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Energising adaptation

Key considerations for coupling energy access with climate adaptation and resilience

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Figure 6 icons: Eucalyp from The Noun Project.

People who rely on 'dirty' fuels and methods to cook their food and live without electricity are also some of the most vulnerable to the negative impacts of climate change. Yet, energy is a crucial enabler of socioeconomic development. Energy products and services have the potential to support climate mitigation and adaptation efforts, but the links to adaptation and resilience remain murky. We believe that a clearer recoupling of climate adaptation and energy access efforts would allow us to align the benefits of fulfilling climate adaptation needs through energy access and create more resilient households. With care, this would enable a quicker scale up and achieve stronger outcomes for everyone.

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Acronyms

ARIC	Adaptation and Resilience Investors Collaborative
CRD	Climate-resilient development
CRISP	Climate Resilience Investments in Solutions Principles
CSO	Civil society organisation
GALS	Gender Action Learning System
GARI	Global Adaptation and Resilience Investment Group
GHG	Greenhouse gas
IEA	International Energy Agency
IMP	Impact Management Project
IPCC	Intergovernmental Panel on Climate Change
LLA	Locally led adaptation
LPG	Liquefied petroleum gas
MSME	Micro, small and medium-sized enterprise
NGO	Nongovernmental organisation
PPI	Poverty Probability Index
PV	Photovoltaic
SDG	Sustainable Development Goal
SHS	Solar home system
SME	Small and medium-sized enterprise

Summary

In 2023, 2.3 billion people used 'dirty' fuels and methods to cook their food and 746 million people had no access to electricity. They are also among the most vulnerable people to the negative impacts of climate change. Yet energy access is a crucial enabler of socioeconomic development, and energy products and services have the potential to support both mitigation and adaptation efforts.

The climate adaptation and energy access sectors are struggling to secure higher volumes of funding and finance to scale up projects and interventions. We believe that linking the two more tightly would allow us to synergise the benefits of fulfilling climate adaptation needs through energy access pathways. It would also enable us to scale up efforts and achieve better outcomes for everyone, particularly women and other groups who are experiencing marginalisation.

Climate change is putting energy infrastructure at risk through acute hazards — such as flooding and storms — and chronic hazards, such as temperature and precipitation variability. At the same time, people's experiences of these hazards differ according to their context and circumstances. For example, women are less likely than men to have access to resources and assets that could help them recover from or adapt to climate hazards over time.

This begs important questions around which individuals or groups have decision-making power, who identifies the climate risks, who decides what to invest in and where the funding might come from.

There is much uncertainty about climate projections into the future. This necessitates mechanisms for learning and iteration, and requires institutions to integrate new behaviours, processes and tools into intervention designs that can enable community climate adaptation needs. Critically, if energy services do not help address the root cause of vulnerability — such as social norms and poverty — there is a risk of maladaptation, which increases, reinforces or redistributes vulnerabilities.

Adaptative capacity is the ability to anticipate, absorb or adapt to climate risks. And while this needs to be thoroughly contextualised — for example, through local knowledge — we argue that it needs to go a step further to include transformative adaptation. As well as enabling people to anticipate, absorb or adapt to climate risks, transformative adaptation reconfigures power dynamics and relationships in a community to ensure a more equitable distribution of benefits. But an individual energy product or service alone is unlikely to bring about transformative adaptation. Rather, there is a need to design deliberate elements and actions alongside the deployment of energy systems, to change institutional support, policies and know-how, and for people to successfully interact with technologies in their contexts.

When thinking about resilience, it is useful to ask, 'Whose resilience?' and 'Resilience to what?' to recognise the risks and who will benefit from interventions. For example, a solar irrigation pump may generate resilience against a drought, but would not create resilience against a flood. In fact, irrigation may make land more susceptible to flooding, due to higher soil moisture content. Resilience might be best conceptualised as an ability for stakeholders to cope with all kinds of risks and shocks, whether predicted or unforeseen. This general resilience works at different levels and is not static. And as with uncertainty, iterative learning is crucial, as institutions need to have the capacity to facilitate and respond to such learnings.

Energy systems should be designed to contribute to climate-resilient development, which is the "process of evaluating, valuing, acting and adjusting various options for mitigation, adaptation and sustainable development, shaped by societal values as well as contestations of those values" (IPCC 2022). This means not only moving beyond top-down technical designs, but also aiming to influence more equitable power dynamics and improving outcomes for people experiencing different forms of marginalisation, whether through gender, language, age or another factor. Co-designing energy products and services through participatory and inclusive processes with communities will help ensure people can use technologies within the opportunities and confines of their own contexts.

This also means designing additional supporting elements — such as access to finance, mentorship and extension services — which enable people to successfully use technologies. An inclusive process can also help identify the unique challenges faced by women and other groups experiencing marginalisation.

To support learning, institutions, governments, communities and companies must all measure energy access against climate adaptation and resilience outcomes. This includes understanding who is being impacted (people, environment and economies); what the outcomes are (more money, more opportunities for women and so on); how many stakeholders are experiencing the outcome, to what degree and for what duration; whether and how the product or service is contributing to the outcomes; and the likelihood that the impact will differ from what was expected.

With these concepts in mind, we posit several broad recommendations that we hope will help guide further thinking around their practical implementation:

- Use local knowledge to build locally valuable resilience services and outcomes
- Take a whole-of-society approach, where public and private stakeholders with a range of perspectives work together for successful outcomes and to avoid maladaptation
- Develop a resilience narrative that articulates how a product, service or intervention helps build energy end users' wider resilience to specific climate risks
- Take a strategic, iterative approach to assessing resilience that captures changes over time, and use that information for ongoing learning
- Recognise and reduce the barriers to climate-resilient development faced by different people and groups, particularly around vulnerability, which is tied to social, political and economic marginalisation, and
- Screen for maladaptation risk, using our draft questions.

This paper is a contribution towards ongoing broader conversations looking to link energy access and climate adaptation and resilience. To practically build out our suggestions, we need to gather more evidence and more clearly identify the roles and incentives that governments, enterprises, communities and investors have in different contexts.

The next step is to establish and test a framework for practitioners to integrate energy systems in their projects that improve resilience against a range of hazards and risks, challenge dynamics and power imbalances, and help communities fulfil their adaptation needs. We hope this can help guide large energy project portfolios.

In particular, we believe that large energy access portfolios — such as Acumen's Hardest-to-Reach programme (US$250 million); the World Bank's Accelerating Sustainable and Clean Energy Access Transformation (US$5 billion); and Nigeria Distributed Access through Renewable Energy Scale-Up (US$750 million) programmes — would benefit from incorporating some of the climate concepts and principles we have posited in this paper, such as screening for maladaptation, establishing a robust resilience narrative and striving for transformative resilience.

1 Introduction

Energy is crucial in modern economies and climate impacts are amplifying the challenges of delivering socioeconomic development for all. The investment and delivery gap in energy access, for both electricity and cooking, is still enormous; so too is the climate adaptation gap. There is general recognition that more ingenuity is needed in the realms of finance and business models, as well as sociocultural and technical innovations, to facilitate energy access and measures for climate adaptation and resilience. Momentum, particularly in the energy access space, is mounting to better connect and synergise it with climate adaptation investments. Without such efforts to unlock the energy sector, the path to Sustainable Development Goal (SDG) 7 — access to affordable, reliable and modern energy services — and other SDGs will remain unachievable and climate impacts will hit harder, particularly for women and other vulnerable groups.

Energy investors and the businesses they finance see opportunities to deploy technologies to help address climate risks, but there is limited evidence on clear pathways that energy offers. Investment theses often lack the nuances of building resilience, which may be useful in establishing stronger business cases. While private and public climate finance could provide the funding boost necessary to derisk and incentivise investment, many energy stakeholders lack the knowledge of its demands relating to social inclusion, participation and properly assessing transformative change.

Climate adaptation stakeholders, including governments, are gradually integrating climate risk into planning across sectors but often fail to see the value that an energy lens can add to planning. Energy can be a key piece of the climate resilience puzzle but the opportunities are not clear enough for government officials and many nongovernmental organisations (NGOs), particularly when it comes to new technologies powered by renewables.

Energy and climate investors are likely to know their own sectors well but may not know much about the other. And while energy investors may know some of the climate vocabulary and have a level of understanding of climate issues, investment prospectus often sits on vague assumptions that access to energy technologies equates to climate resilience. But this narrative is too simplistic and skips many causal steps.

Historically, governments and energy investors have measured impact by counting outputs — such as technologies or connections deployed — with an average calculation of impact through a formula. But building resilience is not straightforward. Smallholder farmers face trade-offs with every investment, particularly when investing in expensive technologies that guide them down a particular path. For example, investing in a solar irrigation pump and a drought-resistant crop variety may help increase production and income even if drought occurs. But focusing on a single crop can increase risks to disease and pests, which are becoming a larger threat with climate change in many contexts. As this example shows, combining the energy product with other choices can make smallholder farmers more or less resilient. The technology has potential to increase farmers' resilience to certain shocks, but this is not assured. When investors assume it is, it can lead to maladaptive outcomes.

This paper aims to help financiers and investors looking to succeed in climate-vulnerable contexts develop a more nuanced understanding of the markets they are investing in and how climate impacts might affect those markets. Central to this is understanding:

- Climate uncertainty, climate risk and the implications of climate-resilient development (CRD)
- Vulnerability and how it is unequally distributed within and between communities

- The important distinctions between wellbeing, resilience and adaptive capacity
- The importance of a whole-of-society approach to forge the necessary interlinkages between institutions to shape positive outcomes, and
- How to measure impact and demonstrate a technology or product's contribution to climate goals.

Without meaningful consultation or co-design, there is a risk that energy systems can have negative or suboptimal outcomes related to livelihoods, wellbeing and climate resilience for different types of people. Energy systems sit within patriarchal decision-making processes and political systems, which often dictate who can or cannot access financing, gain skills, use infrastructure or public services, and access markets or business services. Consequently, failure to provide a gender lens can result in electricity systems that align better with the preferences and needs of men. For example, evidence shows that because of these structural issues, electricity often favours male-dominated vocations, such as carpentry and welding (IDS and GIZ 2019) or may favour men's climate adaptation strategies, which often differ from women's. This has consequences for who can control or use technologies in households (Johnstone et al. 2023). Maladaptive business cases and delivery models reduce investors', companies' and social enterprises' opportunities for scale and growth, and in worst-case scenarios, can actively harm end users and communities.

Meaningful consultation in the energy and climate nexus may take inspiration from locally led adaptation. Decades of development experience have shown the value of locally led approaches to adaptation and community development in general (Carthy 5 July 2022). Such approaches prioritise decision-making at the lowest appropriate level (known as subsidiarity), build local institutional legacies, recognise the root causes of vulnerability and take a whole-of-society approach to addressing the complex challenge of climate change. Among many others, promising initiatives include the Sustainable Island Resources Framework Fund in Antigua and Barbuda and Devolved Climate Finance in Senegal, Mali, Kenya and Tanzania (Steinbach et al. 2022). Locally led approaches foster the conditions for prosperous and resilient societies with innovative and growing private sectors. And through this pathway, the energy access sector has the opportunity to build demand for energy, which it has struggled to do at scale in many contexts around the globe in the last decade.

But there is a lack of engagement between civil society, local and national governments and other stakeholders, which is needed to ensure decision making is locally led and adds value to local contexts, and to mitigate maladaptation risks. There is also a risk of greenwashing, as seen in the carbon offsetting market (Greenfield 18 January 2023) and more recently, with cookstove projects (Greenfield 23 January 2024), which has reduced the credibility of those markets.

Many stakeholders have a simplistic comprehension of resilience, impacts and the pathways to achieve them and, as a result, may misrepresent impact. This undermines the work of investors, governments and civil society in making local and national development plans and poses a risk of sending good money after bad investments. A more nuanced understanding of these concepts could help guide smarter long-term investments and reduce the risk of maladaptation, which makes people more vulnerable to climate impacts.

The climate and energy sectors have historically focused on technology engineering and deployment. Depending on where technologies are deployed, this can have mixed results (Johnstone et al. 2023). For example, companies that solely focus on delivering technological solutions often fail (Wayne 27 June 2023). We believe that incorporating climate risk and its impact on communities would enable energy stakeholders to improve their success rate while mitigating the risk of doing more harm than good. In general, there is a need to better understand the role that access to energy plays, as this can inform investments and their supporting functions that can help or hinder just and equitable CRD and transformational change.

To reduce the risk of maladaptation, we posit that energy and climate stakeholders must develop a greater understanding of the challenging characteristics of climate change. With better measuring, learning, and iteration, it is easier to spot maladaptation over time and keep the focus on adaptation outcomes. If energy stakeholders understand local power dynamics and how they affect wellbeing, it can enable approaches and business models that are more inclusive of vulnerable groups. Energy investments that embrace uncertainty may offer robustness in the face of variable and unpredictable climate futures, improving longevity and reducing risk of losses. All this hinges, in part, on taking a whole-of-society approach with better coordination between public, private and civil society actors.

To paraphrase the London School of Economics, a just transition is fairer outcomes for workers and their communities as the world transitions to net zero carbon emission economies (LSE 2024). To achieve and be able to claim to contribute to a truly just transition, stakeholders must internalise a more radical definition of adaptation, in transformative adaptation. They can also support, finance and reorganise their institutions to support CRD in a way that integrates understanding of risk across sectors and institutions and, importantly, shares that risk more equitably among stakeholders, from households and communities upwards.

This working paper is a first step towards promoting a common understanding between the worlds of climate adaptation and resilience and energy access. It aims to encourage energy access investors to consider maladaptation in their decisions, and help climate adaptation or resilience investors better understand energy access and how to incorporate it in their projects. Chapter 2 aims to explain to people who are less familiar with the challenges and opportunities in the energy sector the reasons for focusing on basic electricity and cooking. Chapter 3 should help those who are less familiar with the impacts of climate change understand why it is vital that development — including energy access — is climate resilient. Chapter 4 offers ideas on how to conceptualise people interacting with technologies and thoughts on how to measure energy and climate outcomes. In Chapter 5, we offer broad recommendations in building out some of the concepts here to bridge across climate and energy. We hope that by highlighting these issues, we can help steer investors towards better measuring and thinking on how energy access can enable a wider ecosystem of resilience against many climate impacts.

2

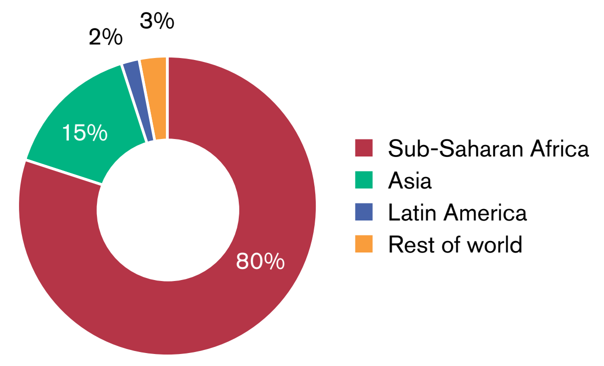
Understanding energy and energy access

Energy in all its forms — including electrical, mechanical, chemical and thermal — is crucial to our daily lives. We use fuels and appliances to cook our food, from microwaves to open flames. We use energy to power machines and equipment that help us make money and live better lives. We move people and products on cars, ships and planes. Energy pulses through our economies, supporting commerce and livelihoods, transport, water supply, sewerage and telecommunications, as well as healthcare, governance, education and other critical services. SDG 7 seeks universal access to affordable, reliable, and modern electricity and cooking fuels and appliances for households. But not everyone has access to these when they need them, and many simply cannot afford them. Energy systems are also inextricably linked to the environment, both through emissions and adapting to climate change.

2.1 Electricity access for most, but not yet all

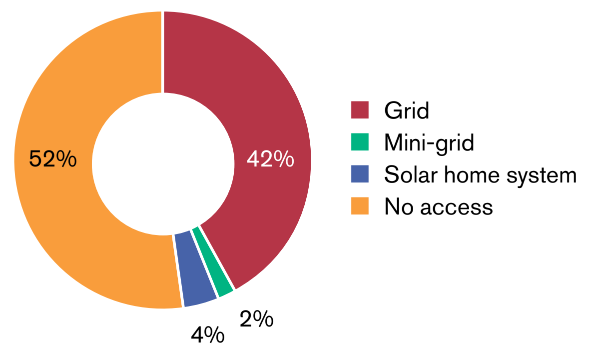
Electricity is a crucial element in modern economies. Despite tremendous progress in some regions over the last decade, the International Energy Agency (IEA) estimates that 746 million people in 2023 lived without access to electricity, including a slight reversal in access during the COVID-19 outbreak. Figure 1 shows that most of these live in sub-Saharan Africa and Asia — 80% and 15%, respectively (Cozzi et al. 15 September 2023). In sub-Saharan Africa, only about half the population — some 600 million people — have access to electricity (Cozzi et al. ibid.).

Figure 1. Share of population without access to electricity, by region



Source: Cozzi et al. 2023

Figure 2. Access to electricity in sub-Saharan Africa



Source: IEA 2023a

The IEA projects that electrification rates will barely keep pace with population growth without enormous additional investments and supportive policies for energy infrastructure. In this scenario, 660 million people will still have no electricity in 2030, with 560 million of them (85%) in sub-Saharan Africa (IEA et al. 2024).

Immense overlap exists between people living in poverty, electrification rates, access to modern cooking systems, gender inequality and vulnerability to climate impacts. These correlated challenges demonstrate that the people who are least responsible for climate change, and have the least capacity to respond, are bearing the brunt of its impacts.

Historically, reaching the last people in any context that are living without electricity has also required the most investment. The reasons are myriad, interlocking and complex. We highlight some of the main issues here, but it is by no means a comprehensive analysis.

Households living in poverty often express limited demand for electricity. They tend to only use a couple of lights and possibly some phone charging, often because they cannot afford the energy products or services on offer in their area. This limits the types of business model companies can use to deploy energy systems. Globally, electrification rates for households is higher in cities than rural areas, at 98% and 84%, respectively (IEA et al. 2024). But these averages mask large disparities in countries and regions. For example, rural areas without access to electricity in sub-Saharan Africa increased from 376 million to 473 million in recent years, with population growth outpacing access (IEA et al. 2024).

