted infant deaths for any given year. For each year, we estimate the time period when these individuals will enter the labour force (14 years later). We then calculate the labour market impacts from this period until 2044.

Parameters	Definition	Value	Primary source
$\Delta VACC_{ELE}$	Increase in full-course vaccination rates following the electrification of healthcare facilities	0.121	https://link.springer.com/article/10.1186/s41043-019-0164-6#Tab6
$\Delta MORT_{VACC}$	Impact of polio, BCG or measles vaccinations on the infant mortality rate	0.22	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9194613/

2. **Short-term immunisation impact:** our model quantifies the impact of electricity access in healthcare facilities on the disease burden and the health costs associated with improved immunisation. An increase in the number of healthcare facilities with energy access leads to a decrease in the incidence of disease. Additionally, we also measure the costs associated with immunisation strategies.

   Using the change in child immunisation coverage calculated in the long-term immunisation impact, we calculate the rate of children getting vaccinated effectively using parameter EFF. This allows us to calculate the reduction in the incidence of measles in the optimistic scenario compared with the baseline, and the reduction in costs incurred in treating measles.

Parameters	Definition	Value	Primary source
EFF	Measles vaccine efficacy	0.99	https://www.ncbi.nlm.nih.gov/books/NBK554450/

Indirect economic pathway

This pathway measures the indirect economic impact of spending (costs) on the electrification of healthcare on other economic sectors, namely construction and electricity. Impacts on the construction sector are captured through the additional capital expenditure in electrifying hospitals while electricity sector impacts are captured through the operational and maintenance expenditure of running electrified hospitals.

The indirect economic impact of construction and maintenance of electrified healthcare infrastructure is calculated as follows, where CAPEX is the capital expenditure and OPEX is the operational expenditure of investment in resilient energy systems for healthcare infrastructure.

- Economic impact, construction (US$) = $(CAPEX_{grid} + CAPEX_{off\text{-}grid} + \text{Backup costs}_{capex}) * (MULT_c - 1)$
- Economic impact, O&M (US$) = $(OPEX_{grid} + OPEX_{off\text{-}grid} + \text{Backup costs}_{opex}) * (MULT_e - 1)$

Where:

- $MULT_c$: Construction multiplier
- $MULT_e$: Operations and maintenance multiplier

Parameters	Definition	Value	Primary source
$MULT_c$ Construction multiplier: Tanzania	Total economic impact (direct, indirect and induced) for every additional dollar of investment in the construction sector	2.21	https://set.odi.org/wp-content/uploads/2015/08/Using-a-Social-Accounting-Matrix-to-Calculate-Output-and-Employment-Effects-in-Tanzania.pdf
$MULT_c$ Construction multiplier: Pakistan	Total economic impact (direct, indirect and induced) for every additional dollar of investment in the construction sector	1.80	https://www.adb.org/what-we-do/data/regional-input-output-tables
$MULT_e$ Operation and maintenance multiplier: Tanzania	Total economic impact (direct, indirect and induced) for every additional dollar of investment in the electricity sector	2.18	https://set.odi.org/wp-content/uploads/2015/08/Using-a-Social-Accounting-Matrix-to-Calculate-Output-and-Employment-Effects-in-Tanzania.pdf
$MULT_e$ Operation and maintenance multiplier: Pakistan	Total economic impact (direct, indirect and induced) for every additional dollar of investment in the electricity sector	2.40	https://www.adb.org/what-we-do/data/regional-input-output-tables

Calculating investment costs

Our model quantifies the impact of investing in energy resilience across healthcare facilities, covering the capital expenditure (CAPEX) and operational expenditure (OPEX). The costs are divided into a) new connections and b) backup connections. We use the WHO's *Energising health: accelerating electricity access in health-care facilities* report from 2023 as the basis for the calculations. Assumptions around daily electricity requirements, load factor, grid vs off-grid based connections, CAPEX and OPEX, and backup peak loads are taken from the technical appendices of the WHO report for both Tanzania and Pakistan.

