Climate finance for hydropower

Incentivising the low-carbon transition

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Related reading

See also the related briefing: Patel, S, Rai, N, and Shakya, C (2019) How climate finance can help repurpose hydropower. IIED, London. https://pubs.iied. org/17737IIED

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Climate funds should facilitate the transition to a low-carbon and climate-resilient future. Energy storage and ancillary grid services are critical to expanding the proportion of intermittent renewable generation on the electricity grid. Hydropower remains the largest and most cost-effective provider of bulk energy storage, offering the flexibility to provide most other recognised grid services. While *sustainable hydropower* may not broadly meet climate finance criteria, hydropower projects with the necessary characteristics for transition do meet these objectives and should attract climate finance support. Meanwhile, concerns about the social and ecological integrity of hydropower, such as the impact it may have on local communities, provide more reasons for climate finance to incentivise hydropower designs that are socially, environmentally and technically appropriate for future conditions, supporting the shift to accessible, affordable, clean, distributed smart grids.

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Summary

At 475g CO_2 per kilowatt hour (kWh), average global electricity grid emissions are not in line to meet the Paris Agreement target of restricting global warming to less than 2°C. The 1.5°C ambition is even further out of reach. To have any chance of achieving either target, we need a near 90% reduction in grid emissions to 50g/kWh.

This issue paper looks at how hydropower can contribute to the transition to a low-carbon future. *Sustainable hydropower* is a subset of all hydropower projects that emerge from a basin-wide process and respect good practice, as defined by the International Hydropower Association. We propose that *transition hydropower* is a subset of sustainable hydropower, defined by an explicit design focus to support intermittent renewables on the grid by providing grid ancillary services and energy storage. We also propose that green finance support transition hydropower.

The paper explores how hydropower project developers could usefully draw on climate financing and how climate financiers could position climate finance to incentivise a shift in hydropower design and operations that would increase their contribution to the needed transformation to low-carbon and resilient energy systems. We conclude by highlighting where action is needed to understand and incentivise the value of hydropower in the transition to a sustainable, low-carbon future and where climate funds can contribute to this.

Hydropower has often been controversial. Nevertheless, it remains the predominantly reliable, low-carbon, low-cost technology that is accessible to developing and middle-income countries seeking to replace thermal power plants with low-emission energy and can support intermittent renewables such as wind or solar.

Hydropower can provide a number of ancillary services such as voltage stabilisation, black-start services and dispatchable energy. It can also follow demand, provide peak power without losing efficiency, store energy when intermittent renewables generate more than is being consumed on the grid and offer inertia to stabilise grid frequency when wind and solar-generated voltage fluctuates with gusts and/or cloud cover. Pumped hydropower storage provides over 94% of the world's installed energy storage capacity and over 99% of stored energy.

Of the 23 multilateral and bilateral climate funds reported on in the Climate Funds Update database, only four have supported hydropower projects. Of these, the Clean Tech Fund and the Scaling-Up Renewable Energies Program have a mitigation mandate, while the Global Environmental Facility and Green Climate Fund support both adaptation and mitigation. Between them, these funds have supported 36 hydropower projects of varying sizes. Our analysis shows that, between 2003 and 2018, US$693 million in public climate finance went to hydropower projects. This is significantly less than the almost US$300 billion of public and private climate finance that flowed to renewable energy (90% to wind and solar) in 2016 alone.

We review the reasons why climate funds accept and reject projects, exploring two approved projects in depth: Morocco's ONE Wind Energy Plan, which integrates the transition characteristics of dams in supporting the grid's increased wind capacity; and the Solomon Islands' Tina River Hydropower Development project, which supports a shift to renewable energy-based grid.

We find four main reasons why climate funds have restricted investment in hydropower:

- Dams are already proven investments, so are not seen to represent the transformational change in renewable energy technologies that climate funds were set up to support. Most hydropower in developing countries is operated purely to generate a constant electricity supply rather than respond to fluctuations in demand. Many hydropower project proposals have also been rejected by climate funds for lacking evidence of 'additionality' which refers to evidence of climate benefits beyond what could be expected to occur in the absence of climate finance.
- Hydropower has the potential to significantly impact communities and downstream ecosystems. The balance of costs and benefits is often controversial.
- Hydropower projects take eight to ten years to design and build; and climate fund managers justifiably seek to support rapid technology change. Large infrastructure projects also carry significant risk of delays.
- All reservoirs emit greenhouse gases to some degree, so there are concerns around how low-carbon hydropower-generated energy really is.

Given the urgency of climate action, it is understandable that climate funds value fast returns. But they must also develop a long-term strategic focus to support the transformation of energy systems to renewable grids by establishing grid stability and energy storage capacities that enable higher penetration of intermittent renewables.

Setting out the types of project climate funds should invest in and how hydropower developers can make the case for climate finance support, we recommend that project developers, international climate funds and energy regulators work together to support a long-term sustainable transition by:

Supporting basin assessments for strategic hydropower development. Best practice should consider a range of scenarios around hydropower placement, design and operation to optimise development objectives linked to irrigation (food), energy, water and ecosystems (wetland conservation). There is widespread agreement that the negative impacts of hydropower are best managed at basin scale, avoiding sensitive areas, rather than at project level, where the margin for manoeuvre is more limited. Hydrological risks also need to be identified and managed at basin scale.

Increasing hydropower performance for climate objectives. Where hydropower is already a major source of energy, and plays or could play a transition role – by enabling more intermittent renewables on the grid, or where reservoirs play a vital role in water management – there is a legitimate case for climate funds to invest in rehabilitating existing projects, building in support to achieve specific mitigation and resilience objectives.

Restructuring markets to reward transition services. Energy dispatch, stabilisation and storage services show how transition hydropower enables the paradigm shift to a clean energy system built around intermittent renewables. Energy markets need to identify, value and pay for these services to achieve stable grid management with intermittent renewables providing the bulk of the power. Energy storage and grid stabilisation services must be valued highly enough to encourage investment.

Reducing the cost of capital for transition hydropower. Climate funds can help create the right financing incentives by balancing risks for public and private sector actors.

Hydropower projects are high risk and incur high capital construction costs. They are often supported by large investors, including multilateral development banks and private developers. It is important to balance public and private interests to ensure projects consider social and environmental outcomes, revenue streams are attractive for private investors and tariffs are affordable for consumers.

The public sector can only build a fraction of the **transition hydropower** required to support renewables and achieve a 50g CO_2e/kWh grid; the private sector must also play a role. Climate funds have the mandate to help finance the transition to a low-carbon future, which must include energy storage and ancillary services to maximise the role of intermittent renewables. While battery development provides some energy storage, hydropower remains the single largest bulk storage provider.

Building hydropower dams has recognised downsides, including high costs, long delivery times, potential social and environmental impacts and the need to manage investors' political and reputational risks. The variability of reservoir emissions has also led to concerns around including all hydropower investment in the carbon market under Kyoto. But transition hydropower can play a critical role. Significant recent advances in understanding and predicting carbon emissions from reservoirs and identifying pathways to sustainable hydropower suggest that climate funds and carbon markets should refine their response to supporting hydropower under the Paris Agreement rules that are under negotiation.

Acronyms

AfDB	African Development Bank
BOOT	build-own-operate-transfer
CFU	Climate Funds Update
CIFs	climate investment funds
CO_2e	carbon dioxide equivalent
CTF	Clean Tech Fund
FELT	finance-engineer-lease-and-transfer
FiT	feed-in tariff
GCF	Green Climate Fund
GEF	Global Environment Facility
GHG	greenhouse gas
GW	gigawatts
IDA	International Development Association
IEA	International Energy Agency
IHA	International Hydropower Association
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
kWh	kilowatt hour
MIGA	Multilateral Investment Guarantee Agency
MW	megawatts
MWh	megawatt hour
NGO	non-governmental organisation
OME	Office National de l'Electricité/National Electricity Office (Morocco)
PPA	power purchase agreement
PPP	public-private partnership
PV	photovoltaic
SDGs	Sustainable Development Goals
SIEA	Solomon Islands Electricity Authority
SIG	Solomon Islands government
SONI	System Operator for Northern Ireland
SREP	Scaling up Renewable Energy in Low-Income Countries Program
tCO_2e	tonnes of carbon dioxide equivalent
UNFCCC	United Nations Framework Convention on Climate Change

Introduction and scope

1

This issue paper looks at how hydropower can help us transition to a sustainable future. It argues that climate finance could be used to incentivise a shift in hydropower design and operations that would increase their contribution to the needed **transformation** (see Box 1) to low-carbon and resilient energy systems. After setting out how hydropower can support the transition to a more sustainable future through energy storage and grid system balancing, we explore how climate finance has supported hydropower projects to date. We then recommend ways climate funds can shape their investment criteria for hydropower to incentivise design characteristics for the transition. We conclude by highlighting where further research is needed to understand the value hydropower can provide to the transition to a sustainable future.

With average global grid emissions at 475g CO_2 per kilowatt hour (kWh),[1] we will not meet the Paris Agreement global warming target of under 2°C. The 1.5°C ambition is even further out of reach. Indeed, we must see a near 90% reduction in grid emissions to 50g/kWh to have any chance of achieving either target.[2]

In transitioning to a low-carbon energy mix with a greater proportion of **intermittent renewables** (see Box 1) such as solar and wind, a grid network will need context-appropriate services to support grid stability and store energy. Several options for delivering these services – such as lithium batteries or compressed air energy storage technologies – are already available or in development.[3] Hydropower dams also provide these services; in many cases, more cost-effectively than the alternatives.

By storing water in reservoirs, hydropower dams store potential energy, allowing them to provide power to the grid on demand. Hydropower can respond rapidly to frequency imbalances on the grid, which is increasingly important as levels of **intermittent renewables** also increase. And although hydropower construction and reservoirs have both embedded carbon and lifetime emissions from decomposing vegetation, many hydropower plants are a relatively low-carbon renewable energy source.[4] Electricity generation, however, is business as usual for hydropower development and does not represent a transformational shift in energy systems.