Despite energy being a lynchpin for socioeconomic development, energy provision alone does not typically spur it (IEA 2002). A study in India concluded that, to achieve desired impacts, electricity must be combined with other public policy support in areas such as employment, health or education, for example (Sedai et al. 2021). Others, including IIED, have found similar challenges, where households, particularly those living in poverty, need packages of support for different value chains to leverage initial access to energy. For example, smallholder farmers often need a technology like a solar irrigation pump that has the potential to produce revenue to pay for itself, coupled with access to financing, training and markets among other support to ensure they can increase their income to help pay for the technology (Johnstone et al. 2022; see Chapter 4 for more on individual context).

Governments have a role to play enacting policies and frameworks that can support faster electrification, yet many do not provide an adequate enabling environment. For example, less than 20% of African countries have targets to achieve universal access, and energy planning does not consistently integrate grid and off-grid pathways (IEA 2023a) (see Box 2).

There are other contributing issues around perceptions of access. An Afrobarometer survey, for example, shows that people without electricity access often do not prioritise it. Conversely, once people gain access, they prioritise reliable access (Lee et al. 2020). Related to this, there are longstanding public and government perceptions that large grid power is the only 'proper' source of electricity.

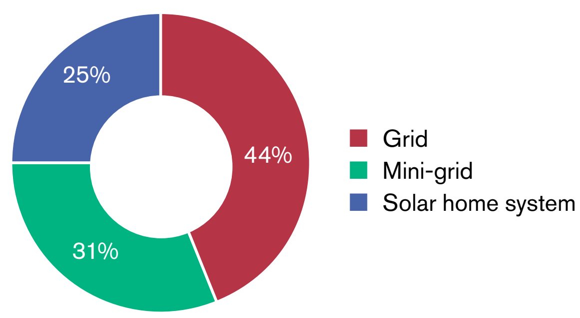
Reinforcing this perception is a history of failed distributed renewable energy projects implemented by governments and NGOs, such as solar streetlights. Some distributors have also delivered poor quality products that have contributed to poor perceptions of solar-powered equipment. The quality and reliability of the energy access (including companies and customer service) is crucial as the impact of a nonworking energy product or service that is used to generate an income can be much larger and have implications on financial stability for users (Harrison and Adams 2024). Other challenges include investors' perception of risk and limited government financing. And wrapped up in these and other challenges are questions of climate justice (Box 1).

2.2 Innovations and new opportunities for electricity

Most people across the globe have gained access to electricity through large, centralised grids and these will continue to play an important role. Figure 3 shows an IEA model where most people are projected to gain electricity access through off-grid (56%) rather than grid (44%) technologies in a scenario that achieves universal access by 2030 (IEA et al. 2024). This highlights the importance that off-grid technologies will play in the coming years. For an overview of off-grid technologies, see Box 2.

Figure 3 emphasises the continued importance of the grid for the future of electrification. It also illustrates the belief that a convergence of drivers and trends will continue to open opportunities for alternative

Figure 3. Projected global access to electrification by 2030, by technology type



Source: IEA et al. 2024

BOX 1. CLIMATE JUSTICE: WHO SHOULD FOOT THE BILL?

The term 'climate justice' has a plethora of definitions. Massachusetts Institute of Technology states that "[c]limate justice is the principle that the benefits reaped from activities that cause climate change and the burdens of climate change impacts should be distributed fairly" (Arcaya and Gribkoff 2022).

Regarding causes, it is widely recognised that many countries in the global North have socioeconomically benefited from emitting huge amounts of greenhouse gases (GHGs). A Carbon Brief study links emissions to extractive colonial systems, reallocating higher emissions responsibility to countries such as the United Kingdom, France and the Netherlands than would have otherwise been counted within the carbon dioxide (CO2) budget (Evans and Viisainen 2023). Emphasising the lopsided nature of the causes of climate change, the IEA notes that "Africa accounts for less than 3% of the world's energy-related CO2 emissions to date and has the lowest emissions per capita of any region" (IEA 2022 p 15). In other words, many countries in the global South bear little to no responsibility for causing climate change.

Importantly, global South countries are some of the most vulnerable to climate change and therefore disproportionately bear the burdens of its impacts. While switching to renewables is an ideal pathway for everyone, countries must be able to choose the pathway that works for them. In the short term, that might mean following the global North's pathway of fossil fuel-powered growth. If people living on less than US$2.15 a day increased their consumption in line with historical patterns of economic growth and emissions, the impact would be marginal, increasing 2019 global emissions by only 4.9% (Wollburg, Hallegatte and Gerszon Mahler 2023).

Many mitigation projects that include renewable energy system installation — with potential adaptation co-benefits — are arguably not happening in the places they are needed most. The United Nations Conference on Trade and Development recently highlighted that "30 developing countries have not registered a single international investment in utility-size renewable energy generation since the landmark [Paris Agreement] was adopted in 2015" (UN 5 July 2023). There are still reporting gaps on mitigation efforts, but there is some evidence that spending on mitigation through official development assistance is not associated with lower emissions (Kenny 2024). Many global South countries, therefore, desperately need access to grants and low-interest financing to be able to choose the renewables path.

technologies and business models that offer new pathways. A virtuous cycle of increasing production and falling component costs, combined with innovations in business models, financing, preparation and planning, increasing investor interest and other factors is making it increasingly economical to deploy standalone products across a range of contexts and to scale mini-grids. This is not guaranteed, as the relentless pursuit of cost reductions can lead to unintended consequences, such as the increasing number of solar modules that are breaking (Wood Mackenzie 2024). But this convergence of factors is driving success so far.

To this point, seven countries — Bangladesh, Cambodia, Kenya, Myanmar, Nepal, Rwanda and Tanzania — have achieved some of the fastest gains in electrification in the last decade through comprehensive planning that integrates traditional grid extension with mini-grids and solar home systems (SHS) (ESMAP 2019). Combining the strengths of different technologies, business models and funding sources in this way can offer a blueprint for a practical least-cost electrification pathway, but it does not guarantee that households and communities can access a level of electrification that fits their needs or aspirations.

Pathways to full electrification will vary by context and are influenced by a range of socioeconomic, financial and political factors. Each country faces unique circumstances, opportunities and challenges. For example, one study that modelled pathways to universal electrification in 40 sub-Saharan African countries recommends that countries with large populations — like Ethiopia, Nigeria, Tanzania and Uganda — would benefit from first prioritising increased grid densification, then private off-grid schemes, and finally, subsidies for areas with the highest cost (Egli et al. 2023).

Beyond the grid, the World Bank estimates that 490 million people are being served by decentralised products (IEA et al. 2024). More recently, consumer financing, where households make monthly payments using mobile money-enabled products, has taken off for solar lanterns, SHS and other lighting systems, allowing more households to purchase them. Surveys have shown that on average, 55–68% of households using solar lanterns, SHS and mini-grids have reduced their energy spending as a result (Harrison and Adams 2024). Companies deploying renewable energy-powered mini-grids have generally struggled with profitability, particularly when trying to reach rural communities that are characterised by high levels of poverty and limited purchasing power.

Once companies have delivered electricity products and connections, end users must be able to use the electricity to their benefit. They cannot do this if it is unreliable or unavailable when they need it, or if the electricity is of poor quality. In many global South countries, the main grid systems are unreliable in terms of quality and availability. For example, one study of 34 African countries found that only 43% of respondents said their electricity supply worked most or all the time (Lee et al. 2022). Modern mini-grids are generally thought to have higher uptimes, though this varies by context. For example, the Africa Minigrid Developers Association claims that its mini-grid operator members have 99% uptime, but this data has not been independently verified (AMDA 2022). However, one survey found that 37% of mini grid end users surveyed experienced challenges, the highest amount compared to solar home system (33%) and solar lantern (21%) end users. Challenges often translate into lower incomes and affects energy company trustworthiness (Harrison and Adams 2024).

End users also have different needs, depending on their context. For example, due to gender norms, men and women have different opportunities and constraints. This translates into different capacities and needs for using electricity. Women also typically have the double burden of household duties alongside other paid work, which can hinder their opportunities.[1] Energy access offers pathways for gender equity and other desired outcomes (see Section 4 for more details on the importance of individuals and their context).

2.3 Cleaner cooking

Cooking food is essential for human survival and is deeply wrapped in tradition, culture and personal preferences. Households around the world use a variety of options for cooking appliances and fuels, from wood and wood products to electricity, liquefied petroleum gas (LPG), biogas and other gases, kerosene and coal. But not everyone can access or afford different types of stove or fuel. See Box 3 for a discussion on measuring energy access.

In 2021, 2.3 billion people used biomass fuels to cook their food — such as wood, charcoal, dung and agricultural residues — which are particularly polluting when combusted (IEA et al. 2024). The last decade has seen almost 700 million people gain access to modern cooking fuels and appliances, mostly in Asia and Latin America. China, Indonesia and India have all made huge progress, mostly by funnelling resources into subsidised access to LPG, while in sub-Saharan Africa, one billion households (almost 80%) use dirty biomass fuels (IEA 2023b).

Gender norms often dictate that women and girls undertake cooking-related activities — from gathering fuel to preparing and cooking food and cleaning up — on top of their other household responsibilities. As a result, women and girls are disproportionately impacted by the negative effects of cooking. Burning dirty fuels, such as biomass, pollutes homes and their surrounding areas, particularly in urban places where households are more densely packed. In sub-Saharan Africa, about 60% of early deaths in women and children are attributable to smoke and indoor air pollution exposure (see Box 4) (IEA 2023c). As such, it is often argued that progress on cooking would have outsize positive impacts on women and girls. Many interventions focus on reducing the drudgery of cooking or time spent collecting wood fuel. In one survey, 80% of people surveyed who had recently bought a stove stated that it reduced the time needed to cook; 95% said they enjoyed more leisure time as a result (Harrison and Adams 2024). Although this is good news, the survey only includes people who have purchased a new stove, and reducing time spent on cooking-related activities does not always translate into time for rest or productive activities for women and girls. Gender norms can also mean that time saved transfers to other household duties, as women and girls do not necessarily have the power to negotiate how they want to use that time.

Globally, roughly 1.7 billion households without access to cleaner burning fuels live in rural areas (IEA 2023c). Rural households use biomass fuels, particularly wood and charcoal, as they are often available to harvest from surrounding areas. The nature of cooking influences livelihoods, ability to save, participate in decision making fora, and create time to learn about and implement adaptive strategies. Gains made in cooking have huge potential for households being able to adapt to climate change, particularly for women and girls.

Unsustainable harvesting and using biomass fuels can put pressure on natural environments, contributing to the degradation of ecosystem services and soil health, and contributing to climate change via black carbon and carbon dioxide emitted from burning fuels and through deforestation. Reducing the use of biomass fuels could help mitigate these impacts, for example, reducing emissions and deforestation. Indeed, IEA modelling suggests a net reduction of 1.5 gigatons of carbon dioxide equivalent by 2030 (IEA 2023c). Cookstove offsets had been the fastest growing segment of the voluntary carbon market, supporting subsidisation and deployment of cleaner fuels. However, a recent pivotal study found an overestimate of carbon savings by a factor of 9.2 (Gill-Wiehl, Kammen and Haya 2024). Without significant reform, this greatly reduces the credibility of the cookstove offsets market and its potential for attracting larger sums of climate finance.

1 www.energia.org/what-we-do/why-gender-and-energy

BOX 2. OVERVIEW OF OFF-GRID ELECTRICITY TECHNOLOGIES

Governments have historically focused on a centralised main **grid** that electrifies large settlements, such as cities and towns, where demand for electricity is high and end-user capacity to pay is high. These grids then slowly expanded into smaller (usually more rural) communities, where demand and capacity to pay are typically lower. Extending the grid into rural areas is expensive, averaging US$2000 per connection (ESMAP 2019). But new innovations in technologies and business models are offering different pathways for — and the possibility of speeding up — electrification.

Mini-grids are generally small grid systems that serve clusters of houses and businesses in a village or town. They can be powered by solar, hydro, wind and, less ideally, fossil fuels. As they require customisation for each context, they vary widely in technical design, size and reach, as well as business, ownership and operating models. They can be public, private or both. They range from an individual running a small generator and selling power informally to nearby houses to a system that reaches thousands of homes through prepaid meters. The World Bank estimates that 210,000 mini-grids could play a role in achieving universal access by 2030, costing a total of US$220 billion (ESMAP 2019). Mini-grids typically require 10-to-15-year financing, which is more akin to infrastructure development projects (USAID, nd). Modern mini-grid developers generally struggle to turn a profit, but are starting to raise significant funds from investors. One example is Husk Power Systems, which reportedly operates 200 mini-grids in India and Nigeria, and recently raised US$103 million in a mix of equity and debt to expand its operations, including into the Democratic Republic of Congo, Zambia and Madagascar (Kene-Okafor 24 October 2023).

Standalone products use small solar panels to power equipment such as refrigerators and freezers, milling machines and irrigation pumps. A World Bank report on productive use cases for solar-powered equipment in agrifood systems estimated addressable market valuations for irrigation pumps, cooling and refrigeration, and agroprocessing systems at US$3.5 billion, US$6.2 billion and US$3.5 billion, respectively; larger still, if affordability can be increased for households with low purchasing power (IFC 2019). Another report estimates that US$1.2 trillion is needed to address the entire productive use gap — excluding the infrastructure needed to power it — by 2030 (Ismail et al. 2021). The challenges and opportunities are enormous.

Powered through small solar panels, **SHS** usually have a couple of lights, sometimes alongside some other functionality such as phone charging or a radio. **Solar lanterns** are individual lights, powered by a tiny solar panel on their back, that cost considerably less than SHS. Like mini-grids, both SHS and solar lamps have benefitted from recent technical efficiency gains and price reductions in manufacturing. But unlike mini-grids, SHS and solar lamps are fast-moving consumer goods and have secured millions in equity and debt for expansion across several countries — such as Kenya, Tanzania, Nigeria, Togo and many others — bringing initial electricity access to millions.

BOX 3. MEASURING ELECTRICITY AND COOKING

The challenges and limitations in defining and measuring energy access — including the lack of standard definition and limited data availability — means we need to simplify the way we measure energy access (IEA 2020). The World Bank designed the Multi-Tiered Framework (MTF) in 2015 to offer a more nuanced and aspirational conceptualisation of access. Indicators are categorised into a more useful continuum that tracks availability, quality, supply and affordability of the energy delivered to end users. The MTF features some measures of inclusivity, such as gender-disaggregated data on who owns and uses electrical appliances within households.

The MTF is useful if all the data can be collected and analysed. But the World Bank has only completed MTF surveys in ten countries, with the last one completed in 2019, highlighting some of the challenges of using it. The MTF's five-tier capacity dimensions do not always correspond to country-specific availability of those tiers from providers. A recent study concludes that the framework is too complex to adequately measure real-life circumstances, suggesting an alternative energy access framework that looks at energy supply and household energy poverty status, while referencing households' different service and appliance preferences, among other considerations (Pachauri and Rao 2020). Measuring the impacts of energy access should focus on people's desires, needs and ambitions, grounded within their contexts. Much like climate vulnerability, these will vary widely between countries, within communities and even within households.

Collecting and selling biomass is often a crucial livelihood activity for rural communities, which sell on to other communities or into larger cities, particularly in sub-Saharan Africa. Households adopting new stoves and fuels could displace this critical livelihood, which would have implications on people's ability to adapt. This highlights how complicated these interlocking challenges can be, particularly around unforeseen or unintended consequences.

The IEA estimates that US$8 billion is needed annually to increase access to cleaner cooking options for households and that, if governments can achieve this, it could reduce premature deaths by about 2.5 million annually (IEA 2023c). Without such investments, one model shows that 1.9 billion people will still not have access to cleaner cooking options by 2030, mostly in sub-Saharan Africa (IEA et al. 2024). And the harmful impacts of cooking will continue to be mostly borne by women and girls.

There are many challenges to increasing household access and use of cleaner cooking fuels, stoves and methods. These include availability, affordability, the higher costs of cleaner fuels, mismatches between cooking technologies and household (particularly women's) needs and local recipes, unreliable fuel supplies, and a focus on single technology or fuel interventions (Shankar et al. 2020). Furthermore, a lack of attention to discontinuing dirtier stoves and fuels can lead to households continuing to use the old ones alongside the new ones, also known as stove and fuel stacking (ibid.). Although this diversity of fuel sources reduces the co-benefits and impacts of using only improved cookstoves or cleaner fuels, stove and fuel stacking can increase a household's resilience. For example, one study found that it allowed residents in Accra, Ghana to navigate changing urban conditions, including grid blackouts and fluctuating fuel prices across different fuel types (Eledi Kuusaana, Monstadt and Smith 2023). Finding the right balance will be difficult and highly context specific.

Due to the multisector nature of cooking and its impacts, responsibility for addressing these challenges often sits between ministries. However, with concerted efforts, governments have navigated these difficulties — for example, Malawi has a thriving local cookstove manufacturing sector, thanks in part to strong and sustained government support (Johnstone 2020).

Enterprises providing fuels and stoves face multiple challenges. Young and local companies struggle to access affordable and appropriate capital, greatly hindering their growth and potential climate benefits. One 2022 study found that cookstove and fuel companies raised only US$215 million of the roughly US$8 billion they need to invest annually because they were unable to articulate a strong business case that can scale (Clean Cooking Alliance 14 December 2023). Investments were also highly concentrated, with seven enterprises raising 90% of the total (Clean Cooking Alliance ibid.). Many cookstove companies often manufacture their stoves overseas and import them, contributing to emissions. Local cookstove

BOX 4. CLEAN OR CLEANER COOKING?

There is much debate regarding cleaner fuels and stoves and their harmful effects on human health. Fuel combustion in enclosed areas contributes to polluted air that people in households breathe in, especially women and girls. Fuel combustion of all fuel types releases harmful pollutants, including nitrogen dioxide, which is particularly harmful to humans.