Parameters	Definition	Value	Primary source
ELE_{NH}	Estimated daily electricity requirement (non-hospital) (kWh)	15	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023
ELE_{H}	Estimated daily electricity requirement (hospital) (kWh)	1500	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023
LF_{NH}	Load factor (non-hospital)	0.15	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023
LF_{H}	Load factor (hospital)	0.21	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023
GRID	% of grid-based coverage of the country	0.93	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023
NGRID	% of off-grid-based coverage of the country	0.07	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023
$CAPEX_{GRID}$	Grid capital expenditure (US$/kW)	$CAPEX_{GRID}$	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023
$CAPEX_{NGRID}$	Off-grid capital expenditure (US$/kW)	$CAPEX_{NGRID}$	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023
$OPEX_{NGRID}$	Off-grid operating expenditure (US$/kW)	$OPEX_{NGRID}$	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023
$OPEX_{GRID}$	Grid operating expenditure (US$/kW)	$OPEX_{GRID}$	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023
ALTPEAK	Backup peak load (a combined PV–battery–diesel off-grid backup system was considered, based on assumptions developed by the WHO)	0.5	WHO, Energizing health: accelerating electricity access in health-care facilities, 2023

Limitations and data requirements

The analysis undertaken for this research significantly contributes to the existing body of data and literature by elucidating the return on investment and socioeconomic advantages associated with fostering energy resilience in crucial sectors such as healthcare, education and water. Nonetheless, it is imperative to acknowledge certain limitations that underscore the necessity for additional data. Specifically, there is a pressing need for further information to deepen our comprehension of energy resilience. Addressing these limitations will not only enhance the robustness of our findings but also facilitate more informed decision-making regarding investments in energy resilience.

Estimating energy resilience. In our research, energy resilience is characterised as the capacity of the energy system to withstand and promptly rebound from unforeseen and severe disruptions while preserving its critical functions. However, it is important to note that the definition of energy resilience lacks consensus within the literature. Consequently, our calculations are constrained by the absence of a universally agreed-upon definition. Primarily, we rely on two key indicators to measure energy resilience: (a) access to electricity and (b) the frequency and duration of power outages within a given country. Although these indicators provide valuable insights, the absence of a standardised definition underscores the need for further refinement in our approach to measuring energy resilience.

Estimating the socioeconomic returns from investment in energy resilience in the healthcare, education and water sectors. The study concentrates on quantifying the immediate, measurable benefits resulting from investments in energy resilience within healthcare facilities, schools and water facilities. These short-term impacts, while significant, possess the potential to catalyse long-term impacts. However, this study does not delve into assessing these ramifications. This arises due to two main reasons: (a) the analysis is constrained by a time horizon extending only to 2030, aligning with the focus on meeting the SDGs; and (b) existing literature offers inconclusive insights into the magnitude of the prolonged effects.

The healthcare model is subject to certain limitations, particularly concerning data availability and assumptions. The calculation of benefits relies on assumptions in cases where actual data are lacking, such as regarding in-facility access to healthcare. Additionally, while the model acknowledges the enhancements in both the quality and quantity of healthcare services resulting from improved energy resilience, it fails to incorporate the potential increase in healthcare demand associated with facilities being electrified. As electrification makes in-facility treatment more accessible, it is plausible that there will be a subsequent rise in demand for healthcare services, which is not currently accounted for in the model.

The education model also has specific limitations. A primary challenge arises from the less-than-ideal data availability across the countries under scrutiny, particularly for enrolment rates, dropout rates and progression between primary and secondary education. In certain instances, crucial data points, such as dropout rates, necessary for measuring overall grade-level progression had to be manually calculated from enrolment rates across years. This reliance on in-house calculations rather than official data introduces a degree of uncertainty into our model and necessitates the careful consideration of contextual differences and potential biases that may exist. However, despite this limitation, the education model remains a valuable tool for assessing the impacts of energy resilience investments in the education sector, albeit with the caveat of data constraints and proxy estimations.

The water model is also subject to certain limitations, particularly concerning data availability and assumptions. We start with connecting the reliability of electricity supply (power outages) to first order impacts in our model. As the data on electricity reliability (power outages) specific to water utilities was not available, we take the power outages at firm level as a proxy, which could subject our analysis to a certain degree of uncertainty. Additionally, we assume linearity in the impacts that power outages have on the quantity of water supplied and electricity consumed by water utilities. However, in reality the impacts could be non-linear. Moreover, our model is limited at capturing the impact of resilient energy access on agricultural production, while potentially being agnostic about the devastating crop failures that a lack of water for irrigation (led by power failures) could lead to.

To promote a more holistic understanding of the impacts of energy resilience investment across these sectors, future research could dive deeper into exploring long-term effects. Additionally, future studies could also broaden their scope beyond the three sectors examined in this research, extending to areas such as public security and infrastructure development. By having this expanded analysis, research would not only enrich the energy resilience debate but also facilitate more informed decision-making regarding investments in energy across diverse sectors.

Endnotes

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are no power outages i.e. full electrification. Hence, the calculated costs are the cost of reducing these power outages to zero. This results in overall low costs for Tanzania.

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