Historically, most climate funds have restricted investment in hydropower for four main reasons:

- As proven investments, they do not perceive hydropower systems as representing transformational change in renewable energy technologies, which the climate funds were set up to support.
- Hydropower dams can have significant impact on local communities and downstream ecosystems. The balance of costs and benefits is often controversial.[5]
- Hydropower projects take eight to ten years to design and build and climate fund managers justifiably seek to support rapid technology change.
- Given the observed greenhouse gas (GHG) emissions from reservoirs, there are concerns around how low-carbon energy generated by hydropower really is. While most reservoirs generate similar emissions per kWh to other renewables, a significant minority have emissions above those of thermal power, which creates uncertainty.

This paper looks at when climate funds have and have not invested in hydropower development to identify the barriers to investment and opportunities to incentivise the type of hydropower that enables transition to a low-carbon future. We review the hydropower projects approved by climate funds, as documented in the Climate Funds Update (CFU) database, and those projects they rejected, as far as this information is available from fund websites and other public sources. To explore good practice, we also do an initial review of the integration of hydropower ancillary services into grid systems in different contexts.

The value of hydropower in the transition to a low-carbon future will only be clear when there is deliberate design and contracting for specific transition characteristics, alongside market reform to value and pay for these roles. We explore several case studies to understand their experience in designing and using hydropower and present two in greater depth.

Annex 1 outlines Morocco's ONE Wind Energy Plan (approved in 2011), a project that supports the grid's increasing wind capacity by integrating a pumped hydropower storage reservoir into an existing hydropower plant to provide energy storage when the wind turbines built under the plan produce excess energy.[6]

Annex 2 outlines the Solomon Islands' Tina River Hydropower Development project, a scheme that supports a shift to renewable energy and enables a higher penetration of photovoltaic (PV) power in the grid without the need for large and expensive energy storage or diesel generators.[7]

In both cases, climate finance plays a role in supporting the transition characteristics of hydropower. Climate funds are mandated to finance climate actions, reducing emissions and increasing resilience to impacts. Multilateral and many bilateral funds expect investments to be transformational or create a **paradigm shift** (see Box 1). They also expect projects to tackle concerns around the social and environmental impacts of hydropower directly, as these are essential to ensure transition is just and equitable, to build stakeholder and investor confidence and to reduce the risk of delays in construction.

There is plenty of knowledge on how to ensure good social outcomes and mitigate social risks in large dam projects. But however strong the understanding, ensuring that projects avoid social harms remains problematic, given the political economy challenges in practice.[8]

In this paper, all references to **sustainable hydropower** assume that individual projects have emerged from a basin-wide, optimised water and energy assessment that has properly balanced economic, social and environmental outcomes and that they meet the International Hydropower Association (IHA) Sustainability Protocol's Level 3 good practice standard as a minimum.[9,10]

Building on our analysis of hydropower projects the climate funds are already funding, we explore the case for further incentivising the development of sustainable hydropower by promoting characteristics that will support the transition to a low-carbon future and a global average grid emission of 50g CO_2/kWh.

Opportunity for transitioning to a low-carbon future

2

2.1 The urgency of action

The Intergovernmental Panel on Climate Change (IPCC) 1.5°C report shows the increasing urgency of rapidly reducing emissions to achieve net zero emissions as early as possible.[2] This has significant implications for all countries, not just the bigger emitters, with regards the approach they take to supporting a just transition to a low-emission development pathway. The growing number of countries committing to net zero targets means that transforming energy systems to be consistent with low-emission pathways is increasingly inevitable. But many countries are not yet able to provide reliable and universal energy services. From a climate justice perspective, it is important for developing countries to get the support they need to tackle this gap in energy services and the **transformation** to a low-emission energy system as a single coherent vision.

According to the International Energy Agency (IEA)'s sustainable development scenario,[11] renewable capacity additions need to grow by over 300 gigawatts (GW) on average each year between 2018 and 2030 to reach the Paris Agreement goals and Sustainable Development Goals (SDGs). But IEA data found that in 2018, this growth failed to show a year-on-year increase for the first time since 2001. New net capacity from solar PV, wind, hydro, bioenergy and other renewable power sources only increased by 180GW or 60% of the net additions needed to meet the sustainable development scenario target.

IEA analysis reported that "the main reason [for the global stagnation of PV capacity] was a sudden change in China's solar PV incentives to curb costs and address grid integration challenges to achieve more sustainable PV expansion."[12] Although global economic slowdown was also a factor, this example shows the need for stable, forward-looking policies underpinned by a long-term, system-wide vision for the sustainable integration of renewables. The UK introduced a capacity market to value critical services for reliable energy with increasing **intermittent renewables**. Such system-wide analysis is vital if countries are to move at the pace and ambition needed to achieve rapid **transformation** to low-carbon energy systems.

The need for energy storage increases as **intermittent renewables** are added to the grid because wind and solar provide energy when it is windy or sunny rather than in response to demand. Storing any unconsumed energy produced by **intermittent renewables** is now a valuable feature for grid management. **Pumped-storage hydropower** (see Box 1) represents 99% of global installed **energy storage capacity** (see Box 1), at over 125GW.[13] Although the deployment of lithium ion batteries is increasing in countries like UK, Australia and Germany, they are short-lived and remain innovative and small-scale.[3] And although costs are falling, battery technologies remain relatively expensive. Pumped-storage hydropower systems cost US$177/kWh, while lithium ion batteries cost close to US$400/kWh and are expected to fall to under US$250/kWh by 2050.[14]

As we discuss in the following sections, storing water through a hydropower network is likely to be a critical part of many countries' long-term low-emission and climate-resilient strategies. Indeed, global hydropower construction plans for over 3,700 dams of capacity greater than one megawatt (MW), primarily in countries with emerging economies, with the aim of increasing the 2015 global hydroelectricity capacity by 73%,[15] suggests this is the case.

2.2 Hydropower on the grid: penetration and function

Hydropower is the world's leading renewable energy source for electricity generation, supplying 71% of all renewable energy. In 2016, hydropower reached an installed capacity of 1,064GW and generated 16.4% of the world's electricity from all sources.[16] Nearly half of the 47 Least Developed Countries rely on hydropower for between one third and all of their electricity.[17]

The primary function of most hydropower infrastructure is generating **baseload power**.[18] But as it can respond in seconds to changes in demand, it can also provide peak demand services, **grid stabilisation** and storage for surplus energy produced by **intermittent renewables** (see Box 1).

Hydropower dams are a long-term investment, with an average life expectancy of 50 years. But they also create a footprint that is likely to last in perpetuity.[20] So it is critical to design hydropower projects that are fit for future social and climate conditions and comply with changing technical requirements as we shift to distributed, smart, clean grids.

BOX 1: ENERGY AND CLIMATE FINANCE TERMINOLOGY[10]

Additionality: Evidence of climate benefits beyond business as usual or what would occur without climate finance.

Arbitrage: When a product can be bought at a time (or place) for a lower price, then sold later (or elsewhere) at a higher price. With energy storage, this means charging during hours of low demand at low cost and discharging during high demand at better prices.

Automating the grid: Automatically adjusting generation to respond to demand, thus maintaining grid frequency within defined parameters.

Baseload power: Electricity generation intended to operate constantly rather than respond to fluctuations in demand. Baseload is the minimum demand on a grid.

Black start: The ability of a generating unit to start without an outside electrical supply. Black start service is necessary to ensure the reliable restoration of the grid following a blackout.

Business-as-usual hydropower: Hydropower with design and operation aimed at traditional baseload and peak generation, that does not consider its potential to provide energy storage or grid services, or the climate resilience of energy and water systems.

Climate finance: Local, national or international financing – drawn from public, private and alternative sources of financing – that seeks to support mitigation and adaptation actions that will address climate change.

Energy dispatch: Varying generation output to meet changing supply requirements in real time, without losing efficiency.

Energy storage capacity: The energy available in a storage system to respond to demand. Pumped-storage hydropower accounts for 99% of bulk energy storage worldwide and typically has 6–20 hours of reserve storage.[15]

Fast Frequency Response: the delivery of a rapid active power increase or decrease by generation or load in a timeframe of two seconds or less, to correct a supply-demand imbalance and assist in managing power system frequency.

Flexible generation: Generating capacity whose output can be varied as needed. Flexible generation is said to be dispatchable.

Grid stabilisation services: Services to increase or reduce generation to ensure supply and demand is balanced, maintaining the right frequency on the grid to prevent damage to equipment. Such services help maintain a state of equilibrium during normal and abnormal conditions or disturbances.

Inertia: Resistance to change. Grid inertia helps keep the grid voltage within safe limits and is provided through generators and motors in powerplants and factories rotating at the same frequency as the electricity grid.

Intermittent renewables: Many renewable sources of energy are not continuously available to be converted into electricity. Wind turbines produce energy when there is wind, solar panels when there is sun. It can be predictable but is not dispatchable in response to demand.

Low-carbon grid: An electricity grid that uses energy sources with low CO_2e emissions over their lifecycle, such as wind, solar, hydropower, geothermal, biomass and nuclear. To stay well below 2°C or reach the 1.5°C ambition, a low-carbon grid would need an emissions factor that is 90% lower than current levels, about 50g CO_2e/kWh.

Load shedding: The deliberate shutdown of electric power in part or parts of a power distribution system, generally to prevent the failure of the entire system when demand strains its capacity.

Paradigm shift: A change in what is understood as 'normal'; a change in how issues are framed.

Peak power: The maximum demand a grid can respond to or the maximum power an energy system can provide. It is designed to respond to short surges or peaks in demand that occur at different times in a day as well as having seasonal variation.

Pumped-storage hydropower: Where water is pumped up from a lower reservoir to a higher one when more energy is produced than needed and released when demand exceeds supply.

Transformation: A fundamental and large change in social, ecological and economic systems creating a new 'normal' or a new 'stable state'. Climate finance seeks to transform systems to be low-emission and climate-resilient.