Gas has been touted as a clean alternative to biomass, but it is more accurate to describe it as 'cleaner'. Although it has long been known that cooking with gas releases harmful pollutants, there is mounting evidence about the scale of these impacts (Kahn 15 January 2023; Blair, Kearney and Scholand 2023) and the industry has cynically long fought such claims (Song 28 January 2023). The truth is that gas appliances contribute to poorer indoor air quality at all times, and have been found to leak even when not in use (Lebel et al. 2022). Like many other climate issues, this disproportionately impacts low-income households and marginalised groups, and is another example of environmental racism (Uteuova 3 May 2024). The cooking access sector needs to come to terms with this history as it seeks ways to justly increase access to better cooking fuels, which potentially locks in infrastructure investment for decades.

It is exposure to these pollutants, rather than fuels and stoves combusting dirtier fuels, that is more relevant here. Exposure is a combination of four factors: end user behaviour, or how households (usually women and girls) use the cooking system; ventilation, including dilution, air exchange, extraction and kitchen structure; stove type and cooking techniques; and fuel type, including how it is produced, prepared and dried (Roth 2019).

Stove interventions should therefore not assume that access to different stoves and fuels will automatically nurture better outcomes around gender, health and so on. Instead, they should consider how these different dynamics interact in households to achieve the outcomes that women and girls want. Indeed, donors and investors often desire different outcomes. While not necessarily incompatible, these distinctions are important when designing business models for scale.

manufacturers, on the other hand, struggle to raise even minimal amounts of capital, and extending distribution into rural areas is fraught with logistical challenges (Johnstone 2020).

There have also been successes, such as KoKo Networks in Kenya. In just a couple of years, this company has reached the elusive scale that other cookstove companies yearn for using ethanol, an innovative distribution system, and leveraging carbon financing to subsidise stove and fuel costs to end users. This is a novel approach for both carbon financing and cooking (Financial Times 2023; Osiolo, Marwah and Leach 2023).

2.4 Opportunities to link energy access to climate adaptation

Most climate finance goes towards mitigation, rather than adaptation activities. This mirrors energy sector finance, where funds tend to flow towards large, utility-scale energy systems that mitigate emissions. Much less goes towards deploying off-grid systems or cleaner cooking fuels and stoves. But to speed up growth in energy access, particularly in hard-to-reach places, billions more investments are needed annually in off-grid technologies as well as business and sociocultural innovations.

Climate finance may be one source of this investment, particularly as more ambitious climate finance goals are likely to be set through the New Collective Quantified Goal on Climate Finance at upcoming climate change negotiations. If evidence and experience can demonstrate a reliable link between energy investment and improved climate adaptation capacity of vulnerable people, there is a much stronger case for climate finance to incentivise, de-risk and subsidise off-grid technology development and deployment.

Several studies highlight some interesting outcomes that energy technologies have contributed to (see Section 4). But evidence linking energy access and climate is often anecdotal or does not comprehensively identify causal chains to outcomes. A pivotal 2015 report found a lack of high-quality literature linking energy and climate, and that the chain linking energy access to climate adaptation and resilience outcomes is often limited or moderate (Perera et al. 2015). This is not an issue particular to energy access; evaluation studies often have inadequate descriptions of the entire intervention, unsubstantiated claims and other gaps.[2] Other IIED work has tangentially confirmed that there is a gap in high-quality studies with clear climate-related outcomes in sociocultural innovations, technology access for women, and in resilience in agrifood systems (Johnstone 2023), an important sector for energy access.

The Global Off-Grid Lighting Association — an off-grid industry body — published work in 2023 (GOGLA 2023) that looked at viable off-grid products and services and confirmed that more information is needed across product categories and contexts to strengthen the link between energy access and climate adaptation.

There is a general perception that off-grid energy systems have few downsides and that technologies offer direct pathways to building household and community resilience. Ultimately, the ability to use energy for adaptation outcomes hinges in large part on the agency of the user and their ability to operate and innovate within environmental limits. The work to tie energy access and adaptation together needs to explore these linkages, who they work for and when they do and do not work. Questions to explore might include:

- Do different people, including vulnerable groups, use different strategies to leverage energy technologies? Do these lead to different outcomes?
- What kinds of products work for men, women or young people?
- What contextual factors ensure a product can support adaptation?
- What kind of business models are pro-poor and sustainable for people and businesses? Which are suitable for men versus women? What about particularly vulnerable groups?
- Do men and women in different contexts need different technology designs?
- What enabling environments need to be in place to ensure off-grid energy contributes to adaptation outcomes?
- What environmental limits might restrict scaling different off-grid technologies?
- What government services are needed to complement (or actualise) the potential of productive use technologies?

There is need to understand the climate risks that positionality exposes people to and how contexts prevent or enable them from interacting with technologies to achieve their desired outcomes. A person's positionality dictates their barriers and opportunities — for example, women often face additional barriers in accessing or affording technologies.

2 www.gdn.int/ten-common-flaws-evaluations

3

Energy links to climate risk, vulnerability, uncertainty and maladaptation

Climate change presents an enormous, multidimensional challenge for human societies; it has been described as a 'wicked' problem (Fitzgibbon and Mensah 2012; Termeer et al. 2016). This means it is a dynamic, changeable problem with multiple interlocking drivers. Wicked problems are of uncertain scale and size, and rooted in social experience as much as technical know-how or the lack of it (Rittel and Webber 1973). With no neat, simple technical solutions or technological fixes, responses to wicked problems will involve trade-offs between winners and losers. Indeed, they have both intended and unintended consequences that require negotiation and contestation to establish.

One simple, yet illustrative, example of trade-offs is that the widespread deployment of renewable energy-powered lights, appliances and mini-grids will negatively impact livelihoods and jobs in the petrol, kerosene and diesel supply chains. This ranges from sole traders selling petrol in plastic bottles on rural roadsides to national companies selling and providing maintenance and spare parts for fossil fuel-powered equipment. Consequently, interventions must consider how to integrate these existing supply chains and invested interests with renewable energy chains, to reduce disruption to livelihoods and resistance to change.

This chapter touches on five concepts that are central to discussions about climate change — risk, vulnerability, uncertainty, maladaptation and CRD — and why it is vital that stakeholders across development sectors, including the energy access sector, understand and integrate them.

3.1 Climate risk and energy

Climate change is creating a more unpredictable world, where climate-related hazards are generally increasing in variability, frequency and intensity. Hazards can be acute (drought, flooding, cyclones and so on) or chronic (temperature and precipitation variability, soil degradation, water stress and so on).[3] Both types of hazard threaten the foundational conditions needed for ecosystem habitability and for people to function safely and productively. They threaten infrastructure, property, livelihoods and the quality and scale of public services.

3 See https://eur-lex.europa.eu/eli/reg_del/2021/2139/oj, Appendix A.

The scale and depth of impacts on energy systems will vary widely, depending on location and context (IPCC 2022).

Acute hazards, such as cyclones and floods, damage energy systems that have not been climate-proofed. This disrupts electricity supply and reduces system reliability with knock-on effects across economies and borders. For example, Cyclone Idai in 2019 affected five countries, including Madagascar, Malawi, Mozambique, South Africa and Zimbabwe. In Malawi, the storm damaged two hydroelectric power plants, knocking down 84% of the country's electricity capacity (CDP 2019). This reduced Malawi's electricity exports to South Africa, and the resulting load-shedding in South Africa, combined with other deleterious effects from the cyclone, increased the demand and price for diesel fuel for generators, with ripple effects for people (Silliman 2019).

Chronic impacts will also affect technical systems. For example, if the seasonal Harmattan in West Africa — an annual, multimonth event characterised by dry, dusty winds and sandstorms — becomes more variable, it could amplify effects on human health and increase the dust covering solar photovoltaic (PV) panels. One study found that dust accumulation decreased solar PV performance by 20% in Nigeria (Sanusi 2012), with implications on grids that are transitioning to PV and mini-grids that rely on it.

Crucially, greater integration of renewable energy sources will increase the reliance of energy systems on the natural environment, interlocking electricity ever closer with weather and climatic events.

One study argues that the wholesale integration of renewables into electricity systems could increase uncertainty of electricity supply, affecting the severity and frequency of power outages (Xu et al. 2024). Additionally, as demand for electricity for more fans and air conditioning increases to mitigate the effects of increasing heatwaves, so will the need for more generation capacity.

Decentralised energy systems (such as mini-grids and standalone products) will play an important technical resilience role in future energy systems (Xu et al. 2024). And though technical resilience is critical, the Intergovernmental Panel on Climate Change (IPCC) also emphasises that adaptation actions must be comprehensive with long horizons (IPCC 2022). In other words, investments must avoid myopically focusing on energy technologies and assets, and instead integrate energy as an enabler of other sectors to achieve household and community resilience, better human well-being, and other outcomes like higher income and gender equality.

3.2 Climate vulnerability and energy

As outlined in Section 3.1, climate-related hazards will have far-reaching technical consequences on energy systems. Similarly, the impacts on people who interact with energy systems will also be profound and shaped by their positionality within their contexts (Bilgen, Nasir and Schöneberg 2020). Someone's positionality can be understood as the "personal values, views, and location

Table 1. Climate risk illustrative examples

RISK TYPE	CONTEXTUAL EXAMPLE	ILLUSTRATIVE RESULT
Sudden and severe	Storm knocks down mini-grid electricity poles	Reduced electricity access, with knock-on effects for households and businesses
	Acute drought diminishes hydropower reservoir for a mini-grid	Reduced power output and electricity access, with knock-on effects for households and businesses
	Sudden flood sweeps away solar irrigation pump, solar lantern, SHS or cookstove	Reduced energy access, with knock-on effects for households and businesses
Slow and gradual	More rain and cloud coverage over time reduces efficiency of solar PV panels for a mini-grid	Reduced power output and electricity access, with knock-on effects for households and businesses
	Prolonged drought reduces availability of water, and solar irrigation pumps are less useful	Reduced usefulness of electricity access, with knock-on effects for households and businesses
	Reduced rainfall over time reduces hydropower output	Reduced power output and electricity access, with knock-on effects for households and businesses; reduced investment case for hydropower

in time and space that influence how one engages with and understands the world" (Benton Kearney 2022). It is influenced by aspects of identity — such as gender, age, ethnicity, language and disability — which tend to shape how people engage within their context and can establish how vulnerable they are to climate impacts.

Central to vulnerability are the resources an individual, household or community can mobilise to anticipate or respond to various risks (O'Brien et al. 2007) and positionality shapes access to or control of resources, such as energy, household assets, water points, government social protection schemes and family savings. For the world's most vulnerable people, the availability of resources is often shaped by historical circumstances, such as a history of extractive and oppressive colonial policies, failed development programmes or reforms, and political, cultural and social marginalisation (IPCC 2022).

An important aspect to emphasise is that each person's circumstances are unique and might change as they move through different locales. Vulnerability can also vary significantly from person to person in some contexts. For example, a young woman's experience of drought in a rural area will be radically different from that of an older man in the same location. Among other factors, sources of income, location, gender and age shape people's ability to access or control certain resources.

Equally important is the idea that groups are not monolithic; rather, they are made up of individuals with different — sometimes overlapping — identities. With these key points in mind, Table 2 conceptualises

Table 2. How compounding characteristics of identity can increase vulnerability

	YOUNG PEOPLE	YOUNG WOMEN	YOUNG WOMEN WITH DISABILITY
Limited financial independence	✓	✓	✓
Limited ability to influence governance decisions	✓	✓	✓
Traditionally excluded from selling livestock		✓	✓
Traditionally excluded from inheriting land		✓	✓
Social norms often dictate that men control technologies like solar irrigation pumps		✓	✓
Reduced mobility to access water			✓
Negative social perceptions about abilities within their community			✓
Increasing vulnerability	→	→	→
Undermines their ability to:	1. Take anticipatory action in advance of a drought.	1. Take anticipatory action in advance of a drought, **and** 2. Save, sell, or access assets in a crisis.	1. Take anticipatory action in advance of a drought, **and** 2. Save, sell, or access assets in a crisis, **and** 3. Cope in a crisis.

how a person's compounding identity might reduce their ability to prepare for, respond to and bounce back from climate hazards.

A challenge around vulnerability is that a number of factors matter. These include which stakeholder (individual or group) has agency and decision-making power, who identifies the climate risk(s), who decides how to invest to address the risks(s) and where the funding comes from. For example, an individual smallholder farmer may have it within their power to buy a solar irrigation pump to safeguard against drought, but they cannot tackle floods on their own. Safeguarding against flooding requires intra- and inter-community approaches, and individual farmers have limited control over whether local authorities decide to invest in flood defences.

3.3 Climate uncertainty and energy

There is natural uncertainty about the future, as nobody has perfect information. This is true of large natural and human systems, as they interact in complexity and chaos. The IPCC's climate models are becoming more accurate with each passing iteration, but they are still imperfect. Limited data, particularly about specific locales, hinders accuracy and builds in uncertainty on longer timelines.

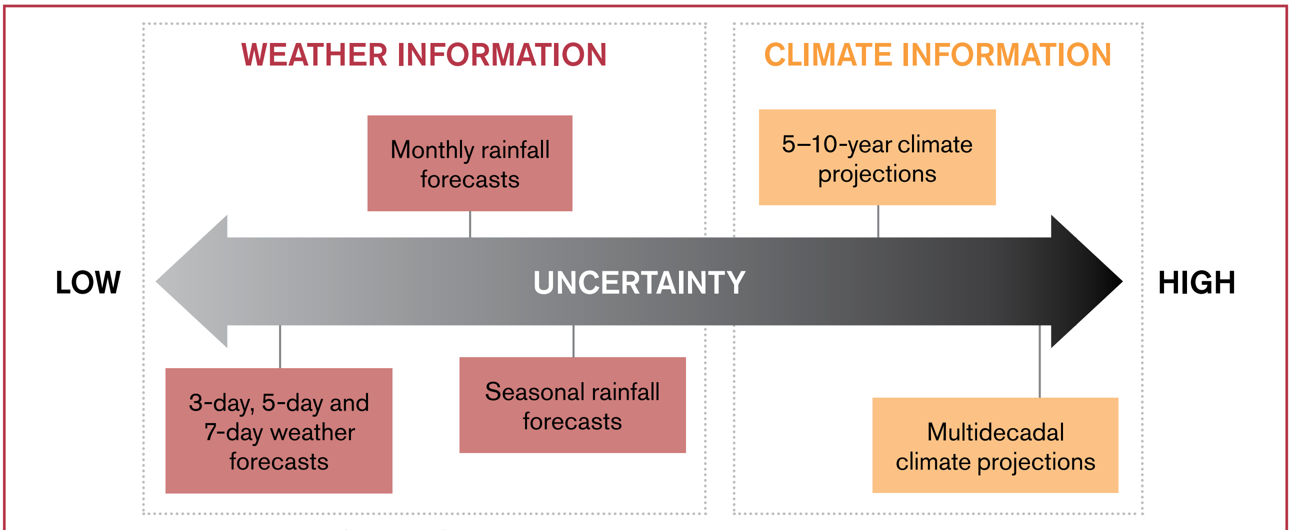
There is also uncertainty about some of the inputs to climate models — for example, the extent of emissions reductions in the future and their subsequent impacts on ecological challenges. Add to this the complexity of social, political and economic human systems, and the further into the future we model, the higher the uncertainty of the outcomes (Figure 4). For example, we have greater certainty about weather forecasts in the near term. The longer into the future we forecast, the less certain the information, which leads to higher uncertainty in the models.

From climate to socioeconomics, a dearth of data arrests our understanding and ability to create accurate climate models. In some places, models show little agreement about future temperature or precipitation (Givertz et al. 2018). For example, in Tanzania, two-thirds of 34 climate model projects indicated higher average rainfall and one-third projected lower rainfall (FCFA 2017). Undermined by poor data quality and inherent uncertainty over time, models that attempt to downscale forecasts to specific locations are unstable and can only make probabilistic guesses.

Uncertainty necessitates ongoing monitoring and iterative learning to help mitigate future risks and incorporating diverse forms of data to inform these processes. In contexts where specific and potentially costly climate adaptation needs are constantly changing, regular review, learning and adjustment ensures adaptation continues to be effective. This includes local knowledge, as the people who live in an area will be more able to identify, collect, and validate the most useful data that are relevant to that space.

One example of uncertainty in impacts on energy systems is greater variability in the water cycle, which will impact small and large hydroelectric systems. One study found varying degrees of increasing risk of water scarcity and flooding for different locations and dam types under three climate scenarios up to 2050. Run-of-river hydro generation assets were more vulnerable to water scarcity than dams with a reservoir, as the latter store water to use for electricity during drought periods when rivers are running low (Opperman et al. 2022). This uncertainty makes designing energy systems like mini-grids particularly fraught, due to the

Figure 4. The relationship between uncertainty and weather and climate information



Source: Courtesy of Sam Barrett, 2023 (unpublished) need to balance technical resilience with financial viability. When considering the most appropriate intervention, robustness in the face of uncertain future conditions is important (Wilby and Dessai 2010).

Through learning, we can identify and respond to unanticipated and cascading consequences that emerge from climate hazards and their intersection with changing ecological contexts or social and economic trends. Adaptation is therefore a process as much as an action, requiring institutions to integrate new behaviours, tools and considerations into their planning and citizen engagement. Failure to ensure that investment choices are robust or adaptive increases the risk of maladaptation.

3.4 Maladaptation and energy

If energy products and services do not address the root causes of vulnerability — such as poverty or social norms — there is a greater risk of maladaptation. This occurs when actions taken to reduce vulnerability to climate risks adversely increase, reinforce or redistribute the vulnerability of social groups, the environment, institutions or sectors (Barnett and O'Neill 2013).

Table 3 highlights the impacts of a desalination project across five maladaptive pathways, and possible mitigation strategies. This example emphasises the pitfalls of over-relying on a technology or asset investment, and illustrates that better alternatives could be designed if policymakers analyse investments using the five criteria (Barnett and O'Neill 2010).

India's maladaptive experience with subsidised electricity and depleting water tables is well documented. One study highlights how widescale access to solar irrigation pumps in Maharastra state reduced operational costs for farmers, but significantly reduced the area's water table as a result of overpumping, and with it, the viability of both the pumps and the farmers' livelihoods (Bandyopadhyay 2019). Another, in-depth report of the sustainability of solar irrigation pumps in sub-Saharan Africa emphasises the need for groundwater resource assessments, capacity building, research and policy components (IWMI and EfA 2021).

A review of 34 empirical adaptation studies demonstrates how maladaptation can reinforce, redistribute or create vulnerability through several contributing factors, including: top-down decision making and articulation of success; elite capture, where people in positions of power influence the allocation of investments or resources; poor understanding of context; excluding distant and/or marginalised communities from decision making; retrofitting previous development interventions; and imposing technical interventions without due consideration to their knock-on impacts (Eriksen et al. 2021).

Table 3. Maladaptive pathways for a desalination plant

MALADAPTIVE PATHWAY	MALADAPTIVE RISK	RISK MITIGATION
Increase GHG emissions	Plant burns fossil fuels to desalinate, contributing to carbon emissions and exacerbating climate change	Use renewable energy source, such as solar PV, to run desalination plant
Disproportionate burden on the most vulnerable	If desalination plant is built on Indigenous land or paid for with a regressive cross-subsidy, it would burden the poorest	Consider targeting brownfield sites, and use a progressive subsidy*
High opportunity costs	Desalination plant is much more costly (financially and environmentally) than other options	Consider an alternative, such as pumping treated wastewater into reservoirs and rainwater harvesting, in combination with good policies
Reduce incentives to adapt	Building the plant could stifle and possibly reverse water conservation attitudes	Consider investing in behaviour change campaigns and incentives such as rebates to reduce water use
Path dependency: set paths that limit the choices available to future generations	Expensive engineering projects commit huge resources in terms of capital, time and institutional momentum for years, reducing future options and pathways	Consider nature-based solutions or less capital-intensive interventions*

Source: Adapted from Barnett and O'Neill 2010, with assumptions (*) filled by the authors of this paper.

Historically, these factors have influenced energy system design and implementation. Processes tend to be top-down, without adequate consultation or lacking a co-design process with communities that builds on people's needs, especially those experiencing marginalisation. For example, some wealthier farmers in India managed to buy multiple subsidised solar irrigation pumps for their farms, while more marginalised farmers could not access a single pump because the initial investment was too high, even with the subsidy (Bandyopadhyay 2019). Technologies, products or services that are only accessible to a few risks reinforcing vulnerability — for example, by further increasing the burden of responsibility for productive labour to one gender or age group. As a result, those unable to access an adaptation-linked technology risk losing their capacity to participate in local politics and development processes.

Structural, gendered power relations can also mean that electricity infrastructure benefits men, as they tend to dominate the livelihoods that have the most potential to gain from electrification, such as carpentry and metalworking. This is often because of structural issues, where gender norms dictate access to resources and opportunities within local economies. Women usually face additional barriers, such as more limited access to financing or education, which are both critical elements that support access to certain livelihoods, energy products and systems (IDS and GIZ 2019).

General principles for avoiding maladaptation include carrying out in-depth and inclusive research before an intervention to assess local vulnerabilities and understand how power dynamics affect interventions and social relationships (Magnan and Mainguy 2014; Schipper 2020). Such community-based processes should also shape the co-design of adaptation solutions that ensure sustainable, locally-appropriate outcomes. As the implications of technologies can vary across locations, identifying contextual factors early on and monitoring these is essential for knowing when maladaptation happens, allowing stakeholders to make necessary changes.

Recognising that there will be different definitions of adaptation success within a community helps to ground new investments or interventions in the complexity of the environment. For example, some groups may prioritise preserving the environment or particular social roles over objectives like economic growth, typically promoted by governments.

Ontological pluralism, which recognises the different forms of knowledge and values held by those on the receiving end of resilience-building efforts, is also advised. Such local knowledge may take a more holistic and grounded view of local conditions and, when supported, may enable wider local ownership of solutions (Eriksen et. al 2021). For example, some communities value preservation of their environment over the increased income and economic development preferred by many transnational actors.

3.5 Transformative adaptation

Stakeholders across sectors have built useful resilience frameworks. For example, GOAL's ARC-D Toolkit identifies community attributes for absorbing, adapting and transforming in the face of climate shocks across eight sectors: education, economy, environment, governance, health, infrastructure, social/cultural and disaster risk management (McCaul and Mitsidou 2016). Other approaches frame household or community attributes using the Sustainable Livelihoods Framework, which explores human, financial, natural, physical and social capital (Quandt 2018). Finally, the Food and Agriculture Organization of the United Nations' SHARP+ tool identifies indicators across 13 areas, including capacity for reflecting learning, interconnectedness and diversity of ecosystems, with economic, social, governance and environmental subindicators in each (FAO, nd).

Evidence from one study that applied multiple objective and subjective resilience frameworks found that "various commonly-used frameworks produce similar resilience outcomes, suggesting that debates over the exact composition of resilience-characteristics may matter little" (Jones and D'Errico 2019); others approve of "methodological pluralism" (Jerneck and Olsson 2019).

The concept of adaptative capacity — the ability to anticipate, absorb or adapt to climate risks (Bahadur et al. 2015) — features prominently in many frameworks, but should also be thoroughly contextualised for where people live. This includes integrating local knowledge and endogenous technologies. We should go further, adding the concept of transforming in response to climate risks and being explicit about creating structural changes that address root causes of vulnerability (Jeans et al. 2017). Central to transformative adaptation is change in institutional processes or configurations that facilitate qualitatively different and more equitable relationships between citizens, private actors and government in decision making, planning or accountability. Since unjust or unequal systems are themselves resilient, opportunities for transformative reform may emerge at moments of crisis or vulnerability, such as climate shocks, constitutional reform or demographic shifts, when innovation and reformation are needed most (Folke et al. 2010).

Transformative adaptations are unlikely to be triggered by one service, product or appliance. If transformation requires new behaviours, relationships and practices, then these will require changes in institutions, policy,

Table 4. Transitioning to disruptive resilience

AREA/SECTOR	BUSINESS AS USUAL	DISRUPTIVE RESILIENCE
Informality	Ignore residents of informal settlements or, in some cases, invite them to 'participate' superficially in decision-making on urban resilience	Treat local people and institutions as full partners to ensure that decision-making on risk management devolves and draws on expertise of those living in informal settlements
Finance	Overlook the need to finance urban resilience efforts or send funds that are too little or too late	Ensure urban centres can augment external financing by using internal mechanisms and methods (such as resilience bonds) to raise financing swiftly, at scale
Services and systems	Emphasise estimating probability of a hazard and basic contingency planning to ensure continued service	Enhance the ability of those running urban services to make decisions under certain conditions, using approaches such as adaptive management and tactical urbanism
Innovation	Mostly overlook novel approaches for reducing risk or use structured and expert-led models of innovation	Enable autonomous innovation that is frugal, 'good enough' and relies on local knowledge for swift solutions to disruptive risk
Data	Employ static, arduous, expensive approaches to gathering and analysing risk-related climate information	Use big data and self-enumeration exercises undertaken by people in informal settlements to provide dynamic risk data cheaply and easily

Source: Bahadur and Dodman 2020.

technology, know-how and more. Table 4 shows examples from one transformative approach targeted at urban centres that outlines disruptive resilience, combining finance, services, data collection and approaches to informality (Bahadur and Dodman 2020).

People need to first interact with energy services and technologies within the confines of their own contexts. To reach more and different groups of people, this means bundling sociocultural and technical innovations with energy services and technologies, while supporting self-determination and building institutional support. In other words, these bundles need to overcome various social and economic barriers and leverage opportunities based on people's positionality, enhance their wellbeing and livelihoods, and build assets to cope with any economic, social or environmental shocks (Johnstone, Aung and Barrett 2023). In Section 3.6, we build on this concept and its relevance for energy products and services.

3.6 Learning from adaptation and resilience practice

Without a real understanding of the nature of resilience to climate risks in different landscapes, investments can turn maladaptive, fail to properly account for uncertainty and changing contexts or miss opportunities to learn, grow and add value to a nascent business. Without useful measurements of change in resilience, governments and the public have no common way to gauge their readiness or preparedness for climate risks. Nor can they hold anyone accountable for their activities in relation to development goals. This section highlights some of the key considerations for measurement in the wider CRD literature and their implications for energy and development stakeholders seeking to contribute to CRD. Early conceptions of resilience focused on the idea of households, institutions or ecological systems coping with crises or shocks and either remaining unchanged or being able to bounce back to their original state. The concept remains technically relevant for various energy systems that need to remain predictable and functioning during shocks like storms or flooding.

More recent perspectives in the context of increasing threats to biodiversity and a stable climate recognises how social processes and the ecological systems people inhabit constantly shape each other. Consider, for example, how repeated flooding may change local behaviours in terms of the crops people grow, how and where they grow them, who grows them, and the positioning and scale of flood defences — which, in turn, have social, cultural and environmental consequences with cyclical outcomes. Socioecological systems are complex, dynamic and naturally adaptive, with many independent actors responding to change while learning and influencing others. Crucially, such systems can have more than one stable, resilient state (Holling 1973). And after a shock, they may change or adapt key features, with trajectories of change determined by actors within the system (Folke 2006).

To understand resilience, we must recognise people's agency and power to make decisions and mobilise the resources they need to shape their responses to threats. Socioecological systems are dynamic and prone to cycles of growth, rigidity, change and various types of reformation driven by both internal and external stressors (Folke et al. 2010; Villasante et al. 2022). This creates windows of opportunity for transformational innovation and change when agency and power can be redistributed. For example, in a coastal environment, small-scale fishers identify a commercially attractive species, generating quick financial return. But as more fishers join, professionalisation and improved technologies, coupled with poor governance, leads to unsustainable fishing practices and a subsequent collapse of the species' availability and associated livelihoods (Villasante et al. 2022). An alternative reformation may have emerged, had strong governance led to greater species management and a new temporary stability of the socioecological system. An example of this can be seen in the solar lanterns promoted as replacements for kerosene lamps that fishers use on Lake Victoria in East Africa to attract fish. The solar technology is cheaper, but overfishing is now a threat to the area, as more people are attracted to the profession (Walcott 2020).

'Resilience' is not intrinsically worth pursuing. This may be the case where a highly-resilient system is deeply unjust or unethical — for example, if it undermines the rights of the many to serve an elite, such as slavery, or systematically marginalises minority groups to satisfy the majority. And the continued intensity of fossil fuel use and biodiversity-damaging farming practices, in the face of damning evidence, suggest undesirable, yet resilient, systems. So, if it is to be non-neutral and worthy of pursuing, resilience cannot be separated from social, political, environmental and economic considerations.

When we think about resilience, we usually ask "Whose resilience? To what?" This recognises that the qualities required to cope with and respond to drought, for example, might be different from those required for a flood, or different for men and women. Investing limited resources in trying to build resilience to one kind of risk may also leave people vulnerable to other kinds of risk (Folke et al. 2010). For example, encouraging diversification of rural livelihoods into tourism-related businesses may reduce household sensitivity to drought but create vulnerability to pandemics or insecurity scares that quickly collapse tourism industries. In the context of deep uncertainty, overlapping climate hazards and potential unanticipated consequences, focusing on "Whose resilience? To what?" may increase vulnerability, if applied too simplistically (Gill and Malamud 2016). For example, farmers face incomplete information and difficult trade-offs for investments in farm improvements and risk management. A farmer who invests everything into resilience to floods (drainage and flood defences) but fails to invest in drought-resistant crops, drip irrigation systems or diversified income sources becomes vulnerable to other hazards like drought or pests.

General resilience takes a wider approach, focusing on the resilience of a set of interlocking processes, technologies and approaches to governance and considers the range of risks that might threaten food systems or stable economies (Jones and D'Errico 2019). But resilience could more ambitiously be conceptualised as an ability to cope with all kinds of shock, both predicted and unforeseen (Folke et al. 2010). This kind of resilience builds on the abilities of actors within a system to recognise, absorb or adapt to a risk and, most importantly, to learn from it and integrate learning continuously (van der Merwe, Biggs and Preiser 2018). The importance of learning in this concept implies that products or services need institutions that facilitate societal learning and responsiveness. Iterative learning based on experience of risk is central, requiring tools and systems that can facilitate such learning.

Being clear about the kind of resilience an intervention, product or service contributes to, supports transparency and enables stakeholders to understand how interventions are being applied. It also ensures that: governments can report more effectively on their adaptation efforts and track resilience to various risks; investors and entrepreneurs can more easily identify gaps in the market; and donors can more easily pick out cost-effective efforts to subsidise or stimulate nascent markets in response to challenges.

3.7 Resilience and uncertainty

Data quality is often not strong enough to support reliable predictions about future conditions. As a result, climate-resilient development investments need to be robust to a range of possible futures. Without considering uncertainty, investments are more likely to be maladaptive.

As with all resilience planning, local knowledge and experience can offer estimates of future resilience without significant data requirements. This is useful in Least Developed Country contexts, where data availability is limited. Scenario-planning workshops can explore a range of possible climate futures with people from certain landscapes or contexts, opening discussions on what investments or interventions might work across a range of situations.

Returning regularly to test resilience-building measures against ongoing and emerging future risks is also essential, as changing risk profiles will have consequences that are unknowable until they emerge. This kind of long-term, iterative approach to resilience requires a long-term financial commitment that may be beyond the interest or capabilities of some investors and energy enterprises. As such, it may be a role for governments and donors.

The unavoidable lack of knowledge about the interdependence of actors and activities in a changing and dynamic system also creates uncertainty. Change is rarely linear or directly correlated to a single intervention. Complexity can give rise to three types of unknown:

- Temporal unknowns around how an intervention will affect intergenerational equity
- Spatial unknowns around how changes in ecosystems will affect each other, and
- Cross-sectoral unknowns around trade-offs, risks and choices across sectors as a result of the intervention (Beauchamp et al. 2022).

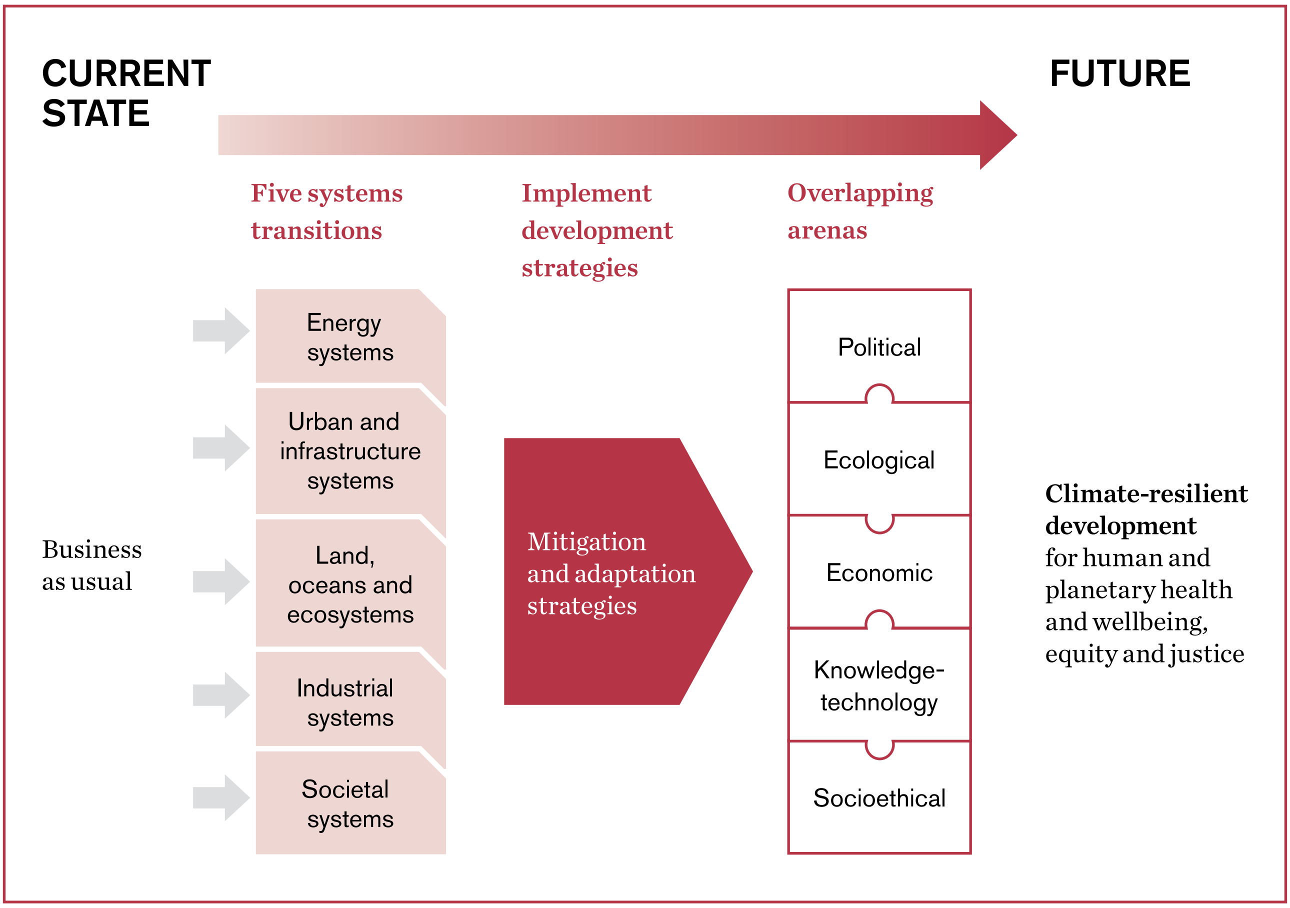
Engaging directly with communities is the surest way to uncover and identify these uncertainties.