Unbundling: Regulatory provisions that separate entities in different stages of the business cycle to create more competitive energy markets, either through the separation of accounts, the legal separation of entities or ownership bundling, ensuring each entity has independent decision-making mechanisms.[19]

2.3 Hydropower in the transition: low-carbon energy

Hydropower is a renewable energy that usually produces low-carbon electricity. In 2018, the global median lifecycle GHG emission intensity of 178 single-purpose dam reservoirs and 320 multipurpose dam reservoirs was 18.5g CO_2e/kWh; 84% of these reservoirs exhibited emissions lower than 100g CO_2e/kWh.[21] This is comparable to the median lifecycle carbon equivalent intensity of other renewables (11g CO_2e/kWh for onshore wind, 12g CO_2e/kWh for nuclear and offshore wind and 48g CO_2e/kWh for solar PV) and significantly lower than fossil fuel energies (490g CO_2e/kWh for gas and 820g CO_2e/kWh for coal).[22]

Emissions from hydropower start during construction and continue via the release of methane and carbon dioxide throughout a reservoir's lifetime.[23] These vary considerably according to the reservoir's design and location.[24] Shallow reservoirs with a large surface area-to-volume ratio and a low installed capacity, for example, typically emit more CO_2e/kWh than deep reservoirs with a smaller surface area-to-volume ratio and high installed capacity. Tropical sites also emit significantly higher levels of emissions. For example, Brazil's Balbina hydroelectric reservoir in the Amazon emits an estimated three million tonnes of carbon dioxide equivalent (tCO_2e) a year, which is almost half the CO_2 emissions from burning fossil fuels in São Paulo city.[25] Emissions from a reservoir typically decline gradually over its lifetime.

We must therefore consider the context when estimating a hydropower system's lifecycle emissions to understand the carbon intensity of the electricity it produces.[26] The IHA and UNESCO have developed the G-res tool, a standardised methodology for assessing reservoirs' potential GHG emissions.[27] This tool should give greater confidence in these estimates and allow project proponents to better compare emissions from different generation options, ensuring a trajectory towards an average of 50g CO_2/kWh across the grid.

2.4 Hydropower in the transition: for energy storage and grid stability

Beyond its potential as a renewable and low-carbon source of energy, hydropower can provide critical grid services to enable the transition to low-carbon electricity grids.

Electricity grids are complex systems. Their voltage and frequency need careful management to balance demand, transport electricity efficiently and reliably provide the right voltage of power to households. To increase levels of **intermittent renewables** on a grid, its systems need greater storage capacity[3,28] and ancillary services such as **flexible generation** and **grid stabilisation** (see Box 1). So, energy generation technologies that can offer this are essential in the transition to a low-carbon future.

For example, Ireland's EirGrid and System Operator for Northern Ireland (SONI) undertook a joint process to identify and value the services their integrated grid needed to support a transition. The programme, 'Delivering secure sustainable electricity system (DS3)', established in 2011, aims to develop the grid to meet the challenges of operating the electricity system in a safe, secure and efficient manner while facilitating higher levels of renewable energy.[29] As part of this process, EirGrid and SONI identified 14 system services and several other ancillary services and system charges, such as **black start** (see Box 1). Hydropower can provide 13 of the 14 system services identified.

Because it can respond to increasing or decreasing demand, hydropower can offer dispatchable energy and provide **peak power** (see Box 1) without losing efficiency. Hydropower systems range from pure run-of-river constructions to structures that use reservoir storage. Run-of-the-river projects use no or small reservoirs behind a turbine to store water, so they have limited **energy storage capacity**. Some therefore can, or have the potential to, offer daily storage, which can be highly useful for grid integration of renewables. They are, however, less flexible in offering wider services on the grid than hydropower systems with larger reservoir storage. But this can change if the run-of-river constructions are integrated with other forms of bulk energy storage.[30] It is possible to retrofit hydropower systems to expand the services they offer – for example, by adding power generators to dams that were not built for hydropower or creating additional reservoirs to enable greater storage potential.

Reservoir storage hydropower plants store water that can be used to generate energy at any time. It is possible to increase flow quickly during peak demand to increase electricity generation and reduce or stop it during quieter times when energy demand is lower. This is an advantage over energy sources such as coal, geothermal or nuclear, which are better suited for **baseload power**. These other sources take several hours to change their output and lose efficiency at higher or lower levels of generation, while frequent changes reduce the life of equipment.[31] Hydropower, on the other hand, can reach full power in less than one minute.[32] This near-instantaneous dispatchability means that hydropower can respond to sudden changes in energy supply and demand, supporting the integration of **intermittent renewables**, such as solar and wind.[33]

Pumped-storage hydropower systems have two reservoirs at different heights with a reversible turbine between them. When intermittent sources produce surplus electricity, they pump water up to the higher reservoir for storage, releasing it back into the lower reservoir to generate electricity at times of peak demand.[34] As turbine generators can both respond rapidly and spin without producing power, hydropower can stabilise grid frequency and smooth out the peaks and troughs of solar and wind generation that fluctuate according to the weather and the time of day. This becomes increasingly important as the proportion of intermittent energies on the grid increases. And because operators need to physically open a sluice to start the turbines, hydropower can provide **black-start** services, enabling other sources of energy to be restarted after a blackout.

2.5 Increasing ambition

As we have seen, hydropower is a flexible, renewable energy resource. With the correct design, it can provide bulk energy storage and ancillary grid services that support higher levels of **intermittent renewables** on the grid. Given the urgency of climate action, the time required for building hydropower systems and ensuring appropriate environmental and social safeguards have limited the opportunities they represent in the immediate term. However, the versatility of hydropower technology is critical to the **transformation** we will need for 2050 pathways to transition to a low-carbon future.

Pumped-storage hydropower is the most mature storage technology. It provides more than 94% of installed global **energy storage capacity** and houses over 99% of energy stored.[21] Although finding sites that are suitable for a double reservoir can limit the deployment of larger schemes, adding a reservoir to existing hydropower systems would probably be highly cost-effective. Given the flexibility in services that hydropower systems offer in supporting the transition to net zero emissions, their further development should be part of any integrated clean energy system.

There continues to be exciting innovation in hydropower, including the development of underground closed pumped-storage systems that can also provide thermal energy for heating buildings, and systems that integrate hydropower with other renewables for stable mini grids. These integrated systems can also be digitised, bringing together automation technology, big data analytics, artificial intelligence and the industrial internet of things to manage demand as well as generation, improving grid efficiency and reliability,[35] particularly as grid systems become increasingly multifaceted and complex. While **automating the grid** can require a high level of investment, it points to a significant area of innovation for many grid systems. There is also a critical need to invest in testing new approaches for proof of concept and business model testing, given the potential of innovations to support a rapid transformation of grid systems

Most hydropower in developing countries is operated purely for **baseload power**. Integrating its transition characteristics into grid planning and management is an important opportunity to create a resilient **low-carbon grid** (see Box 1) in the long term; and climate finance can play a critical role in this. Retrofitting and upgrading current hydropower infrastructure can be relatively cheap and fast. These opportunities enable national governments to increase their climate ambition while delivering SDG7 (affordable, reliable, sustainable and modern energy for all). They are critical to delivering the Paris Agreement.

Climate finance for hydropower

3

3.1 What is climate finance?

Climate finance refers to "local, national or transnational financing – drawn from public, private and alternative sources of financing – that seeks to support both mitigation and adaptation actions that will address climate change".[36] When invested in mitigation, climate finance seeks to reduce emissions; when invested in adaptation, it supports societies to adapt to the impacts of climate change.

3.2 Climate funds

Under the United Nations *Framework Convention on Climate Change* (UNFCCC), the Kyoto Protocol and Paris Agreement both set out mechanisms to deliver financial assistance from richer countries, who have historically emitted more GHGs, to poorer countries, who have emitted less, yet are more vulnerable to the effects of climate change.

The Global Environment Facility (GEF) has served as a financial mechanism since the UNFCCC entered into force in 1994, managing the Special Climate Change Fund and the Least Developed Countries Fund. The Adaptation Fund was established under the Kyoto Protocol in 2001 and the Green Climate Fund (GCF) in 2010. These financial mechanisms are accountable to the UNFCCC's Conference of Parties, which decides on its priorities and eligibility criteria for funding.

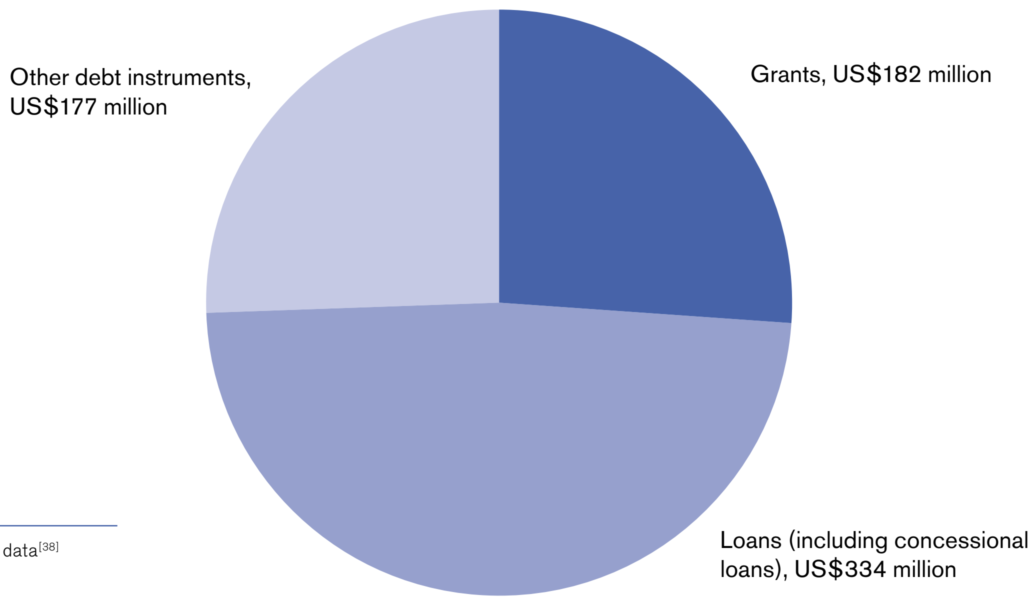
In 2008, the World Bank Group set up the Climate Investment Funds (CIFs). Intended as an interim measure while the GCF was established, the CIFs have continued to function, given the challenges of accessing the GCF.[37] The CIFs – comprising the Clean Tech Fund (CTF), the Forest Investment Program, the Pilot Program for Climate Resilience and the Scaling up Renewable Energy in Low-Income Countries Program (SREP) – all work through the multilateral development banks as implementing agencies.

Although these climate funds were established for different purposes, they have similar criteria for investment. These broadly include meeting requirements for **additionality** (see Box 1) and **transformation** or **paradigm shift** in systems (see Section 4.1); adaptation to climate impacts; and reducing carbon emissions below business as usual levels.

3.3 What has been funded by multilateral climate funds?

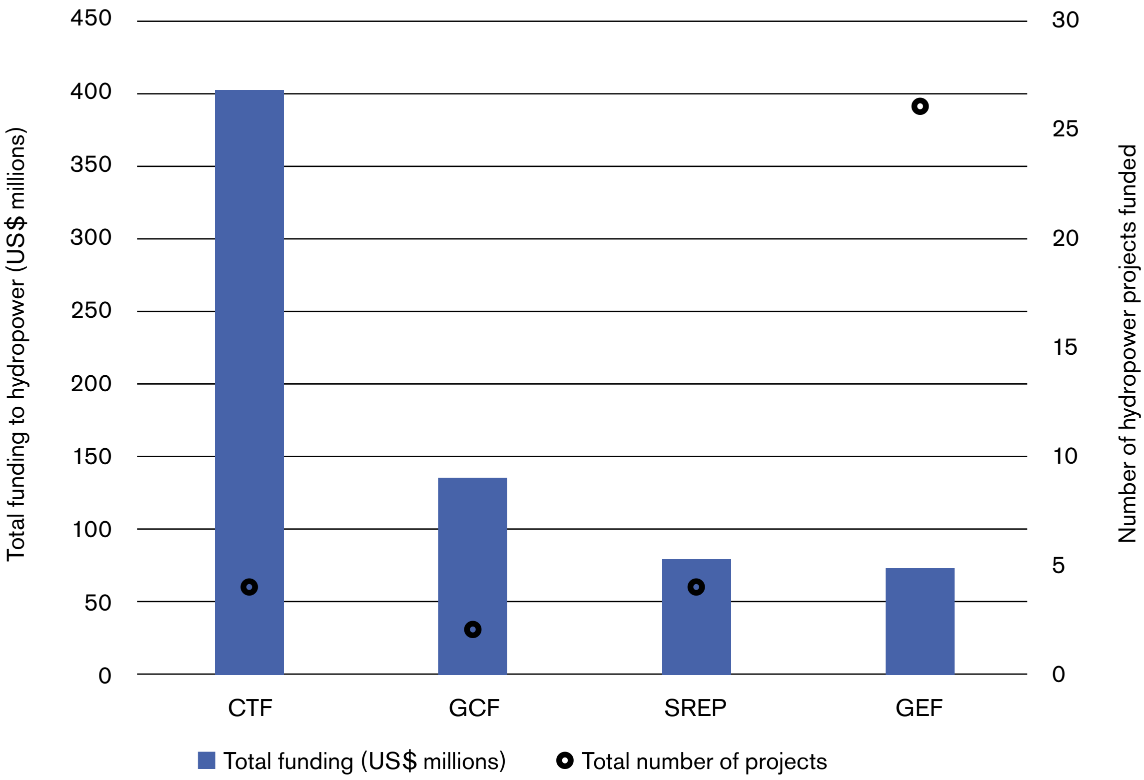
Climate finance flows to hydropower projects from 2003 to 2018 amount to US$693 million (see Figure 1).[38] But these figures pale in comparison to the almost US$300 billion of public (US$238 billion) and private (US$57 billion) climate finance that flowed to renewable energy (90% to wind and solar) as a whole in 2016 alone.[39]

Figure 1. Instruments used by multilateral public sector climate funds in financing hydropower projects



Source: CFU data[38]

Figure 2. The multilateral climate funds financing hydropower projects



Source: CFU data[38]

Of the 23 public-sector climate funds in the CFU database, 11 are mitigation-focused, six are adaptation-focused and six are cross-cutting funds. Hydropower projects can offer both mitigation and adaptation benefits, depending on the project objectives. By helping decrease energy systems' carbon intensity and ameliorating floods and droughts, they can support adaptation.[40] But they are usually focused on mitigation. Of the four climate funds to support hydropower projects, two – the CTF and SREP – have a mitigation mandate. The other two – the GEF and GCF – support both adaptation and mitigation.

Barriers to accessing climate finance

4

Between 2003 and the end of 2018, only 36 hydropower projects received support from multilateral climate funds (see Table 1). Exploring the hydropower projects that climate funds rejected for funding highlights five areas of concern around their funding criteria and perceptions around hydropower risks:

- Proving **additionality** and **transformation** potential
- Sustainability
- Political risk and regulatory regimes
- Value to energy markets, and
- The interpretation of climate fund mandates.

4.1 Additionality, transformation and paradigm shifts

Climate funds have rejected many hydropower project proposals for lacking evidence of **additionality** and **transformative** change. Here, **additionality** refers to evidence of climate benefits beyond what could be expected to occur without climate finance.[10] A **paradigm shift** refers to bringing about a fundamental change from current systems. Climate funds could achieve a **paradigm shift** by supporting projects that demonstrate the viability of technologies or innovation in financing that enable a transition from fossil fuel reliance to a low-carbon energy grid. Hydropower has huge potential for generating electricity with very low emissions (see Table 2) and facilitating penetration

Table 1. Funding of hydropower projects by the primary public sector multilateral climate funds

FUND	WHAT HAS BEEN FUNDED	ALIGNMENT WITH FUND MANDATE
CTF	Number of projects: 4 Total funding: US$404 million Capacity:[41] large hydropower 70–1,334 MW	With average funding size of US$101 million, the CTF has provided loans for large-scale hydropower projects. This is in line with the fund's mandate to "promote scaled-up financing for demonstration, deployment, and transfer of low-carbon technologies with significant potential for long-term greenhouse gas emissions savings."[42]
GCF	Number of projects: 2 Total funding: US$136 million Capacity: large hydropower 15–48 MW	The GCF's mandate is to help developing countries limit or reduce their GHG emissions and adapt to climate change. The two projects it has funded are in line with its objectives of promoting a **paradigm shift** to low-emission and climate-resilient development. One project aims to facilitate a power system transition; the other focuses on climate-resilient development for environmental and social sustainability.
SREP	Number of projects: 4 Total funding: US$80 million Capacity: small hydropower 4.3 MW; others not specified	These four projects have been funded under the SREP's mandate to support projects that demonstrate the economic, social and environmental viability of low-carbon development pathways in low-income countries' energy sectors. All four projects concern increasing electricity access through mini or micro grids.
GEF	Number of projects: 26 Total funding: US$73 million Capacity: small hydropower 0.025–14.2 MW (mostly <10 MW)	These have tended to be small-scale marketing, promotion (through small pilot constructions) and capacity-building projects, in line with the GEF's mandate to cover the incremental costs of a measure to address climate change relative to a business-as-usual base line.

Source: CFU database[38]

of other renewables into the grid as a co-benefit. As such, it has a role to play in the transition.

Hydropower is not a new technology, so climate funds do not normally consider it to be game changing or have **transformational** benefits. Providing climate financing to any project requires a strong argument, justified on the business-as-usual trajectory, on how it demonstrates **additionality** and **paradigm shifts** or how it **transforms** an energy system. As well as being considered internally by the climate fund, project proposals are closely scrutinised by the international community. The poor history of hydropower developers' engagement with affected communities and of mitigating environmental impacts has effectively led non-governmental organisations (NGOs) to object to any argument for their transformational impact.[43]

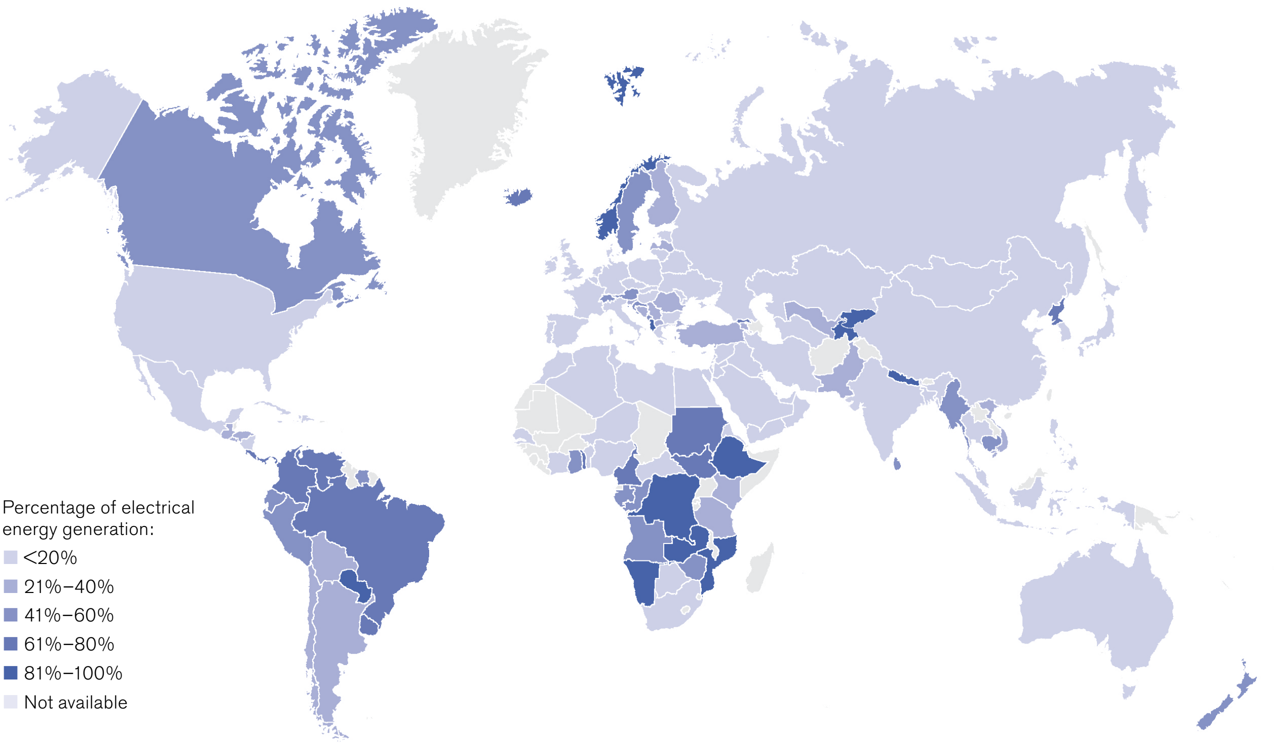
This is illustrated by the Nepal 216MW Upper Trishuli-1 project proposal submitted by the International Finance Corporation to the GCF in 2016 (though it never reached the board).[44] A number of NGOs – including Friends of the Earth, Heinrich-Böll-Stiftung Foundation and the Centre for International Environmental Law – wrote a joint letter to the GCF board, arguing against this and two other hydropower projects that the fund was in the initial stages of considering. The letter argued that the Upper Trishuli-1 project "would have no transformational impact" and therefore should not receive climate finance funding.[45] However, this claim did not consider broader considerations, such as the role that Nepal's hydropower could play in offering energy storage and ancillary grid services as part of any future Asian regional grid,[46] helping transform neighbouring grids to operate on renewables. There are plans for expanding Nepal's energy trading capacity with India,[47] Bangladesh and China. But these plans are facing issues around risk management and grid harmonisation,[48] which climate finance could reasonably play a role in resolving.