3.8 Claiming climate-resilient development

Traditional models of development focused on discrete sectors and often treated public and private stakeholders as operating independently within development sectors, such as health, water, education and energy. To avoid these old paradigms and tackle the inherent complexity of climate change across human and natural systems, the latest IPCC report calls for CRD, a "process of evaluating, valuing, acting and adjusting various options for mitigation, adaptation and sustainable development, shaped by societal values as well as contestations of those values" (IPCC 2022). This includes:

- Transforming **governance** and livelihoods for nature, poverty and climate (transformative)
- Requiring **interaction** across actors, sectors, systems and stakeholders (whole-of-society)
- Centring considerations of **equity**: vulnerability tied to exclusion, marginalisation poverty (equitable), and
- Recognising that change is a **political** process, requiring contestation and compromise (IPCC 2022).

Figure 5. Pathways to pursue climate resilience development



CRD places the equitable transformation of societies and their relationship to ecosystems at its centre. Anything less than transformational may be maladaptive for significant proportions of the global community. The IPCC pathways to CRD consider transitions in five systems, which implement mitigation and adaptation development strategies in five overlapping arenas, ending in a CRD future (Figure 5).

The fact that energy systems are one of the major transitions shows their critical importance, but the IPCC examples focus on decarbonising, increasing the efficiency and managing the demand of those energy systems. There are no specific examples in this section on expanding energy access, either in terms of electricity or clean cooking. To achieve a CRD future, simply rolling out new energy technologies at scale to power low-carbon development is not enough. Universal access must be an integral part of this work, with impacts measured over time, particularly around who is benefitting and who is not, to achieve just outcomes. It is not enough to think about energy access only in terms of connections and productivity; rather, it is important to also consider how energy access and structures influence power relations, access to services for marginalised groups and equitable societies. To this end, it is important for energy systems and actors to consider energy systems holistically, from mineral extraction to recycling (Box 5).

Individual energy enterprises can have influence over the deployment of different energy systems. Larger distributed energy systems — such as a field of solar panels and wind turbines, or larger biogas systems and water turbines — can compete for local land use and resources, with negative impacts on biodiversity, water tables, food security and ecosystem services, particularly affecting marginalised groups (Sánchez Rodríguez and Fernández Carrill 2024). Meanwhile, SHS distributors have considerations around end user debt and protections (GOGLA 2024; Schützeichel 4 May 2022). All providers must therefore consider how their systems influence and shape vulnerabilities and gender equality, among many other considerations for CRD.

CRD is as much about the processes involved as the outcomes. Dialogue, systemic learning, stakeholder participation, adaptive management and integrating climate information into decision making all help make different CRD pathways visible and therefore open for community consideration around energy systems (Taylor et al. 2023). There is no single path to achieve CRD. Each country has its own starting point and strategies that are politically and socially expedient. Countries will have to identify the political settlements they need to achieve universal energy access (Sánchez Rodríguez and Fernández Carril 2024).

A global approach to CRD must consider how policies are implemented at national and subnational levels to ensure they do not reproduce and aggravate shortcomings and limitations in adaptation, mitigation, and climate finance in countries (Sánchez Rodríguez and Fernández Carrill 2024).

BOX 5. TOWARDS JUST CLIMATE-RESILIENT DEVELOPMENT

From mineral extraction to component recycling, renewable energy systems — academics, practitioners, developers and governments — must also consider intended and unintended consequences along the supply chain and product lifetimes. Electricity systems account for about 70% of mineral demand, and that will continue to grow (IEA 2021). Solar panels and wind turbines in particular rely on minerals that are extracted in locations where minimal governance regimes can leave people vulnerable and their local environments exploited without compensation, reward or transparency (Figueroa 28 May 2024). Energy enterprises often have little control or influence over the direct extraction of minerals, as responsible sourcing efforts for lone distributors do not go far without enormous scale to sway sourcing considerations. But there can be no just transition while human rights are being violated or people are suffering to extract resources for renewable energy systems. National and global associations, including the Global Off-Grid Lighting Association, must use their collective memberships to sway responsible sourcing demand.

There are huge challenges to overcome in recycling different components, from the smallest solar lanterns up to wind turbines (Lopes 18 April 2024; Khalid et al. 2023). Business modelling must apply a lifecycle assessment — from material extraction to end-of-life recycling — to comprehensively understand the environmental impacts of renewable energy products and systems (Mukoro, Sharmina and Gallego-Schmid 2022).

4

Measuring climate resilience and investment impact

With resilience remaining a relatively abstract concept, detectable largely through proxy indicators, there is plenty of room for methodological pitfalls and challenges associated with evaluation and field research more generally. We explore some of these in this section, with examples.

Circularity: when an energy enterprise selling solar irrigation pumps uses proxy indicators to track product sales and use across different market segments, some of the information gathered can indicate product usefulness for individuals and farm productivity, among others, but does do not indicate resilience. This would require thinking through additional information — such as weather data, insurance claims, and so on — to triangulate whether the pump is offering resilience against drought. This is an example of circularity. The energy enterprise assumes that solar irrigation will build resilience; it tracks the indicators it believes will best demonstrate this; and then assumes that its intervention will lead to resilience gains.

Outputs versus outcomes: recognising the distinction between outputs and outcomes is central to understanding how interventions might affect specific or general resilience. An energy enterprise selling solar irrigation pumps can easily track sales as outputs, but it is more challenging to track and understand whether these sales are achieving outcomes, such as higher income or productivity. Simply put, outputs are results that are immediately attributable to an intervention, product or service rollout. The activity — in this case, the sale and purchase of a solar irrigation pump — and its effect are directly connected. Outputs are often quantitative and can be measured by indicators such as number of people trained, units sold, services delivered and number of customers.

Outcomes, on the other hand, are changes or benefits that result from outputs, usually over a period of time. They might refer to changes in behaviour, systems or institutions, which are more technically challenging to measure and more expensive to track. Other contextual factors can also influence the achievement of outcomes. For example, if a farmer increases crop production with the help of an irrigation pump but cannot sell the excess crops, they would not achieve a higher income. So, despite the irrigation pump increasing farm productivity, the farmer may be worse off, unable to recoup the money borrowed to invest in the new pump.

Focusing only on outputs, such as sales, as an indicator of resilience is highly reductive. It implicitly assumes that higher product sales translate into greater resilience or impacts for growing numbers of people. This may be true for some households. Yet, our understanding of resilience, uncertainty and risk shows that this may be unlikely in many circumstances, given the wide variety of other contextual factors at play. Indeed, an output focus contributes to the kinds of knowledge gaps that lead to maladaptation.

Shifting baselines: with the climate changing, historical data are no longer reliable indicators of future conditions. We are also trying to measure outcomes in a context of complex social and ecological dynamics. This is particularly so in arid or semi-arid landscapes that are characterised by unpredictability and variability (Krätli et al. 2015), where solar irrigation, for example, is often touted as particularly useful. But when 'normal' is constantly shifting, interpreting a baseline can be difficult. If evaluations do not take deteriorating climatic conditions into account, they may consider some interventions that are building resilience to have failed.

Attribution: against a background of changing climatic conditions, identifying confounding factors and counterfactuals allows us to attribute intervention outcomes more robustly. Changes in climate hazards, vulnerability factors, and experiences and perceptions of risk are all important to understanding the development impacts of interventions (Lamhauge, Lanzi and Agrawala 2012). It is both costly and difficult to attribute improvements in resilience to specific activities or actors in a complex and dynamic environment.

Universalisability: universal adaptation metrics would theoretically facilitate comparison across locations and contexts. However, the contextual nature of adaptation makes identifying universal indicators difficult, if not impossible. Measuring changes in income, revenue or expenditure tends to incentivise quick wins, which can draw attention away from the most vulnerable people and hide important details about local institutions and behaviours. Table 5 highlights some of the strengths and weaknesses of universal metrics.

Objective, subjective, qualitative and quantitative indicators: combining different indicator types as proxies for resilience presents more nuanced and valuable information to stakeholders. Objective definitions of resilience use externally developed frameworks to decide indicators and may use independent evaluators to collect and analyse data. Subjective definitions and evaluations rely on the community or household in question.

Subjective and objective frameworks exist on a continuum and can be applied through a range of methodologies. **Objective indicators** offer the tempting proposition of greater comparability across multiple locations, but the danger here is that contexts may become defined by external actors who have different concepts and personal realities. **Subjective measures**, on the other hand, offer greater scope for vulnerable people to articulate their own local knowledge and criteria for improved resilience, and draw on their priorities. They create greater scope for 'ontological pluralism' — the idea that multiple types of knowledge are equally valid — in resilience assessments. But they can also lack explanatory power, as it can be difficult, without further investigation, to understand the factors that affect a respondent's subjective appraisal of a situation.

Attention to qualitative and quantitative measures is equally important. While **quantitative measures** offer the benefits of verifiable figures, they can obscure context and be easily misinterpreted without qualitative investigation. **Qualitative indicators** provide explanations for the jumble of numbers that quantitative explorations of resilience can produce. Using both qualitative and quantitative measures offers a well-rounded understanding of resilience that articulates both the changing circumstances of vulnerable people, and how and why they are changing, allowing us to explain and share the narratives of improved resilience.

Subjective indicators can be relatively low cost and offer an opportunity to compare across contexts to some extent. Such measures can also be heavily influenced by seasonal and economic change. As a result, frequent engagement might be necessary to build a picture over time and as climatic conditions change. For example, where droughts get longer and water access reduces, solar irrigation pumps may not offer the same level of resilience as they would in a context without these changes. Integrating end users into data analysis may provide deeper, more contextualised insights than those gleaned by external reviewers or evaluators. Understanding how resilience is being built and local people's willingness to engage with a particular energy product can inform future business models or iterations of a service. We believe this is the future of energy service provision under climate uncertainty.

Table 5. The pros and cons of universal adaptation metrics

POSITIVE	NEGATIVE
Help measure performance across contexts Provide a conduit for accountability and equality in resource allocation	Disadvantage data-scarce settings in terms of identifying and presenting needs Overlook important sociocultural elements Do not consider the local adaptation context Favour places, sectors or projects where monetisation is easier or income settings higher

Source: Adapted from Christiansen, Martinez and Naswa (2018).

4.1 Fitting technologies into changing contexts

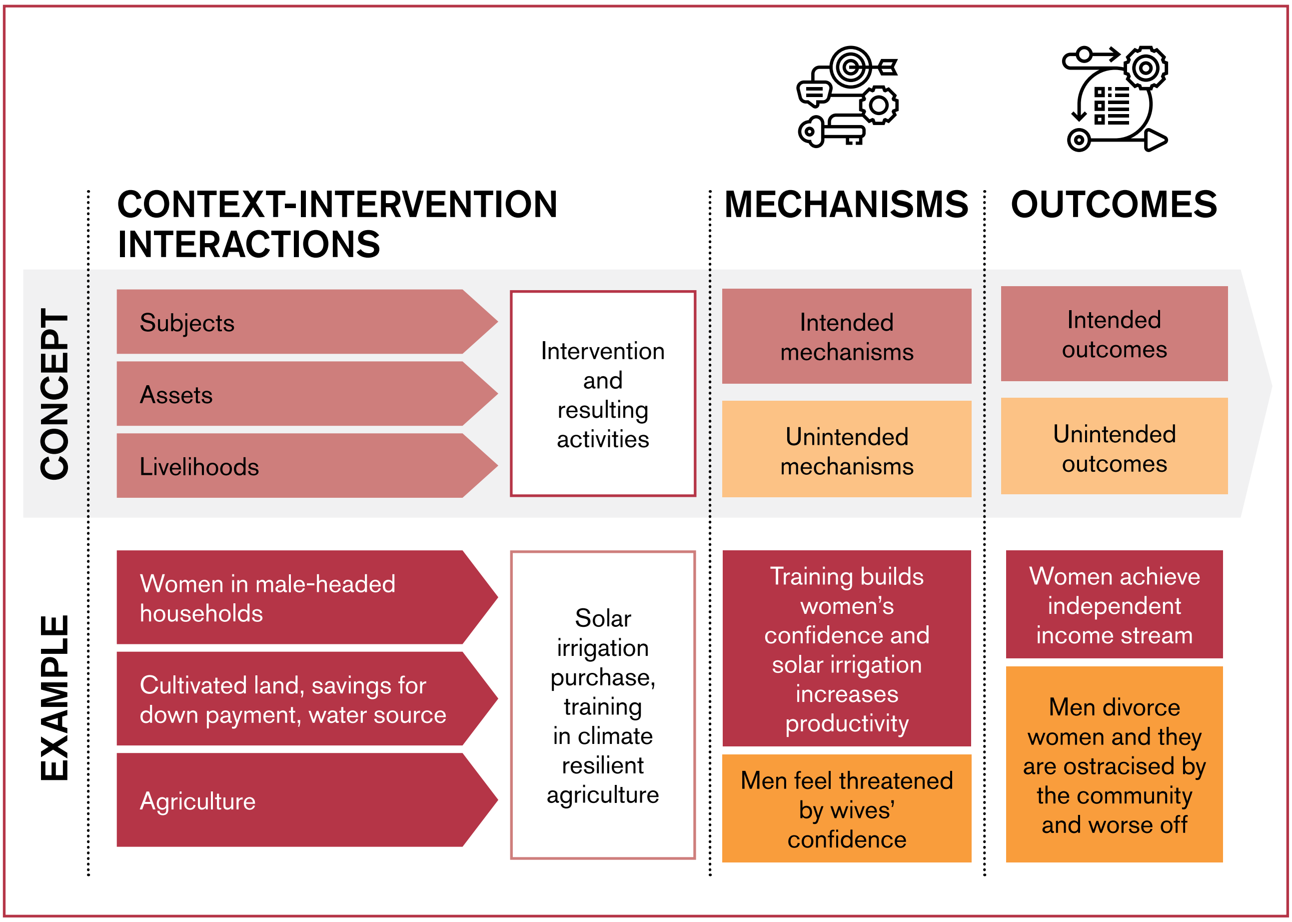
Energy access has historically focused on deploying technologies and fuels without much consideration for the contexts in which they sit. This is a recipe for failure. An important consideration for energy access is that people interact with technologies based on their position within their households, communities and society. This includes the dynamics and relationships that link these three different layers. One way to conceptualise this is through the realist-synthesis model.

Simplified for the purposes of this paper, Figure 6 highlights the realist-synthesis model, starting with examining the context in which people live. The contextual parts could include positionality, assets and livelihoods, as well as elements not shown in the figure, such as supporting environment (institutions, policies and so on) and external factors (climate change, population growth, and so on). The intervention — for example, a solar irrigation pump or a mini-grid system combined with other sociocultural innovations — offers people who are normally constrained by their context a change in resources and opportunities, affecting the outcome (Johnstone 2023). What we label the mechanism are "the thoughts, beliefs, confidence, reasoning and other cognitive triggers and processes within people's minds that are caused by receiving and engaging with [the intervention]" (Johnstone 2023). In short, something shifts in the person's positionality or mind, enabling them to take advantage of access to the technology and associated supporting activities.

People working in the productive uses of energy space may be familiar with such thinking. They similarly state that simply providing technologies is often not enough to enable people to achieve outcomes such as higher incomes or resilience to shocks. Supporting services and market functions, often missing in these contexts, are vital for people to be able to use the energy provided.

Figure 6 also offers an illustrative example around energy and empowerment from Tanzania, of an intervention that supported women to establish their own income stream. Some husbands felt that the intervention undermined their role as the primary income generator, and they consequently reduced their cash support to their wives. Some even divorced their wives, leaving the women worse off (Galiè and Farnworth 2019). This emphasises the importance of identifying the intended and unintended outcomes of energy interventions, as energy products offer similar opportunities for generating income.

Figure 6. A simplified realist synthesis model for people and outcomes



Icons by Eucalyp from The Noun Project.

The most effective way to mitigate these vulnerabilities and avoid maladaptation is for energy enterprises to engage with end users and their communities when they are designing and deploying their energy services. This can start with disaggregated data collection to understand how these characteristics influence strategies and decisions. This engagement must include deliberate actions to meaningfully increase marginalised groups' ability to participate and share their perspectives, which can lead to better system and product designs. It should also apply best practices, such as participatory methods, group work separated by gender or other characteristics, facilitators from the same group (female facilitators for all-women groups) and prior and informed engagements to help marginalised people articulate their needs and aspirations during the primary engagement.

To illustrate this, a case study from Nepal shows how smaller hydro facilities increased community adaptive capacity through several pathways, improving community assets, social resilience, good governance principles and living standards (Gippner, Dhakal and Sovacool 2012). But these outcomes did not manifest simply because a microhydro system appeared. Rather, additional support, including training, experimentation and adaptive learning, helped ensure community members could leverage the electricity into their own priorities.

Table 6 summarises the study's findings and posits logical extensions of the study to desired outcomes related to the deliberate design of the intervention and outputs. The study itself did not explicitly identify these outcomes; but in the absence of higher-quality studies that link to clear outcomes, we have distilled them here for illustrative purposes. We believe that, for energy access work to recouple energy and climate, this is the direction it needs to take. This framing can help energy sector actors think through the additional benefits of off-grid energy services. And while the illustrative focus here is on adaptive capacity, energy practitioners must also consider people's exposure and sensitivity to climate hazards for a complete picture of their vulnerability and the role that energy can play in reducing that vulnerability.

The point on outcomes versus outputs is important. For instance, access to school lighting for evening classes or night study at home does not automatically equate to better educational attainment by students if other structural issues get in the way (Johnstone 2019; Harrison 2018). Teachers not being paid on time can affect their motivation or ability to teach, or a lack of school feeding programme can affect students' ability to perform well. There is evidence that, with the right enabling environment and support, schools can benefit in multiple ways, including reduced absenteeism, gender equality and completion rates (Valerio 30 June 2014; Goodwin 8 October 2013; Sovacool et al. 2013). They can also be used as hubs for different services and functions like powering irrigation and potable water provision (Diniz et al. 2006), increasing community resilience to drought and other climate impacts.

4.2 Measuring energy and climate resilience

Several adaptation and resilience frameworks have been published recently, geared towards different audiences. We reviewed 'Adaptation and resilience impact: a measurement framework for investors' (ARIC 2024); 'Climate resilience investments in solutions principles (CRISP)' (GARI 2024); 'Guide for adaptation and resilience finance' (Standard Chartered, KPMG and UNDRR 2024); and 'Climate adaptation target setting' (Neocleous et al. 2024).