4.2 The changing climate's effect on the energy system

The viability of hydropower in a context of increasing climate impacts also raises concerns for climate funds. They have rejected some hydropower projects, citing the likely unreliability of energy outputs due to changing rainfall patterns and variation in river flow. Drought risk and more intense rainfall with greater sediment loads are both exacerbated by climate change, which means that energy security could be undermined by increasing the proportion of hydropower on the grid.

Hydropower is the most common form of non-fossil fuel electricity worldwide and comprises nearly 100% of electricity in some countries (see Figure 3 and Table 2). Regionally, central and eastern Africa and South America show high dependence on hydropower.

Figure 3. Electricity generated using hydroelectric power and submitted to the grid (2015)



Source: World Bank (2015)[49]

Table 2. Highlighting some countries that have a high proportion of hydropower on their grids

COUNTRY	PROPORTION OF HYDROPOWER IN TOTAL ELECTRICITY GENERATION (%)	GRID CARBON INTENSITY (G CO_2E/KWH)
Democratic Republic of Congo	>99	4.2
Mozambique	>86	0.4
Nepal	>99	3.0
Tanzania	33.5	266.8
Tajikistan	>98	23.2
Zambia	>96	3.2
Zimbabwe	51.4	600.4

Source: World Bank (2015)[49] and Ecometrica (2011)[50]

Ethiopia's energy generation capacity in December 2017 was 1,937MW; 1,858MW of this came from hydropower plants, "leaving the power supply vulnerable both to natural changes in water flows as well as the effects of climate change."[51] Increasingly intermittent rainfall patterns, which impact the output of hydropower plants, are a growing risk to Ethiopia's energy system, particularly in light of the 6,450MW Grand Ethiopian Renaissance Dam – Africa's largest hydroelectric project – which has been under construction since 2011.[52] This is acknowledged in the government's SREP Investment Plan, which includes an objective to diversify the energy mix away from hydropower.[53]

These risks were another factor in the NGOs' objections to Nepal's Trishuli-1 project. In FY 2016, 94% of Nepal's power generation capacity was from hydropower.[54] In their letter, the NGOs argued that the project lacked transformational impact and "face(d) severe climate and disaster risks (and) would deepen Nepal's overdependence on climate-vulnerable hydro."[45]

Hydrological risks due to climate change are likely to reduce the reliability of energy systems where they have a high proportion of hydropower on the grid. Indeed, drought in hydropower-dependent countries such as Malawi, Tanzania, Zambia and Zimbabwe, which are affected by increasingly severe El Niño cycles, has led to significant **load shedding** (see Box 1).[55] During the drought in the last quarter of 2017 in Malawi, low water levels in the Shire river caused electricity generation to fall almost by half – from 300 to 160MW – resulting in power outages across the country that lasted for several weeks.[56]

Drought and successive dry years can result in long-term lower water volumes and insufficient flow to drive electricity generating turbines. In such conditions, electricity utilities can be forced to turn off supply to ration dwindling water resources so they can maintain intermittent electricity generation.[57] Project developers therefore need to demonstrate to the global climate fund managers how they can manage such risks effectively within the energy system on a case-by-case basis, taking into account the opportunities interconnected grids can offer. At the same time, climate funds also need to recognise the role of hydropower as an alternative to gas and coal, in enabling more **intermittent renewables** to diversify the grid system overall. From the pattern of project rejections, climate fund boards appear to be concerned that hydropower could 'crowd out' other renewable technologies on the grid – for example, by providing cheaper electricity than wind or solar – and so disincentivise diversification to other renewables. The GCF raised this concern when considering the Tina River Solomon Islands hydropower project; in that case, it concluded that the project would not substantially displace the development of other renewables.[7] Rather than consider the different renewables separately, the climate funds should look to incentivise low-emission grid systems overall in an approach that includes enabling hydropower projects designed to offer services that support a greater proportion of **intermittent renewables** on the grid.

4.3 Political risks and regulatory regimes

Hydropower is often viewed as a risky investment, which may reduce the climate funds' confidence in such investments. The political risk of changing regulatory environments poses challenges for developing countries looking to attract finance for any infrastructure. Political instability can disrupt the construction of hydropower projects and affect the emergence of an enabling environment that attracts hydropower developers and investors with good social and environmental credentials.

Project developers have cancelled projects or components of projects with agreed climate finance as a result of political instability. For example, the developer of a mini-hydropower plant for the rural communities of the Venezuelan Andes, due to be supported by the GEF in 2014, cancelled the project after political instability led to delays.[58] In Morocco, long administrative delays – also caused by political instability – led to the removal of the hydropower construction component of the ONE Wind Energy Plan project, supported by the CTF. With no foreseeable start date for its construction, the funding allocated to the hydropower component was reallocated to the wind component.[59]

Other projects started and achieved progress in some respects – for example, training officials and domestic project developers or preparing for market reform – but ultimately failed to deliver any hydropower construction as a result of political uncertainty. These include small hydropower development projects in Kyrgyzstan and Haiti, both supported by the GEF.[60]

The Kyrgyzstan project faced issues from "frequent changes on the top governmental level" which "also translated into frequent changes in the structure of government institutions responsible for [small hydropower] development, and the staffing of these institutions". This caused delays and uncertainties in the project.[61] After further political upheaval in 2010, the private-sector investors, representing 89% of the project financing, withdrew their support.

The Haiti project also failed due to the government's lack of progress in regulatory reform. The project provided draft laws, which were required for construction to go ahead. But the authorities did not engage in the process and the GEF eventually cancelled this component of the project, along with its funding.[62]

The barriers faced in these projects could relate to pressure from investors to demonstrate quick results even in unstable and volatile political contexts. But the limited ability of project developers and technical assistance providers to navigate such contexts and elicit political will is also an issue.[63] Given the urgency of climate action, climate funds tend to value fast returns, which may unintentionally lead to a lack of longer-term investments that would deliver the core policies and infrastructure required for more transformational outcomes. However, given the challenges developing countries face, this also represents a strong case for providing climate finance to de-risk the investment in these countries.

4.4 Value to energy markets

Despite high upfront costs, hydropower provides low-cost electricity over a long lifetime.[64] The global weighted average cost of electricity from hydropower projects in 2017 was US$0.05/kWh, making it a very low-cost energy source.[65] Hydropower also provides an opportunity to generate significant revenue from exports to neighbouring countries, reducing the regional grid's overall emission intensity and providing additional services so neighbouring countries can increase the proportion of **intermittent renewables** on their grid. For example, Nepal's Upper Karnali scheme will be the first to export to Bangladesh through India.

The value of hydropower to the grid system, however, depends on how it is used. It can be highly flexible, but the structure of the energy market will determine how its flexibility is deployed. As we discussed in Section 2, hydropower can be used for **baseload power**, as it generates cheap and stable electricity. It can also meet peak load power needs, due to its high dispatchability. Some markets also value the grid ancillary services that hydropower can provide, as we outline in Section 2.4. Payments for services to the grid – such as frequency response and capacity response – are more common in developed markets. In monopoly markets with a single off-taker, it can be hard for hydropower developers to negotiate payments that reflect the full value of hydropower to the grid. In liberalised markets, there are also opportunities to create additional revenues such as inter-operator balancing deals.

Local context – domestic geography, generation potential from energy sources with different characteristics, national and regional priorities and so on – affects the structure of energy markets. The debate in climate funds thus far has assumed that grids are national or sub-national. As such, they see them as closed, with no interconnectors to share power with other grids. But there are many examples of regional grids and bilateral deals between national power pools. Interconnected grids have similar underlying issues around energy storage and grid stability, but they can have additional political complexity.

For example, Norway is developing interconnections with Denmark, Germany and the UK to support grid stability from wind, but providing these services means the domestic electricity tariff is increasing. Norway's large hydropower capacity has facilitated the high levels of wind power on Denmark's grid by providing these stabilisation services.[21] Japan, which has a geographically isolated grid with no domestic oil and gas, developed a nuclear power and coal energy system for baseload energy and use **pumped-storage hydropower** for peak load. After the 2011 tsunami, public concern about nuclear safety stimulated greater interest in solar and wind, which their hydropower could support.[66]

Economic incentives set up to meet national priorities can distort the structure of energy markets. Feed-in tariffs for wind and solar have been introduced in many markets to build investors' confidence to develop capacity from these sources. But it can be challenging to get the rate right and ensure it does not undermine investment in other renewables. Germany's Renewable Energy Sources Act,[67] for example, started in 2000 with a feed-in tariff (FiT) scheme that guaranteed a grid connection, preferential dispatch and a set 20-year tariff rate that was dependent on the technology and size of project.

Such eligibility restrictions can create perverse incentives, leading to unintended consequences.[68] For example, multiple 'must-run' contracts and a cap on maximum hydropower scheme size have in some cases resulted in projects that artificially reduced their output to meet the FiT criteria. Germany regularly reviewed its FiT policy and changed it in response to policy impacts and changing market conditions.[69] A policy revision in 2014 phased out FiTs and brought in deployment corridors to stipulate the extent to which renewable electricity should to be expanded in future, with tariffs set by auction.[70] Auctions for renewables allow the market to set the tariff rate and can allow technologies to compete against each other. However, Germany's Renewable Energy Sources Act has been criticised for setting targets in the deployment corridors that are too low to meet its long-term national climate goals, particularly given the likely electrification of the transport sector.[71] But, whichever method governments use to incentivise renewable energy projects, the full value of hydropower will not recognised and incorporated into the market unless markets reward grid stability and energy storage services.

The cost-effectiveness of hydropower compared to other renewables is also affected by the cost of capital for construction and the way repayment is structured under a power purchase agreement (PPA). Hydropower projects have high upfront costs, relatively long construction times and are slow to start generating revenue. Because of this, hydropower is usually financed by large external investors. And because they are usually characterised as high-risk projects, they have high capital costs.

The Solomon Islands' Tina River Hydropower project created a build-own-operate-transfer (BOOT) arrangement under which the national government partnered with a private company to form a company to oversee the project's construction over four years and operation for 30 years. At the end of this period, ownership of the hydropower is transferred to the country government. Under this type of arrangement, a country government agrees a tariff for purchasing the electricity generated from the project company. In this case, to finance all the project components, the PPA tariff would have been too high for the government's utility to afford. So to bring the tariff down, the government, GCF and others financed some vital non-revenue generating components – such as building access roads and transmission lines – outside of the BOOT agreement.[7] Refinancing hydropower projects post-construction is another approach to tackling the high capital costs of the higher-risk construction phase.

There would therefore be value in the climate funds supporting energy regulators and grid operators to develop grid facility service pricing and energy markets to fully value energy storage and ancillary services so grids could run fully off renewable energy technologies. This will require further analysis and experimentation to understand what works under different market conditions and provide a cost-effective incentive to provide these services. Once these services are in place, private investment into **intermittent renewables** is effectively de-risked, as having the ability to store – and then use – energy created by intermittent sources would save the public purse from paying for unnecessarily unusable energy.

4.5 Climate funds' inconsistency in interpreting their mandate

Our analysis of hydropower projects submitted to the global climate funds suggests that decision makers are inconsistent in their application of the **additionality** criteria and in assessing the hydrological risk to hydropower. How a project frames the argument in its application for climate funds is an important factor. Projects that directly argue that they seek to strengthen climate resilience are more likely to get funding than those that aim to achieve similar outcomes but do not frame the argument within the discourse of climate change mitigation and adaptation.

Framing seems to be particularly relevant for projects seeking financing to increase the climate resilience of existing dams. One successful GCF application was a hydropower project in Tajikistan to rehabilitate a major Soviet-era hydropower facility that needs urgent modernisation and climate-proofing.[72] Many other projects that applied for financing to maintain and increase the resilience of their dam systems were rejected on the grounds of not representing any transformational value and so not needing climate finance to enable other sources of investment.

Nepal has struggled to access climate finance from the GCF and CIFs, including for the Upper Trishuli-1 project discussed in Section 4.1. Given that hydropower is a proven technology, many projects in Nepal were unable to make the case for **additionality**. There were also concerns around the social and environmental impacts of the projects, including their reliance on hydropower, which reduces energy system resilience to climate impacts. Neither side seemed to consider the potential of hydropower systems in terms of regional trading with India, Bangladesh or China for energy storage and **grid stabilisation** services.

Climate finance could help increase the social and environmental sustainability of both these projects; it could also give them **transformation** potential. Where dams apply for financing for maintenance and to strengthen the resilience of ageing structures, climate funds could invest in any opportunity to retrofit to provide the energy storage and ancillary services needed for the transition. Nepal's Upper Trishuli-1 project, which has found other sources of financing,[73] could have used climate finance to incentivise developing these transition characteristics in Nepal's hydropower as part of South Asia energy trading.

4.6 Overcoming these barriers

In Annexes 1 and 2, we unpack arguments that two projects – the Solomon Islands' Tina River Hydropower Development project and Morocco's ONE Wind Energy Plan – could use to meet the GCF and CTF investment criteria.

The five barriers we have highlighted in this section show why climate funds must clarify the criteria by which they assess hydropower for its value to the transition to a **low-carbon grid** and for resilience in energy and water systems.

Communicating this clearly to hydropower developers, investors and policymakers would incentivise them to develop the right type of hydropower projects for transition in the right circumstances. We explore these criteria in the next section.

How can climate finance incentivise transition hydropower?

5

Business-as-usual hydropower (see Box 1) does not meet climate funds' **transformation** criteria and providing climate finance to such projects exposes funds to reputational risk around social and environmental costs. However, given the value that hydropower could offer in the transition to low-carbon energy systems, excluding hydropower from climate finance is a missed opportunity.

Climate finance can play a critical role in improving the design of hydropower for transition, and supporting the development of energy markets that provide affordable energy security with a high proportion of renewables. In this section, we identify and explore five opportunities for climate funds to do this:

- Providing clear criteria for investing in hydropower to incentivise projects to include characteristics that are critical for transition
- Supporting basin assessments for strategic hydropower development
- Increasing the performance of existing hydropower systems to meet climate objectives
- Restructuring markets to reward the transition ancillary services that hydropower can offer, and
- Reducing the cost of capital for private investment into transition hydropower.

5.1 Providing clear criteria for investing in hydropower

To attract climate finance, hydropower projects must offer more than business-as-usual **baseload power**; they need to be part of the **transformation** of energy and water systems. By offering transition services such as energy storage and **grid stabilisation**, hydropower systems promote climate resilience and demonstrate a **paradigm shift**, enabling grids to significantly increase their installed capacity for **intermittent renewables**. This is vital for the transition to **low-carbon grids**. By setting criteria for investing in hydropower, climate funds would incentivise hydropower projects to include characteristics that support **transformation** to renewable energy systems and promote a **paradigm shift** in grid operators' approach to rewarding transition services.

Hydropower can provide low-carbon energy (Section 2.3) without offering **additionality** or a **paradigm shift** from business as usual. But, given the known challenges of hydropower, climate funds should ask projects to ensure that they keep their lifecycle emissions low and hydrological risks actively controlled. Using a robust method such as G-res will provide assurance on lifecycle emissions; robust analysis against possible climate futures also offers assurance on hydrological risk.[27] Supporting this with strategic basin assessments (Section 5.2) will help projects demonstrate that they have optimised their location and design within a basin for lower emissions and greater resilience to hydrological risks; it will also minimise ecosystem and social costs. Asking projects to assure climate funds that they are engaging local communities through benefit sharing or payments for ecosystem services can help engage communities in watershed management, reduce organic matter entering the reservoir with intense rainfall, reduce lifecycle emissions and protect its storage capacity.[32]

Requiring projects to make a clear case on emissions, hydrological risk, and social and environmental safeguarding is important for two reasons. First, managing these risks ensures hydropower makes a greater contribution to the transition to low-emission grids. Second, while a project's good performance on these issues is not enough to justify climate financing, it needs to clear this bar given the scrutiny of climate fund decisions.

Climate funds can clarify that having specific design characteristics can help hydropower projects demonstrate that they facilitate the transition to a **low-carbon grid**. As we noted in Section 2.4, by maximising their flexibility for grid services such as energy storage, load following and frequency response services, projects can enable a grid to increase the share of intermittent renewable energy. Transition hydropower projects that are designed with these capabilities can clearly argue they are not business as usual with respect to emission intensity. Where available, strategic basin and energy system assessments could provide analysis of this value. Climate funds could also fund hydropower design and proposal development with these transition objectives.

One project that is doing this is Morocco's ONE Wind Energy Plan (Annex 2), which aims to expand wind power farms in Morocco. Part of the project is retrofitting a hydropower plant to offer pumped storage for grid stability and storage services, enabling greater wind power to be incorporated onto the grid.[6] This hydropower component effectively de-risks the private financing of wind expansion.

5.2 Supporting basin assessments for strategic hydropower development

Best practice in strategic basin assessments considers a range of scenarios around the placement, design and operation of hydropower to improve decisions across a river basin to optimise development objectives linked to irrigation (food), energy, water and ecosystems (wetland conservation). There is widespread agreement that the negative impacts of hydropower are best managed at basin scale, by choosing and locating projects to avoid sensitive areas, rather than at a project level, where the margin for manoeuvre is more limited.

Undertaking robust water and energy system options assessments can maximise benefits for the transition to low-emission energy systems and climate-resilient development by identifying and addressing issues or sources of potential conflict. It can also help increase stakeholder engagement, bolstering the legitimacy and accountability of such developments. This, in turn, builds investors' (including climate funds') confidence that the project is managing risks and maximising opportunities. The analysis can provide hydropower developers with evidence of the project's transformational value by contrasting business-as-usual gCO_2e/kWh with the proposed development scenarios.

These assessments would help regulators, policymakers and project developers improve the overall configuration of hydropower projects to reduce methane and carbon dioxide emissions, manage hydrological risk and other environmental and social impacts, and maximise the resilience of energy and water systems. Given the longevity of hydropower infrastructure, getting these investments right is critical for enabling reliable and affordable energy in a grid with emissions below 50g CO_2e/kWh. Only robust analysis can help us assess development scenarios against the range of potential climate futures. By setting expectations for the rigour of these assessments and providing grant support for the assessment itself, climate funds would incentivise hydropower development fit for the future.

Climate funds therefore have a strong motive to incentivise better planning and assessment of the impact of hydropower within basins and to reduce the impact of changing basin environments on hydropower. Conducting such assessments will help hydropower projects better manage risks, enabling access to a broader range of public and private financing at a lower cost.

5.3 Increasing the performance of existing hydropower systems to meet climate objectives

Where hydropower is a major source of energy to the grid, or their reservoirs play vital roles in water management, there would be a legitimate case for climate funds to invest in rehabilitating these projects to achieve mitigation and resilience objectives. However, our analysis of hydropower project approvals or rejections suggests it is harder to make the case for rehabilitating and retrofitting existing hydropower plants.