None of the four we reviewed include elements for cleaner cooking. This is a glaring omission, given the potential size of impact. When thinking about energy, these frameworks tend to focus on electricity infrastructure for adaptation, such as grid hardening and energy efficiency work, assuming that these investments will trickle down to benefit people. Metrics such as "number of people using climate-resilient infrastructure provided through the investment" (ARIC 2024) offer an understanding of scale and reach, but do not necessarily guide investments towards giving people first access. If anything, the logic guides investments towards assets that contribute to existing infrastructure without expanding access, as that would be more costly. An investor may conclude that investing in technical resilience for existing systems would be a better investment, given the affordability gap and other major challenges outlined in Section 2.

As we outlined in Section 3.2, people interact with energy services and products based on their positionality within the confines of their context. Reaching outcomes depends on people's ability to access and control energy products, having the necessary supporting environment and services, their ability to overcome their unique barriers, and the long-term usefulness of the products as their context changes.

To this end, measuring impacts becomes critical. The Impact Management Project (IMP) — a forum for organisations to build consensus on how to measure, compare and report impacts on environmental and social issues — was established in 2016 to design standardised interpretations of company and organisation performance and impacts (IMP 2020 and IMP and BlueHub Capital 2020). The IMP established five dimensions of impact specifically for enterprises, providing an important step in (*continues on page 33*)

Table 6. Adaptive capacity advantages of microhydro facilities in Nepal, by category

	DESIGN ANGLE	EXPLANATION	DESIRED OUTCOME*
Environmental	Run-of-river microhydro design	Diverts small amount of river water and opens small dam daily to release sediment collection, with minimal impacts on ecosystem services	Preservation or restoration of nature and minimal long-term environmental impacts
Emissions mitigation	Choice of hydro generation	Reduces community reliance on batteries and kerosene for lighting	Reduced community carbon footprint without sacrificing socioeconomic development
Savings	Lower tariffs than existing fuel costs	Reduces spending on batteries and kerosene for home, and on diesel for carpentry and agroprocessing businesses, with net savings from lower microhydro tariffs	Increased savings allow households and businesses greater adaptive capacity
Direct employment	Community operations and maintenance jobs for mini-grid	Creates four to five new community-level jobs per plant	Sustained, high-quality employment
Indirect employment	Using nationally manufactured components and parts	Supports national-level manufacturing and maintenance jobs	Sustained, high-quality employment
Indirect income generation	Small businesses use electricity	Generates and diversifies income through micro, small and medium-sized enterprises (MSMEs) as people leverage electricity to use agroprocessing and other equipment	Sustained and diversified income for greater adaptive capacity
	Nearby farmers use microhydro canals for irrigation	Generates co-benefits of water use	Sustained and diversified income for greater adaptive capacity
Business training	Implementing livelihood support training	Project implemented training on poultry rearing	Households have greater livelihood diversity
Gender equity	Requiring gender parity within the project	Community mobilisation and gender parity rules within community-based organisations overseeing the plants, spurring more equal gender representation Guidelines require majority of agroprocessing and poultry businesses be operated by women Electrification reduces time needed to fulfil many household chores, such as rice husking and other food processing Electrification provides improved health services, particularly for maternal health Additional training increases opportunities for women and reduces school dropout rates for girls	Greater gender equality in jobs, opportunities and decision making
Communication	Supporting information and communication technology infrastructure	Opens opportunities for information through mobile phones, television and internet Supports MSMEs in promoting their businesses, especially those related to tourism Support MSMEs getting market information to make decisions	Businesses make more informed decisions with more information and reach broader markets to grow
Education	Supporting education infrastructure	Provides more access to teaching materials, computers, lighting and evening classes	Children have better educational outcomes, with positive long-term impacts on socioeconomics

Source: Adapted from Gippner, Dhakal and Sovacool 2012, with logical extensions (column 4)* posited by the authors of this paper.

framing, streamlining and standardising different elements of performance and impact. Some of the frameworks we reviewed have integrated these five dimensions, which offer points of analysis.

In Table 7, we pose a split of two frameworks alongside specific energy metrics from a company called 60 Decibels, all of which integrate the IMP's five dimensions. While the three are inextricably linked, they have different audiences and goals, and our intention here is not to compare them. Stitched together, they offer a broad perspective of what might be necessary to advance thinking on impacts for electricity and cooking.

Column 1 highlights the five IMP dimensions, with detailed explanations. Column 2 shows the Adaptation and Resilience Investors Collaborative (ARIC) Measurement Framework, which aims to help investors think through how to broadly measure contributions to resilience and adaptation in their investments. This publication sums up a lot of the challenges and offers metrics on: increased provision of climate-resilience infrastructure; maintained or improved water availability in response to climate-driven water scarcity and drought; maintained or improved agricultural productivity in response to identified specific physical climate risks; and maintained or improved human health in response to identified specific physical climate risks (ARIC 2024).

Column 3 shows the Global Adaptation and Resilience Investment Group's (GARI) CRISP framework, which aims to help investors identify enterprises that are packaging adaptation 'solutions' that remove barriers to adaptation and reduce risks and adverse impacts to people. It presents examples of an individual or household using climate information services, responding to a drought via a water efficient irrigation system, and recovering via climate parametric insurance (CRISP 2024).

Column 4 highlights energy access metrics from 60 Decibels, a company that primarily uses phone surveys to gather self-reported information from end users across several sectors, including off-grid energy. Dozens of energy enterprises — both electricity and cooking — are working with 60 Decibels to try and understand and measure the impact of their products and services, providing specific data to point to.

In the following section, we offer some highlights that we think are important when designing an energy access, resilience and adaptation framework and metrics. By design, Table 7 shows that the ARIC and GARI frameworks are necessarily broader, to include a wider range of investments — not just energy products and services — that potentially contribute to greater individual and community resilience or adaptation. While they offer some metrics, they do not offer specific methodologies on how to capture them. In contrast, 60 Decibels offers a standardised question set that tries to unpack the five dimensions from the perspective of end users using remote surveys. This standard set allows for comparison between similar energy enterprises but depends on self-reported data. The focus on technology and end-user experience of that technology may preclude understanding of other influences on impact, such as supporting services (business inputs, access to markets, marketing skills and so on) or social norms, including household gender dynamics.

The ARIC and CRISP frameworks also touch on business practices and models, which are important to explore further for energy access. For example, an energy product or service can push people into unsustainable debt because of business practices, which has been a concern in the industry (Kocieniewski and Finch 2022; Schützeichel 2022; Africa Solar Industry Association 2022).

Who

60 Decibels uses very practical methods for measuring types of stakeholder, such as the statistically significant Poverty Probability Index (PPI) and the Washington Group's questions on disabilities. Like all methodological choices, these have trade-offs — for example, the PPI mostly measures consumption as a proxy for poverty —but offer a meaningful window into household circumstances.

Uniquely, ARIC includes guidance not just for impact on people and economic activity, but on nature as a stakeholder. We believe that it will be important to capture this to understand the intended and unintended consequences of energy access investments on nature. Output metrics such as reduction in water abstraction and area of habitat under climate-resilient management would need to be considered for different technology types.

Importantly, gender must be meaningfully incorporated and there is evidence that phone surveys may not be adequate for unpacking intrahousehold gender dynamics. They can offer difference in perceptions between men and women, albeit not within the same household. A representative gender-integrated situational analysis of the local context could offer a pathway forward, though this requires considerable additional resources.

What

A critical element of 'what' is measuring a positive or negative change in outcomes, which necessitates capturing data over an extended period of time, such as multiple harvest seasons. One study using a longitudinal methodology to track the impacts of standalone solar water pumps, electric pressure cookers, solar televisions and refrigerators (*continues on page 36*)

Table 7. Combined analysis of measuring for climate adaptation and resilience and energy (continued over page)

<table>
<tr><th>IMP'S FIVE DIMENSIONS OF IMPACT</th><th colspan="3">ARIC MEASUREMENT FRAMEWORK FOR INVESTORS (ARIC 2024)</th><th>CRISP FRAMEWORK (GARI 2024)</th><th>60 DECIBELS IMPACT METRICS</th></tr>
<tr><td>Who: which stakeholders are experiencing the outcome and how underserved they are in relation to the outcome</td><td colspan="3">Suggests dimensions that generally capture who, in a broad sense, experiences adaptation and resilience outcomes in three aspects — people, natural systems (planet), and economic activity — but does not specify ways to measure these</td><td>Which stakeholder experience is impacted: stakeholder characteristic, geography</td><td>Offers specific ways to measure:
Poverty levels, through the PPI (www.povertyindex.org)
Gender, registered via customer registration information and validated during interview
Disability inclusivity, established through Washington Group questions on disability (www.washingtongroup-disability.com/question-sets/wg-short-set-on-functioning-wg-ss)
Age, by asking respondent directly
Location, by capturing whether respondents live in urban, periurban or rural areas</td></tr>
<tr><td>What: the outcome the enterprise or investment is contributing to, whether it is positive or negative, and how important the outcome is to stakeholders</td><td colspan="3">Duration: length of time over which the adaptation and resilience outcome is experienced</td><td>How a company's adaptation or resilience service/product is contributing to impact in terms of breadth and depth
Qualitative approaches (eg ex-post surveys) can be better suited, particularly if the beneficiaries are people and communities</td><td>Quality of life, by per cent of customers saying their quality of life has improved through access to new product or service
This metric does not show how quality of life has improved
Additional sector-specific indicators, including elements of consumer protection, over-indebtedness and others, for off-grid energy</td></tr>
<tr><td rowspan="2">How much: number of stakeholders that have experienced the outcome, degree of change they experienced and duration of outcome</td><td>Aspect of adaptation & resilience impact</td><td>Scale (extent of the system boundary within which climate vulnerability is reduced)</td><td>Depth (extent of reduction of climate vulnerability)</td><td rowspan="2">How many stakeholders experienced the impact and degree of change (breadth and depth of change)</td><td rowspan="2">Perceptions of change: the most important self-reported outcomes 60 Decibels has found for energy access include income generation (productive use), movement up the conceptual 'energy staircase', changes in energy expenditure, change in use of prior energy sources, time savings, increased study hours, personal safety and health</td></tr>
<tr><td>People</td><td>Output level — eg number of people accessing flood risk awareness training</td><td>Assessing the degree to which people are made more climate resilient using outcome-level metrics — eg number of people able to avoid income losses during flood events</td></tr>
</table>

Table 7. Combined analysis of measuring for climate adaptation and resilience and energy (continued from previous page)

IMP'S FIVE DIMENSIONS OF IMPACT	ARIC MEASUREMENT FRAMEWORK FOR INVESTORS (ARIC 2024)			CRISP FRAMEWORK (GARI 2024)	60 DECIBELS IMPACT METRICS
	Planet	Output-level metrics such as hectares of protected habitat	Bespoke assessment to account for the high context-specificity of climate change impacts on different types of natural system		
	Economy	Scale and depth may be conflated through the use of value-based metrics such as US$ per year of avoided climate-related losses			
Contribution: whether the energy provider's efforts resulted in outcomes that were likely better than what would have occurred otherwise (the counterfactual)	Assessment of adaptation and resilience impact against a hypothetical situation in which the investment does not take place, ideally poised against a credible baseline			Investor's contribution to the achievement of the intended impact — eg the causal chain between the solution and context of physical climate risk targeted	**Product access information:** includes answers to questions such as: ▪ Is this your first time accessing this product category (eg SHS, solar water pump, etc)? ▪ Can you find a suitable substitute for this product?
Risk: likelihood the impact will differ from what was expected and be maladaptive	Consider the wider impacts or unintended consequences that an adaptation and resilience investment may have, as part of investment due diligence and impact monitoring Consider changing external conditions — eg environmental, social, available technologies, etc — that could alter the overall adaptation and resilience outcomes of the investment			Likelihood that impact will be different from expected	Challenge and resolution rates to understand if there is a risk that the impact will not happen, measured through questions such as: ▪ How many end users experienced challenges? ▪ Were those challenges resolved?

Sources: Adapted from IMP 2020a and 2020b; ARIC 2024; GARI 2024; Acumen 2015 and verified by 60 Decibels may be a useful model for future research (Energy for Access and 60 Decibels 2023). To this end, Keystone's constituent voice methodology[4] may offer a meaningful path forward to manage performance through continuous micro-surveys, which seemingly aligns well with 60 Decibels' methodologies.

How much

This speaks to the scale of reach of the energy product or service and the outcomes it helps enable. 60 Decibels focuses on income increases or savings that individuals self-report. Accurately capturing income data is particularly difficult as many households and businesses do not keep records. 60 Decibels benchmarks these data against other enterprises offering similar products and services, which can hint at the scale of changes. However, it is also reliant on the network effect. The value is only inherent if more companies work with 60 Decibels' services.

ARIC offers guidance on the extent of the reduction in climate vulnerability, such as "number of people able to avoid income losses during flood events". 60 Decibels has developed a climate resilience assessment tool, which may provide useful guidance on how to measure resilience to shocks (UNOCHA 2022).

Contribution

Importantly, for their contribution dimension, ARIC and GARI have a 'without investment' counterfactual or causal chain of impact, both of which require a baseline assessment to analyse the context before the investment. This is crucial for understanding the wider landscape of interactions that exist when a person decides to purchase and use an energy product or service, and how that changes over time. 60 Decibels offers very practical questions on whether people encountered challenges with their products and whether these were resolved.

Because of their business model and methodological choices, 60 Decibels focuses mostly on end users that have already bought and used products. This means there are no data to compare why other end users may not have purchased and used products or whether alternative solutions are available that work for different kinds of people — for example, more vulnerable people or households with less purchasing power.

Risk

The ARIC framework highlights a need to identify an investment's intended and unintended consequences and measure external factors or conditions that could influence impacts. Capturing these two types of consequence will be critical for an energy access framework.

It would be useful to further explore some of the methodical pitfalls inherent in climate adaptation with regard to energy access — such as circularity, outputs vs outcomes, shifting baselines, attribution, universalisability and objective, subjective, qualitative and quantitative indicators — and how they can be mitigated when measuring.

4.3 Towards an energy access-specific framework

Many useful frameworks and metrics are available, targeting different sectors and stakeholders. But we believe they can be improved for addressing the question of energy access for both electricity and cooking. Based on IIED's experience working with stakeholders across the energy access space, Table 8 summarises general outputs or outcomes related to electricity and cooking access as a first step towards a new, energy access-specific framework.

4 www.keystoneaccountability.org/analysis-constituency

Table 8. General outputs or outcomes related to electricity and cooking access

STAKEHOLDER TYPE	EXAMPLES	INTERESTED IN INFORMATION THAT…
Community business and end users (often the same actor)	Carpenters, tailors, welders, restaurants, hair salons, households, etc	Demonstrates value to themselves and customers, such as: ▪ Increased productivity, income, or time savings ▪ Better customer experience ▪ Cost savings for customers ▪ Enhanced wellbeing ▪ Better health outcomes ▪ Better educational outcomes ▪ Leveraging different livelihood strategies or diversifying livelihoods
Energy enterprise	Energy service and product distributors or operators	Demonstrates their value proposition, such as: ▪ Generating more end-user income or savings ▪ Highlighting products sold to people experiencing marginalisation ▪ Better end user experience ▪ Emissions reductions or fuel displacement ▪ Increased educational opportunities
Energy investor or financier	Bilateral and development banks, impact investors, financial intermediaries, peer-to-peer platforms, fund management firms, venture capital funds, patient capital funds, philanthropic capital, commercial banks. For example, see: www.get-invest.eu/funding-database	Demonstrates value and impact of investments (dependent on energy product or service), such as: ▪ Investment outcomes for specific locations/groups ▪ Livelihood outcomes (increased income/productivity) ▪ Social outcomes (gender, health, food security, equity, etc) ▪ Emissions reductions ▪ Fuel displacement
Governments and donors	National, regional and local government, UK's Foreign, Commonwealth and Development Office, European Union, United States Agency of International Development	▪ Links to plans and reports on international commitments (eg SDGs, Global Adaptation Goals or national action plans) ▪ Helps develop more effective programmes ▪ Identifies what changes are happening, how, why and to whom, particularly from a landscape perspective

5 Recommendations towards recoupling energy and climate

A couple of studies propose interesting frameworks and metrics for energy access. In Box 6, we republish one of these, which shows a fascinating glimpse into just how complicated energy access can be across heterogeneous contexts. An example of how deep one needs to go to make energy and climate connections, it serves as a good introduction to our recommendations.

In Chapter 4, we explored ways of conceptualising climate resilience. The concepts shape what is likely to be measured and the methodological choices limit the way data can be used and interpreted. The level of ambition can vary, with some concepts focusing on resilience to specific risks and others on a more abstract — but potentially more robust — general resilience. Efforts can be incremental and transformative, and the risks of maladaptation are a constant threat in uncertain, complex and dynamic circumstances.

Methodological challenges abound, with imperfect choices to be made between the types of indicator used and the practicality and affordability of collecting different kinds of data. This chapter presents a set of principles that can help stakeholders with linked but differing individual objectives navigate some of these challenges. For each principle, we outline what stakeholders need to know and actions they might take. Taking the risk of maladaptation seriously by engaging locally and being open and clear about intended ambitions are strong first steps.

Some of these recommendations may seem expensive and time-consuming, and perhaps out of reach for many startup energy access companies. Additional work is needed to evidence and articulate the commercial benefits of deep local market knowledge and robust end-user, potential end-user and nonpotential end-user feedback loops.

Many programme, grant and funding lifecycles are often around three years. Meanwhile, investors want to see loan payments and equity exits on the horizon. If our proposed inclusivity measures do not have positive commercial returns, it may be an opportunity for climate investors, funders and governments to reach more vulnerable people by subsidising demand or supply for energy products and services or plugging gaps — for example, by adding mechanisms to support more patient capital or improve links across sectors to realise synergies.