Strengthening the resilience of hydropower reduces the vulnerability of the people who are served by its energy and water services. Funds rejected proposals for several reasons, including not explicitly explaining how they would manage the impacts of the increasing frequency and magnitude of extreme climatic events.

There is a strong case for investing in rehabilitating existing **business-as-usual hydropower** systems, updating them to offer transitional characteristics, such as a second reservoir or reversible turbines for **pumped-storage hydropower**. For example, to rapidly increase grid firming services with expanding wind and solar generation, Australia is retrofitting reservoir storage hydropower to pumped-hydropower designs and building new sites on disused mining pits.[74] It has invited bids for investment to fund the project in the most cost-effective way. Morocco's ONE Wind initiative (Annex 2) also invested in developing an existing reservoir scheme into pumped storage.

In working towards low-carbon futures, innovation in retrofitting infrastructure is as vital as new technologies. Upgrading existing systems will help strengthen climate resilience, and expanding the transition services required for clean grids will support the rapid **transformation** needed, helping to deliver a **paradigm shift**. Climate funds should therefore incentivise the rehabilitation of existing hydropower projects as well as look to invest in new technology.

5.4 Restructuring markets to reward transition services

Grid services such as **energy dispatch** (see Box 1), stabilisation and storage (Section 2.4) highlight how the flexibility of hydropower enables the transition to clean energy. In **unbundled** (see Box 1) energy markets like the UK and Germany, grid operators and utility companies pay for frequency regulation services, flexibility markets, and **black-start** services in several ways.[75,54] In India and China, although energy markets are vertically integrated, grid operators value energy storage and **grid stabilisation** services highly enough to encourage investment.[13] In most countries, however, it has still been challenging to attract private investment in these services.

Regulators and grid operators have used public finance to improve returns to private investors by underwriting hydropower project components as public goods. For example, public investment in the access road and transmission lines for the Tina River Hydropower Development Project (Annex 1) and a secondary reservoir for Morocco's ONE Wind Energy Plan (Annex 2) show how concessional public financing can enable private investments.

Energy markets evolve around opportunities for returns. **Pumped-storage hydropower** has used **arbitrage** – buying energy when excess generation means it is cheap and selling it expensively through spot markets – to generate revenues for their storage capabilities. This has created some interest in investing in these schemes; by 2016, the global pumped-storage generating capacity was 154GW.[76] However, the increased use of electric vehicles and demand management through smart grids could make this less viable, as these could allow electricity to be used when available. Rewarding ancillary grid services is not without its challenges, because they support grid performance rather than generate electricity as paid for by the consumer.

Some countries have developed capacity markets to offer payments for grid ancillary services. Capacity payments are when grid operators pay per MW rather than per MWh for specified services such as **fast frequency response** or **inertia**. Regulators in Ireland, for example, have identified and incorporated value and payments for grid service provision (see Section 2.4). And in Ghana, the electricity industry is **unbundled** into three main sub-sectors – electricity generation, transmission and distribution – to set up markets for grid services where the grid or transmission operators can buy them from generators in order to sell a stable supply of electricity to distributors.[77] Although experience in countries like the UK or Norway shows that payments are small compared to the revenue available from energy generated, there is an opportunity cost of not maximising energy generation.

There needs to be innovation in markets and in contracting to ensure that payments for ancillary services are commensurate with their value to the grid. Experience in early markets for ancillary services – such as the UK's capacity market – could be used to estimate the benefits of hydropower facilities to the grid to set payments for these services.[78] A BOOT based on capacity payments would incentivise energy storage for peaking or ancillary services. An alternative to BOOT is the finance-engineer-lease-and-transfer (FELT) model, where all project preparation is undertaken by a public sector agency who procures a developer to finance and build the project.[79] The developer then leases the facility back to the public sector body for a defined period, before transferring it to them as with BOOT. This rebalances political, regulatory and other risks between government and commercial actors, making it easier and cheaper to finance. It also delinks energy generation from payments, enabling hydropower to be designed and operated for maximum grid system benefit without disrupting revenue streams. Such schemes can maximise flexibility by using fast response to balance intermittency, **inertia** for **grid stabilisation**, storage for peaking and so on. This model would also enable retrofitting hydropower systems without requiring complex adjustments to contracts for storage expansion or a second reservoir for pumped storage.

Without these ancillary services, it is not possible to maximise the energy generated from wind and solar. So it is vital that we develop markets that make payments for hydropower as a facility that offers a range of services rather than purely for energy consumed. Climate funds can usefully support market innovations to enable the transition to low-carbon energy systems.

5.5 Reducing the cost of capital for transition hydropower

Creating the right financing incentives by combining the interests of public, private, national and international financial actors balances risks and creates incentives for providing flexible hydropower, which is critical for achieving **low-carbon grids**.[80] Energy regulators and grid operators have the mandate to develop the transition characteristics of hydropower. As large, high-risk infrastructure projects, they incur high capital costs for construction. So hydropower projects are often supported by large investors, including multilateral development banks and private developers. Combining investors helps balance the interests of public and private actors, and projects can consider social and environmental outcomes as much as financial returns.

Structuring the investment so that public finance pays for the public interest costs can be critical to creating a viable financing model where revenue streams are sufficiently attractive for private investors while tariffs are still affordable. Climate finance can play an important role in this regard. By underwriting the additional costs of hydropower projects with transition characteristics, it ensures that payments for energy generated and ancillary services are enough to repay private investors' capital.

Private capital is more expensive if the investment is considered risky. For the private investor, knowing the government is also tangibly involved as an investor can provide assurance on political risks being reduced. It also gives the government incentive to provide licenses or reform regulations in a timely manner. But additional risk insurance and guarantees also help encourage private investment at more reasonable costs. The Tina River Hydropower project public-private partnership (PPP) agreement, for example, is covered by an International Development Association (IDA) partial risk guarantee insurance cover and the Multilateral Investment Guarantee Agency's (MIGA) political risk insurance, which played a de-risking role in enabling the private capital investment.

5.6 Recommendations for climate funds

Table 3 summarises our recommendations for what climate funds can do to clarify the eligibility of hydropower projects for climate finance in the transition to a low-carbon future.

Table 3. Linkages between the recommendations and the climate finance criteria

CRITERIA	RECOMMENDATIONS FOR CLIMATE FUNDS
Analysing hydropower transition characteristics that address additionality, transformation and a paradigm shift	Develop clear and explicit fund criteria for hydropower, and set these out in a position paper for climate finance support to hydropower that enables the transition.
Sustainability of the energy system	Support basin assessments for strategic hydropower development. Increase the performance of existing hydropower to meet climate objectives.
Political risks and regulatory regimes	Invest in reforming market regulation. Invest in basin assessments and the strategic placement and design of hydropower to reduce risk to private investment in construction.
Value to energy markets	Reduce the capital costs for transition hydropower by subsidising public good components, enabling affordable tariffs under PPPs such as FELT, BOOT, build-lease-transfer (BLT) or other structural partnership arrangements. Quantify the market value of transition services to enable markets to be designed. Develop incentives for transition characteristics by clarifying the criteria for what climate finance will invest in, including the indicators for assessing transition characteristics. Support the development of policy, regulation, standards and markets for transition services.

Looking forward

6

Multilateral climate funds have the mandate to help finance the transition to a low-carbon future. Energy storage and ancillary services are critical to maximise the role of **intermittent renewables** on electricity grids. While battery development is starting to provide some energy storage, hydropower remains the single largest provider of bulk storage and the most cost-effective option.[13] It also offers the flexibility to provide most other grid services specified by energy regulators to date. But there are also recognised downsides, including high costs, long delivery times, potential social and environmental impacts, and the need to manage political and reputational risks for investors. The public sector can only build a fraction of the dams that will be needed to support renewables and achieve a 50g CO_2e/kWh grid; so the private sector will also need to play a role.

Climate funds have a role in helping countries understand what the transition looks like with varying degrees of different renewables – including hydropower – in their grids. They can incentivise countries to embrace the flexibility and storage that supports this transition by setting out clear criteria for investing in hydropower.

This review has identified that:

1. More specific guidance – including a need for a clearer position across climate finance institutions – would help climate finance investors support a rapid transition to low-carbon energy systems. Incentivising hydropower developers to maximise the transition characteristics is critical for expanding renewables on grids.
2. Hydropower developers need clear guidance on how to access climate finance. With better understanding, they will be able to respond to the criteria set by the different climate funds, which will help them find the right source of climate finance for their project's needs.
3. Further analysis is needed to inform energy market reforms in countries with different proportions of hydropower on the grid. This analysis should assess the challenges and options, based on the experiences of different energy markets that are experimenting with paying for the energy storage and ancillary services needed on grids with high levels of **intermittent renewables**. The pathway challenges facing a country with 10% hydropower and 90% thermal will be different from one with 70% hydropower and 30% thermal. The same goes for different levels of private-public energy mix. So, a case-by-case approach is essential. And given that most developing countries do not yet have reliable energy or universal access, the market analysis would also need to consider how to mobilise increased investment in the energy system to meet and manage demand and operate the grid system effectively.
4. Countries also need support to model the transition pathways to low-carbon energy systems over the long term. This will require identifying the core variables for modelling the resilience of hydropower, their carbon emissions and the volume of ancillary grid services and energy storage needed with different technology mixes. These modelling processes would help identify how far it would be possible to adjust the operating rules of existing hydropower to support renewables, how far retrofitting is possible and what new hydropower would be needed. As well as exploring what revenues would be needed to attract investors and hydropower operators to provide the flexibility in hydropower operations needed for the transition, countries would need to identify the level of public finance needed to make this attractive.

Hydropower can play a vital role in the transition to **low-carbon grids**, particularly in the absence of alternative cost-effective technologies to support **intermittent renewables** at scale. Concerns of environmental and social impacts – not least around the variability of reservoir emissions – have previously led to concerns around larger hydropower investment in the carbon market under Kyoto.[81] However, the critical role hydropower can play, coupled with significant recent advances in understanding and predicting carbon emissions from reservoirs, suggests that climate funds and carbon markets need to develop a more refined response to supporting hydropower under the Paris Agreement rules being negotiated.