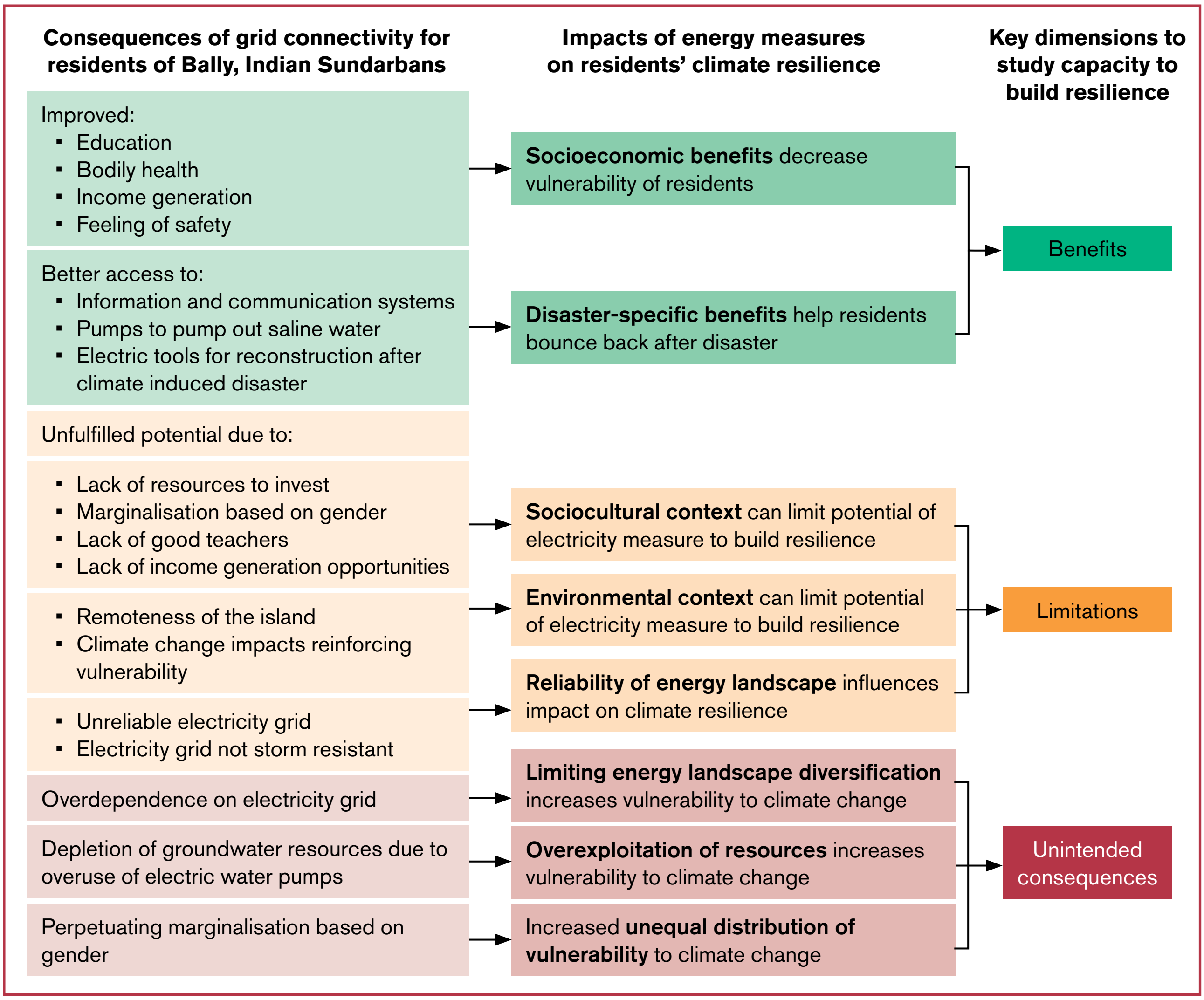
5.1 Use local knowledge to build locally valuable resilience services

To succeed in nascent markets while avoiding maladaptation, energy enterprises must incorporate enough local knowledge and contextual understanding with meaningful consultation. They must co-design services or products with the intended users, building this approach into all their business models. Many tools are available to explore local priorities and power dynamics that maintain vulnerability and resilience ambitions.

BOX 6. GRID CONNECTIVITY IN THE INDIAN SUNDARBANS: THE COMPLEXITIES OF ENERGY ACCESS IN HETEROGENOUS CONTEXTS

The experiences of Bally Island, India, show how people's lived experiences can influence energy access options and adaptation to climate change. After the government subsidised grid extension on the island, it rapidly expanded the number of grid-connected households. Before the arrival of the grid, half the population owned an SHS. But since the arrival of a grid with subsidised tariffs, sales of these off-grid systems dropped to near zero, with households abandoning them altogether over time due to the higher costs of replacing components. This is despite the grid proving to be unreliable, particularly during storms and natural disasters, and stand-alone systems being able to provide important services that households prioritise, such as: sharing forecasts and information to warn of and prepare for a storm, communicating responses before, during and after storms, rapidly pumping out saline water to prevent infiltration into the ground and speeding up infrastructure reconstruction. Although solar-powered products are generally promoted as great backups for fickle grid systems, as this case makes clear, price is a major consideration for people when buying and using solar-powered products. The study's framework is fairly comprehensive, focusing on grid access, its benefits, limitations and unintended consequences on the island (Figure 7). This deeper qualitative work is an example of what may be practically necessary to understand some of the 'how' questions around energy access, coupled with more frequent short surveys to better tie energy access together with climate.

Figure 7. Key impact dimensions of energy measures on people's capacity to build climate resilience



Source for Box 6 and Figure 7: Van Bommel, Höffken and Chatterjee (2024). Figure 7 recreated under Creative Commons BY 4.0 (www.creativecommons.org/licenses/by/4.0). Edits made for concision and UK English spellings.

What to know: the long history of development has demonstrated the value of fully and meaningfully engaging communities in development processes. This includes from design through to evaluation and learning. Maladaptation typically takes place under two scenarios: when the needs of the most vulnerable people in a context are not properly considered, and when goals and priorities for adaptation interventions are set in a top-down manner by relatively privileged groups, rather than being framed by the intended beneficiaries, leading to a skewed distribution of benefits in favour of local elites (Eriksen et al. 2021; Schipper 2020). Successful, sustainable and impactful adaptation actions occur when there is meaningful participation of local people, which generates local ownership, helps identify preferred products or initiatives, identifies future risks and uncovers local dynamics that can shape success or failure. This applies from conception through to evaluation across all aspects of product, service or intervention development. Much of the literature agrees that "it is essential that resilience-building operations and their [monitoring and evaluation] systems are not only specifically designed for, but also with, the program's intended beneficiaries" (Leiter et al. 2019). Unfortunately, top-down planning is a reality of energy access processes, especially the development and implementation of large grid-based power schemes.

Limited resources or know-how can lead to a failure to facilitate satisfactory participation. People in vulnerable positions — due to low income or marginalisation — are often in such positions due to structural inequalities, social norms and historically unfair policies. These barriers also hinder their access to opportunities to share their perspectives as well as the ease with which they can be approached. In other cases, people can be actively excluded from key decision-making and influencing processes by opposing or elite groups with greater influence. For example, many rural women are excluded from customary or traditional decision-making spaces, where key decisions that affect them are made.

Participatory processes also suffer because there are limited incentives to put them into practice. Outreach to excluded communities is more expensive and time-consuming and requires a workforce and know-how that may be beyond the limited resources of small and medium-sized enterprises (SMEs) to carry out. From a value-generation standpoint, it can be tempting for burgeoning energy enterprises to prioritise wealthier end users or market segments that offer quicker routes to satisfy investor expectations on financial returns, and there is evidence that many multinational energy enterprises are doing so (Harrison et al. 2020). But this comes at a cost of potential maladaptive consequences, which can increase future investment costs, reduce market share, exacerbate inequality and so on.

Direct local engagement can also reveal the hidden dynamics, informal institutions, deeper motivations and relationships between these that shape successful livelihoods and households' ability to improve their own wellbeing and resilience. For example, communities are motivated not only by income, but also by building social capital and stronger communities, or living in harmony with their environment.

What to do: adopt a locally led approach to shaping products, services and definitions of success. Direct engagement and research with communities about risks, local priorities and relationships between different groups are essential for designing useful products, services and business models and for understanding effective measurement of change. Utility providers should engage communities during planning processes and/or market research to build a context-specific understanding of risk and hazards and develop interventions that respond to vulnerabilities. Participatory decision making that goes beyond consultation can respond to different vulnerabilities that exist within

BOX 7. PARTICIPATORY TOOLS FOR EXPLORING RESILIENCE

The Gender Action Learning System (GALS) (IFAD 2022) is an action learning methodology that identifies the conditions and routes towards gender transformed outcomes. Using "simple mapping and diagram tools for visioning and planning to empower men, women and youth to make changes in their lives", it takes a qualitative approach to tracking change.

The Pamoja Voices toolkits (Pertaub et al. 2020; McIvor et al. 2020) were developed to help local governments, civil societies and producer cooperatives identify how to build the resilience of local livelihoods or cooperative businesses using participatory methods. Representative workshops run over three to four days, use participatory action and learning approaches, and articulate the differing priorities of men, women and young people in response to climate risks. Like GALS, they use a predominantly qualitative approach, prioritising subjective perceptions of what is important.

Overarching approaches such as the Energy Delivery Model (Garside and Wykes 2017) aim to identify the barriers to and enablers of energy delivery in various communities, using participatory methods and identifying context-relevant solutions.

Table 9. The LLA principles and the energy sector

PRINCIPLE	ENERGY CONSIDERATIONS	MAIN ACTORS RESPONSIBLE
1. Devolve decision making to lowest level	Ensure energy services/designs/models meet local priorities and needs, consider sociocultural factors, local livelihoods, etc	Energy service providers
2. Address structural inequalities	Facilitate equitable access, or priority access for marginalised groups, and co-design products and services around their needs	Government, NGOs, energy service providers
3. Patient predictable finance	De-risk investment over the long term; ensure more equitable risk sharing between stakeholders	Donors, investors
4. Invest in local capabilities	Prioritise in-country SMEs with local expertise and ways of working; support government ministries to invest in energy frameworks/strategies	Investors, donors
5. Robust understanding of uncertainty	Ensure energy service is applicable over longer timeframes; ensure information is available to end users	Government, energy service providers
6. Flexible programming and learning	Collect information regularly; respond and adjust	Energy service providers, government
7. Transparency and accountability	Track impact of energy services on ecosystems, inclusivity and structural inequality; report and share so the sector can build out the evidence	NGOs, government
8. Collaborative action and investment	Whole-of-society approach: convene stakeholders across sectors to seek synergies and reduce risks	Government, donors

marginalised communities and have the potential to stop climate change from exacerbating existing inequalities. The point is to enable energy end users seeking to build resilience and to articulate what success looks like in the local context. This might include recognising that the interests of households and their governments might not always be directly aligned.

Using the many available tools that explore — with communities — power over, access to and control of different resources and services, access to formal and informal decision making and strategies for change will help stakeholders determine indicators or metrics that track changes that are directly relevant to resilience. Five concepts are helpful in navigating power and empowerment: 'power within', 'power with', power over', 'power to', and 'power through' (see thorough explanation: Galiè and Farnworth 2019). Box 7, on the previous page, highlights some examples of tools and approaches using different lenses that may be useful in engaging communities and households.

The eight locally led adaptation (LLA) principles (Table 9), built on research and practitioner knowledge, can offer a useful framing for the energy sector. The principles were put together based on a year of consultation led by Global Commission on Adaptation (now the Global Centre on Adaptation), with facilitation and support of IIED, World Resources Institute, the International Centre for Climate Change and Development and many others. There are multiple logical links between some of the LLA principles and energy access — for example, energy access has been striving for more patient and predictable funding for years (principle 3), and more recently, investing in domestic companies (principle 4).

It may be useful to further develop how the energy access space can connect to the other LLA principles, which have gained a lot of traction in recent years, including from the World Bank. Following the LLA principles offers energy access practitioners a way to navigate the complexity of climate resilience, reducing the risk of maladaptation by centring on local communities.

5.2 Take a whole-of-society approach

In a whole-of-society approach, multiple stakeholders with several perspectives and engagements in aspects of CRD work together for successful outcomes and to avoid maladaptation. Collaboration with other types of organisations might be necessary to finance and deliver this kind of approach, creating more valuable interventions and businesses.

What to know: the drive towards CRD and adaptation generally takes place at multiple scales. International treaties, national policies and plans, public and private financing and local or Indigenous initiatives across multiple sectors of activity interact in each context in the face of multiple and changing risks. This is necessary because the drivers of vulnerability are multilayered, rooted partly in global social change and partly in local access to and control of resources (Ayenlade et al. 2023). No one actor has all the answers, and the complexity of the challenges means that collaboration is necessary across sectors. As well as facilitating knowledge sharing, collaboration avoids the risk of one stakeholder's activities undermining another's. Collaborations might bring together NGOs, businesses, governments and civil society organisations (CSOs) with expertise across energy, water, food systems, disaster risk and more to explore trade-offs of different actions while centring the knowledge and experience of people facing climate risks in practice each day.

In relation to measuring resilience and change, this also means that no single actor — for example, a renewable energy-focused enterprise — has to have all the skills or measure across each conceivable area of change. Governments and some NGOs can have data running back years from reporting for national plans and policies, or international commitments such as the Millennium Development Goals and SDGs, which can help stakeholders understand change over time and reduce the problem of shifting baselines. Accessing secondary and shared information sources should be standard practice for organisations looking to track resilience. Multistakeholder approaches that share knowledge, furnish technical know-how from CSOs or governments and provide finance for in-depth participatory product and business model development are rare but could help public and private energy stakeholders avoid maladaptation risk while crucially adding value through effectively understanding and being able to deliver to a context-specific target market. Co-created approaches can also shape different kinds of local governance, breaking down silos between sectors and seeking synergies behind interventions that are working.

What to do: collaborate with different types of organisation to access their skills, understand local complex systems and contribute to resilience against multiple threats. Energy stakeholders, including donors, governments, investors, enterprises and civil society rarely work in concert currently. Stakeholders need to collaborate to generate and share understanding about how a product or service will affect different people in a community. They must identify consequences for environments and those with less power, influence, land or other key resources, while aligning their resilience ambitions with those of vulnerable people. Donors that are keen to mobilise private finance in support of CRD can couple concessional financing with support for direct local engagement. With their senior government partners, donors have the convening power to effectively bring diverse actors together. Investors can work with their companies to encourage and prioritise understanding of community perceptions of impact in targeted locations and assess impacts accordingly. They can also work with companies to screen for — and then reduce — maladaptive risks. Without such actions, industry claims around equality and 'reaching the most marginalised' are meaningless.

5.3 Develop a resilience narrative

Having a resilience narrative that articulates how a product, service or intervention helps build users' or beneficiaries' wider resilience to specific climate risks or helps build general resilience can contribute to developing indicators and metrics that offer a realistic picture in a given context. The narrative should be developed with communities, who can articulate what successful and equitable resilience-building looks like for them and support context-specific ways of measuring it. Taking the time to develop this narrative properly has several tangible benefits.

What to know: to demonstrate a contribution to CRD objectives, rather than simply access to or use of energy, stakeholders need to make clear what resilience means to their customers or users and how they intend to develop it. This resilience narrative should show how using a product or service will affect households and their environment and how these, in turn, will lead to conditions that build resilience, either to specific hazards, such as drought or heat stress, or in general (Soanes et al. 2019). Subjective, objective, qualitative and quantitative indicators or metrics can be developed that track change in each stage of the narrative, tailored to the capacity, resources and requirements of communities and energy stakeholders. A strong resilience narrative avoids circularity, explaining assumptions and helping to support attribution or contribution to wider resilience impact, as using a product or service should lead to verifiable outcomes in the world.

Developing a resilience narrative has several benefits. They can make clear whether the intention is to support specific or general resilience. There is nothing inherently wrong with specific resilience (that is, resilience to specific hazards) as long as it does not become over-specialised and preclude resilience to other risks. General resilience may be harder to define, as it is context-specific. Yet some efforts — for example, to contribute to food or cash savings — might clearly lean in a general resilience direction. Others, such as those that enable community learning or facilitate connection and community flexibility, might also create resilient institutional structures.

Developing a narrative is the first step in identifying appropriate indicators of change from a new product or service. It helps to identify what is important for whom, and thus what to measure. An impact narrative with an eye for equity will segment benefitting communities and identify the characteristics of particular groups — such as combinations of age, gender and physical ability — that impact their resilience to either specific hazards or to general, undefined risks. It may, supported by representatives of various groups, identify different indicators for them. When developed with local participation, a resilience narrative will help identify how different products or services, or the business models associated with them, might be varied to facilitate accessibility or local innovation in livelihoods. Establishing indicators that explain how a product or service is supporting the ability to adapt, anticipate, absorb or transform in the face of climate hazards can go a long way to being clear on the added value a service has to communities and its ability to have impact more widely.

An effectively articulated narrative, backed by appropriately identified indicators or metrics, is more likely to attract additional private and particularly public investment through loans, subsidies or grants. For public actors, including donors and governments, a clear narrative of how a product contributes to wider societal resilience enables transparent justification for expenditure. This aligns neatly with the concept of climate justice, which is gaining traction among funders.

Making it easy for such actors to support the scale-up of a potentially valuable asset makes good sense for SMEs and their investors as well as for NGOs looking to scale up an innovation. For impact investors or more risk-friendly forms of capital, the resilience narrative forms part of an emergent business' value proposition; for investors seeking real and sustainable impact, a clear definition of resilience in each context should be central to such a proposition. It should also be a key part of investor screening before investments.

Being able to aggregate outcomes across multiple companies is another benefit for investors, donors and governments. Having a clear resilience narrative allows them to compare and assess proposals to identify impact over a wider area. Transparent narratives across multiple actors enable a deeper understanding of what does and does not work and what is and is not changing in CRD outcomes.

Resilience to climate hazards rarely hinges on one specific intervention, product or service; other factors and relationships also play a role. A resilience narrative should make this explicit, identifying the assumptions about the relationships needed for a successful intervention, how the intervention supports resilience in different households and through what mechanisms this is happening, in collaboration with other factors. A recent impact investor report noted that "we need engines, not cogs... Companies and investors that understand the

BOX 8. A SAMPLE RESILIENCE NARRATIVE FROM TANZANIA

An SME selling cold storage for crops in southern Tanzania might use a resilience narrative to identify major risks, such as cycles of drought and flooding that reduce farming yields which, coupled with post-harvest losses to heat and insects, undermines women farmers' capacity to generate savings. Without savings, women are less able to act in anticipation of, and therefore absorb, climate shocks. Its narrative might identify how resilience for women hinges on access to water, social capital and the ability to build up savings that they can hold independently.

It might then articulate how women could access strategically-placed cold storage units — for example, close to marketplaces — using innovative business models through which the poorest women can take loans before a planting season that can be paid off in small amounts. For younger women, a modified business model that incorporates local government and/or NGO support could subsidise the cost of the loan. Farmers who already have resources could use a pay-and-go model.

The intervention contributes to general resilience, enabling women to reduce post-harvest losses, sell more produce and build up savings that offer flexibility in response to a range of threats. Its impact depends on a number of other factors and stakeholders, including the collaboration of local government, continued investment in water supply or irrigation, stability of market prices for local crops, local women's risk appetite and the availability of low-cost rented cold storage spaces near markets. It may also require the support of local opinion leaders who can build trust in new technologies.

It may contribute to CRD if the women are also granted legal and customary rights of access to their own land, which they can manage independently, and decision-making spaces about how land is allocated.

This narrative points to specific indicators that might be tailored to context but could include measuring percentage of post-harvest losses, savings, access to land, access to decision-making spaces, confidence in using markets, confidence in using and taking loans, and so on.

entire system can deliver the combination of solutions that are needed" (Acumen Fund 2023). Recalling the whole-of-society approach, a key role for donors is to create the incentives for companies and investors to appreciate the wider system they are working within.

Finally, transparent information sharing supports governments in their public reporting on national development plans, adaptation communications and SDGs. Data provision from a range of organisations is a public good that supports evidence-based decision making and recognises equity challenges.

What to do: develop resilience narratives. Useful tools that can help to articulate how a product or service contributes to resilience within a wider context include theories of change and impact pathways, which both identify how changes in a system will lead to positive change for groups of people. There are many ways to understand how a product, service or intervention contributes to resilience among other local and wider contributing factors. Subjective approaches might, after discussing the efficacy or value of an energy related service, ask participants to consider other contributing factors. More structured measurement approaches might ask respondents to rank the contribution of the energy service or product against other factors, such as government subsidies, social protection, social capital or newly available farm inputs. A useful starting point for defining resilience might be to consider the following:

- In a given location, who is being made resilient to what climate hazards?
- When will resilience to those hazards be the strongest or weakest?
- How will different interventions, products or services contribute to that resilience?

While donors and CSOs are probably familiar with the concepts of pathways and theories of change, these might be new for private sector actors, who tend to focus on measuring customer satisfaction and revenue generation rather than social impact. But if private investors and companies want to demonstrate their resilience-building credentials to funders, governments or the public, these tools will be crucial.

A CRD approach will also be clear about the need for transformative efforts that are required in their search for long-term, just and equitable solutions. Definitions of resilience in a particular context that are transparent about transforming relationships between different groups — communities and government, men and women, lower and higher income groups, people with and without disabilities, and so on — are more likely to lead to longer-term, sustainable impact. Relying on single metrics, such as improved incomes and productivity, paint a limited picture of whether someone is increasing their resilience in the real world.

5.4 Take a strategic, iterative approach to assessing resilience

Complexity and ever-changing contexts, coupled with uncertainty of climate impacts, local politics and environmental change, mean that efforts that are effective today may be maladaptive in the future. A contribution to resilience livelihoods or wider systems cannot be measured through one-off evaluations and surveys. Adaptation and resilience-building is a continuous process, so it is important to use methods that assess change over time.

What to know: the multifaceted nature of resilience means that methodological approaches to assessing it will be imperfect. Sophisticated approaches are likely to challenge the capabilities of smaller organisations. But generating the right data can inform future business and project decisions, and enable transparency of contributions to CRD outcomes. The challenge of uncertainty and ever-changing local dynamics that affect what will work, for whom and when mean that iterative measurement and evaluation is necessary to ensure that a service, product or business model remains relevant and useful over time. A long-term approach to assessment is central to ensuring sustainable growth and value in a business and to the continuing relevance of government intervention. Understanding that contexts and risks are dynamic and changing also means understanding that approaches to delivering a service, designing products or creating accessible business models might also need to change. This is exemplified in urban settings, where rapid urbanisation continually shapes communities, and in rural settings, where temporary forced and unforced migration, sometimes seasonal, can create cycles of social and environmental change that affect business development or the success of an intervention.

Drawing from the resilience evaluation literature, it is helpful to recognise that the evaluation process can begin before an intervention (Figure 8). Energy stakeholders can consider how they can integrate learning from the evaluation community into their own activities, whether through early consultation, product design, market research, monitoring, tracking, or evaluation.

Ex-ante evaluations: indicators can be applied before a product is rolled out, using evaluative approaches to test, with communities, variation of business models, price points or key design features of a service, and to compare against other options. This process could be carried out multiple times — for example, during different seasons — to see how responses change in different contexts. Doing so can increase knowledge of risk and how to manage it, and therefore increase the

Figure 8. The stages of evaluation

Ex-ante	Monitoring	Ex-post	Continued assessment
▪ Pre-implementation ▪ Test support for variations of a product, model, service ▪ Identify gaps and shortcomings ▪ Establish baseline ▪ Risk assessment	▪ During implementation ▪ Test quality ▪ Tracking outputs ▪ Understand uptake and growth ▪ Understand access	▪ After implementation ▪ Assess outcomes, satisfaction ▪ Unintended consequences ▪ Focus on who benefits or does not, and how	▪ Review outcomes based on changing local factors, including climate risks, demography, other interventions

attractiveness of an investment proposition. Predictive methodologies are rare in the resilience space, weakening assessments because evaluations provide only snapshots of change based on a narrow view of what might work in contexts that might change in the future (Beauchamp et al. 2022). Ex-ante evaluation might include baseline assessments to establish the state of resilience in a target location at the start of a project. It could also compare costs and benefits of a product or service against other options already in place. This might be necessary if a company has spent several years developing a product and needs to check it is still relevant to the target market or community.

Monitoring: taking place during the implementation or rollout of a service, tracking progress as it is happening is key to adaptive management. It allows flexibility in response to public reactions to a product and provides understanding of how households and citizens are using and accessing the service. Most stakeholders will undertake monitoring, considering it part of project management.

Ex-post evaluations: ex-post evaluations apply a framework or set of frameworks to assess and identify the drivers of changes in outcome or behaviour that result from interventions. Evaluation design can have various levels of complexity, and may include qualitative and quantitative methods, objective and subjective indicators, and various data processing approaches to notice trends. No evaluation is perfect because no one framework can perfectly capture resilience, but it is important to select methods that serve a useful purpose for the organisation and its collaborating stakeholders (Béné 2014).

Ex-post evaluations are more typically discussed in relation to adaptation and resilience programmes established by governments, donors and NGOs, and less so in relation to services provided by the private sector. What is important, however, is to consider outcomes rather than outputs, taking the time to recognise how resilience might be changing for different groups since the intervention has taken place. Traditional development actors are usually also interested in why an intervention has been successful, not just whether it has been widely used and accessed. Ex-post evaluations must take care to also identify unintended consequences, and in the context of maladaptation, effects on ecosystems or more vulnerable groups. This is where the wider definition of resilience is essential, as it helps articulate the wider factors that may have greater influence.

Iterative assessment: since climate-related uncertainty of future risks spans long, potentially decadal, timeframes, iterative assessment is necessary to explore how certain services are being used, their impact and their positive and negative consequences. Understanding that adaptation has to be effective both now and in the future suggests that tracking resilience must be continuous, aware of fast and slow-onset hazards in a given context and recognise the need for measurements and assessments long into the future. Continued assessment helps prevent maladaptation by identifying whether or how an intervention might be leading to negative consequences, thus enabling a corrective response. It may be that responsibility for aspects of future iterative assessment shifts from companies or NGOs to governments, who have longevity and responsibility for assessing societal change and resilience over the long term.

What to do: develop transparent monitoring plans and methodologies. If a company or organisation wants to demonstrate its contribution to CRD, developing transparent plans and methodologies for how tracking will take place are an important first step. Seeking support from other stakeholders with the right expertise or paying for the services of assessment or evaluation companies might make this easier for SMEs. Investors could set aside money specifically for these purposes. Crucially, recognising that change is a constant and that failing to take this into account may have maladaptive consequences implies the need to consider iterative approaches that track change and context over time. If a wider, general form of resilience requires the capacities for learning, reflection and ongoing innovation, then it will be based on these methodologies. Adaptation requires feedback mechanisms that enable monitoring, evaluation and learning outcomes to inform design, decision making and implementation.

5.5 Recognise the barriers to climate-resilient development

Transformation is necessary to address the scale and unpredictable nature of climate risks that affect whole societies. CRD recognises that vulnerability of some groups is tied to social, political and economic marginalisation, and that their increased vulnerability is both unjust and risks the quality and longevity of other resilience-building efforts. Transformation to climate-resilient societies requires the recognition of barriers facing different groups.

What to know: transformational approaches recognise that long-term, equitable and sustainable resilience outcomes require changes in relations between different groups, access to decision making, key resources and services, and power to influence situations in the face of ongoing and overlapping risks.

Indicators that track these kinds of change are key to a meaningful understanding of an organisation's contribution to wider change. Transformative change is the standard by which anyone claiming to engage in resilience-related impact should be working. When establishing metrics and developing new products and services, recognising and targeting the barriers to more resilient livelihoods that affect vulnerable groups should be central. These might be access to finance, access to government services, participating in community planning or gaining priority at shared water sources. Disaggregating changes in outcome by vulnerable group — for example, separating findings for women, men, young people and, where necessary, caste, ethnicity, livelihood or location — can help track how a product or service is creating equity. Understanding the drivers of exclusion and their impact on resilience might be difficult, but stakeholders may be able to explore proxies such as representation and participation in governance processes, changes in ability to control rather than simply use resources, changes in the nature of available resources or changes in capabilities to invest in their own future. Tracking changing relations between groups and institutions will also help surface the equity issues that undermine resilience.

If transformation hinges on overcoming barriers, it follows that products and services that support transformation are developed specifically to target those barriers. That means using design processes that develop solutions to address context-specific problems in collaboration with the people experiencing them, rather than bringing in external solutions that might only partially address the issues or could make things worse.

Clearly defining transformative change at the outset can also help clarify the institutional changes and enabling environments needed to facilitate climate-resilient futures. Even if the measuring organisation cannot directly influence these, being transparent about what it can and cannot do in relation to supporting this type of change helps other actors to be strategic about their own interventions.

What to do: as part of ex-ante evaluations or market research, work with target communities to build a sense of how a climate-resilient community might function. Identify the indicators that might record progress towards this vision, recognising that some — such as finance and resource access or political representation — will be more relevant to marginalised groups who risk losing out when it comes to resilience-building efforts. Consider how energy-driven tools might support transformation by providing appropriate information and easing access to resources, tools, markets, electricity or energy. Developing and supporting businesses in the context of CRD objectives may inspire more ambitious or more targeted delivery models. Donors and governments might incentivise these kinds of approaches through regulations for disaggregated reporting or by funding evaluations that consider them.

5.6 Screen for maladaptation risk

Maladaptation presents a significant risk to donors and investors who seek positive social, economic and environmental impacts. It can come in several forms, through negative consequences to environments or people. Actively screening and monitoring for maladaptation needs greater priority than is generally recognised.

Tracking indicators of resilience at different scales and across different sectors relevant to the community can help to identify maladaptation. For example, it can help identify whether certain social groups are adapting at the expense of others' resilience or spot how incremental adaptations may be insufficient and might be locking in certain strategies that will soon become unsustainable, such as widespread solar irrigation use in contexts where water stress is likely if average global temperatures rise to 2°C.

Drawing on the Navigating the Adaptation-Maladaptation Continuum framework (Reckien et al. 2023) and wider literature on recognising and managing maladaptation risk, we propose a series of screening questions for SMEs, investors and development partners, that they can integrate into their impact assessments (Table 10).

Table 10. Screening questions to measure impacts on households and communities

CRITERIA	SUGGESTED QUESTIONS
Ecosystems and ecosystem services	1. How are aspects of ecosystems and ecosystem services affected by the intervention, product or service over time? 2. How is land, land tenure and land use affected by the use and scale-up of the product? 3. How are local water resources affected? 4. How is soil health and fertility affected? 5. How are forests, oceans or wetlands likely to be affected?
GHG emissions	6. What GHG emissions might be linked to the intervention, product or service? 7. What direct GHG emissions might be caused by the production or manufacture of the product or service? 8. What GHG emissions might be produced through use of this product, particularly when it is scaled out to larger numbers of people? 9. How much would ecosystems' capacity to absorb carbon dioxide be affected by the use and scale-out of this product or service? 10. What indirect emissions might result from the products' role in a wider supply chain?
Systemic change	11. How does the product, service or intervention contribute to systemic change? 12. Does it address one specific climate risk, or many? 13. Does it address the root causes of vulnerability, as identified by potential clients or customers? 14. Does it contribute to changing the nature of how institutions relate to communities or the landscape they manage? 15. Is there a risk that it might lock in certain approaches or livelihoods that may become maladaptive or ecologically unsustainable over time?
Low-income groups	16. How does the product or service affect social vulnerability or the adaptive capacity of low-income groups? 17. Is it accessible to low-income groups? 18. If it is not accessible to low-income groups, how would its widespread use affect them, their social vulnerability or adaptive capacity?
Women/girls	19. How does the product or service affect women's and girls' social vulnerability? 20. How is it used by men and women in different contexts? 21. What differences in its access or control might affect who is able to benefit from its use? 22. Is there a possibility that it might lead to greater exclusion or reduced freedoms or powers of women or girls? 23. How might its use affect gender relations in the context it is being rolled out in?
Marginalised and vulnerable groups	24. How does the product or service affect the social vulnerability of marginalised ethnic groups? 25. How accessible is it to people from marginalised ethnic groups? 26. If the product were to be scaled out, how would marginalised groups be affected? 27. How might its use affect the relationships of marginalised ethnic groups with institutions or other communities?
BEHAVIOURS AND PRINCIPLES TO AVOID MALADAPTATION	
Taking a whole-of-society approach	28. How much engagement has there been with other stakeholders, including government, civil society, regulators and people with additional sets of expertise? 29. How much does the energy service or intervention contribute to a wider strategy or package of measures? 30. How much coordination has there been with other resilience stakeholders?
Uncertainty and robustness	31. Has the product, intervention or service been tested with communities against different possible climate futures and scenarios to anticipate and prepare for future uncertainties? 32. Is it adaptable or protected across different conditions, including drought, flooding, heat stress, temperature rises, saline intrusion and other climate hazards?

6

Towards a framework for recoupling energy and climate

This paper aims to complement the sizeable body of literature already out there on energy access and climate adaptation and resilience. It is a first effort to build a foundation for a larger, more specific conversation that is trying to bridge the energy and climate sectors. In a subsequent phase of this work, we intend to investigate the 'how', which is broader than energy, in the same way that we believe energy is only part of a broader contribution to building resilience.

If energy sector stakeholders wish to access more climate financing, it is beholden on them to understand the climate space, the concepts and vocabulary. In this respect, Acumen's Hardest-to-Reach programme (Green Climate Fund 2023) offers lessons in how energy stakeholders can frame energy within the climate space and secure climate financing, in this case, through the Green Climate Fund. However, more must be done to solidify these links.

There is opportunity. Several multimillion-dollar energy access programmes have enormous potential to influence how energy access players engage with climate adaptation. Some of these programmes — such as the World Bank's Accelerating Sustainable and Clean Energy Access Transformation (ASCENT) programme and Nigeria Distributed Access through Renewable Energy Scale-up (DARES) programme, or the Global Energy Alliance for People and Planet (GEAPP) — would benefit from incorporating some of the concepts and principles we have posited in this paper, such as screening for maladaptation, establishing a robust resilience narrative, and striving for transformative resilience. Integrated approaches are the way forward. The Shine Collab, for example, calls for a climate, gender and energy nexus that is rooted in a 'just transition framework' (Shine Collab, nd).

We anticipate additional phases of this work, which will enable us to be more directive in our approach and allow us to test out the concepts and ideas we have posited here in different contexts and with various combinations of energy systems and supporting services. Leveraging IIED's extensive experience in the climate and energy space, we are working with the International Renewable Energy Agency (IRENA) to convene the energy access sector, from investors to communities, to establish what a 'good' energy investment for climate adaptation and resilience might look like, and develop a methodological guide on how to design, implement and track it. We would like to invite key stakeholders across climate and energy spaces to work with us to develop the principles into a framework to guide investors, enterprises and practitioners operating within both spaces. In particular, we are looking for:

- Energy and climate investors, donors and financiers who are keen to explore how their investments can better enable resilience across different layers, from individual to community level
- Community businesses and energy end users
- Energy and climate NGOs and community-based organisations, and
- Energy and climate enterprises with a business model and mission that supports experimentation.

To find out more, contact kevin.johnstone@iied.org

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People who rely on 'dirty' fuels and methods to cook their food and live without electricity are also some of the most vulnerable to the negative impacts of climate change. Yet, energy is a crucial enabler of socioeconomic development. Energy products and services have the potential to support climate mitigation and adaptation efforts, but the links to adaptation and resilience remain murky. We believe that a clearer recoupling of climate adaptation and energy access efforts would allow us to align the benefits of fulfilling climate adaptation needs through energy access and create more resilient households. With care, this would enable a quicker scale up and achieve stronger outcomes for everyone.

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