Annexes

Annex 1: Solomon Islands' Tina River Hydropower Development Project case study

Key dates

Project proposal submitted:	2016
Approved for implementation:	early 2017
Implementation started:	July 2017
Expected financial closure:	June 2022

Capacity of hydropower facility: 15MW

Main actors:

Accredited entities:	International Bank for Reconstruction and Development and International Development Association (World Bank)
Executing entity:	Ministry of Finance and Treasury
Beneficiaries:	Ministry of Mines, Energy and Rural Electrification and the project company

Project characteristics:

The Tina River Hydropower Development Project is a scheme to build a 15MW hydropower facility, developed and operated under a 30-year concession that sells power to the Solomon Islands Electricity Authority (SIEA) under a long-term PPA. A key project objective is to contribute to replacing diesel-based power with hydropower energy using a PPP model.

The hydropower facility will be implemented on a BOOT basis by the project partner Korea Water Resources Corporation (K-Water), which was selected through a competitive bidding process managed by the International Finance Corporation. This will be the first utility-scale independent power producer in the Solomon Islands and its first PPP project. The US$216.1 million project represents 19% of GDP (at 2015 GDP of US$1.1 billion).

K-Water is the project's engineering, procurement and construction contractor. The project company is a partnership between K-Water and the Solomon Islands government (SIG). The project company and K-Water have entered a fixed-price turnkey contract, with the works supervised by the project company. K-Water holds 51% of the shares and SIG holds the other 49% through its state-owned investment vehicle, Investment Corporation of the Solomon Islands. The development is under a 34-year PPA concession (which includes a four-year design and construction period). SIEA is the off-taker for the PPA, under which the project company will own and operate the hydropower plant and sell the generated electricity to SIEA over the 30-year operation period. During this period, the project company is also required to train SIEA personnel in preparation for handing over the project. At the end of the concession period, the project company will transfer its shares and thus the power plant ownership to SIG. The company has entered into a government guarantee agreement and an implementation agreement with SIG.

The project has an estimated lifespan of 50 years. The accredited entity (the entity developing the funding proposal in close consultation with the national designated authority) is the World Bank. The national designated authority is the Ministry of Environment, Climate Change, Disaster Management and Meteorology. The executing entity is the Ministry of Finance and Treasury.

Project components

The project has four components, each with different financing sources, structures and its own outputs:

Component 1	15MW dam-tunnel hydropower plant: 77% of project financing.
Component 2	Access road to gain access to various sites during construction and for operating hydropower plant: 10.7% of project financing, ringfenced to be paid for by public (including GCF) financing.
Component 3	A transmission line: 9.8% of project financing, ring-fenced to be paid for by public financing.
Component 4	Technical assistance to support SIG activities during project implementation: 1.9% of project financing.

Table 4. Overview of financing actors and totals for the Tina River project

INSTITUTION NAME	INSTITUTION TYPE	FINANCIAL INSTRUMENT	AMOUNT (US$ MILLION)
GCF	Multilateral climate fund	Loan and grant	86.00
Korea Water Resources Corporation (K-Water) and Hyundai Engineering Corporation (HEC)	Private investor	Equity	25.29
SIG (using IDA credit)	National government	Equity	20.00
IDA	International financial institution	Loan and grant	13.60
Asian Development Bank	Multilateral development bank	Loan and grant	30.00
Economic Development Cooperation Fund, Government of South Korea	Bilateral financial institution	Loan	31.60
International Renewable Energy Agency (IRENA)/Abu Dhabi Fund for Development	Project facility fund	Loan	15.00
Government of Australia	Bilateral financing	Grant	11.00
SIEA	Counterpart financing		1.49
Total project financing			234.00

The GCF and other public sources are financing non-revenue-generating components — so, Components 2 and 3 — that hold public benefit. Financing these components was essential in enabling a PPA between the public (SIEA) and private (K-Water) bodies at an accessible rate: a 30-year levelised tariff of no more than US₵22/kWh.

The project is covered by an IDA partial risk guarantee and MIGA political risk cover. The IDA partial risk guarantee covers investors and their shareholders for the risk of a government (or government-owned entity) failing to perform its contractual obligations with respect to a private project. Eligible for the insurance are projects with private participation dependent on certain government contractual undertakings, such as the BOOT agreement reached in this project. This insurance helped attract private lenders by covering a range of sovereign or parastatal risks, as discussed in Section 4.3. MIGA provides political risk cover against war, expropriation, currency inconvertibility and breach of contract for the duration of the construction period. The MIGA insurance was paid for under the PPA tariff.

Table 5. Overview of the Tina River project in relation to the GCF's six investment criteria

GCF CRITERIA[82]	HOW DOES THE PROJECT MEET THE CRITERIA?
1. Impact potential. Potential to contribute to achieving the fund's objectives and results areas. For mitigation, this includes contributing to the shift to low-emission sustainable development pathways. For adaptation, it means contributing to increased climate-resilient sustainable development.	The hydropower plant will annually generate 78.35GW; that is 65% of the 120GWh demand projected for 2022, with a net GHG emission reduction of 49,500 tCO_2e/year and a total of 2.48 million tCO_2e over the project's 50-year life. The project's annual GHG emission reduction potential is more than two-and-a-half times higher than SIG's commitment in its intended nationally determined contribution to reduce emissions by 18,800 tCO_2e/year by 2025, and 60% higher than the target reduction of 31,125 tCO_2e/year by 2030 with appropriate international assistance. The project has the largest GHG emission reduction potential in the Solomon Islands.
2. Paradigm shift potential. Degree to which the proposed activity can catalyse impact beyond a one-off project or programme investment. This includes: potential for scaling up and replication, and overall contribution to global low-carbon development pathways being consistent with a temperature increase of less than 2°C; potential for knowledge and learning; contribution to creating an enabling environment; contribution to regulatory framework and policies; and overall contribution to climate-resilient development pathways that are consistent with a country's climate change adaptation strategies and plans.	The project facilitates a shift away from a 97% diesel system to a >65% renewable energy system. It is the first utility-scale hydropower plant and the first privately invested BOOT project in the Solomon Islands. It is also the first sizeable renewable energy development in a 97% diesel-generated system, with reservoir capacity that will provide flexibility to the power system to enable higher penetration of PV power without the need for large and expensive energy storage or diesel generators running at low efficiencies to respond to the intermittent PV output. By giving the Solomon Islands reservoir capacity, it also gives the power system the flexibility to enable higher penetration of PV power as an alternative to building energy storage batteries or diesel generators.
3. Sustainable development potential. Wider benefits and priorities, including: environmental co-benefits; social co-benefits; economic co-benefits; and gender-sensitive development impact.	The project will greatly increase access to a reliable electricity supply, doubling the number of households supplied by SIEA by 2021 and increasing the use of renewable energy. This will reduce the cost and volatility of a diesel-driven electricity tariff to stimulate household and business savings and investment. The Solomon Islands' retail electricity tariff is one of the world's highest – at US¢82/kWh for residential customers – due to the high cost of diesel. The project is expected to contribute to lowering the tariff, easing the significant cost burden to households and businesses and enabling SIEA to invest more in increasing the grid-connected electrification rate of 12%. Global oil prices are at historic lows, but the project will enable SIEA to lock in to a favourable PPA price for the 30-year concession period, which will significantly limit its exposure to global oil price fluctuations, providing households and businesses with more market stability.
4. Needs of the recipient. Beneficiary country and population's vulnerability and financing needs in terms of: the country's vulnerability; vulnerable groups and gender aspects; economic and social development of the country and the affected population; absence of alternative sources of financing; and need to strengthen institutions and implement capacity.	The funding is critical to removing barriers for financial viability to the project, both for the private investor and SIEA as the off-taker. The project needed maximum concessionality to be financially viable, largely due to high investment costs and the low cost of the diesel alternative forecast for the project life, which has been adjusted downwards due to recent low oil prices. The concessional funds from GCF and other co-financiers enable the project to meet private investors' return on equity while keeping the PPA tariff at levels that would allow SIEA to enter into a PPA.

GCF CRITERIA[82]	HOW DOES THE PROJECT MEET THE CRITERIA?
5. Country ownership. Beneficiary country ownership of, and capacity to implement, a funded project or programme. This covers the existence of policies, strategies and institutions, including: a national climate change strategy; coherence with existing policies; accredited entities; entities with capacity to deliver; and engagement with civil society organisations and other relevant stakeholders.	The project is being developed by SIEA, and they will have full ownership of the dam after the 34-year concession period, with handover training for staff. The project is in line with the country's climate goals and policies and the Ministry of Environment, Climate Change, Disaster Management and Meteorology. The national designated authority has issued its No Objection and is fully supportive of the project.
6. Efficiency and effectiveness. Economic and, if appropriate, financial soundness of the programme/project, including: cost-effectiveness and efficiency regarding financial and non-financial aspects; amount of co-financing; programme/project financial viability and other financial indicators; and industry best practices.	In terms of achieving the project's objectives of transitioning the country's energy system towards a low-emission sustainable development pathway and meeting – or overachieving on – mitigation targets, the project is efficient and effective. Assuming total project development costs of US$233.98 million, the emissions reduction per unit of investment over the project life of 50 years is 10.6 kgCO2e/US$. In terms of impact of the requested GCF financing of US$86 million (US$70 million loan plus US$16 million grant), the impact delivered is 28.8 kgCO2e per GCF dollar invested.

Sources: GIF (2018)[83] and GCF (2017)[7]

Annex 2: Morocco's ONE Wind Energy Plan case study

Key dates

Project proposal submitted: 2009

Approved for implementation: October 2011

Expected financial closure: 2020

Capacity of hydropower facility:

M'Dez el Menzel hydropower facility 170MW (cancelled); STEP Abeld Moumen facility (retrofitting an existing hydropower facility with pump storage): 350MW

Main actors:

Accredited entity: African Development Bank (AfDB)

Executing entity: Ministry of Energy, Mines, Water and the Environment

Project characteristics

Morocco's Wind Energy Plan is a key part of the nation's energy strategy implemented by the state-owned electricity utility Office National de l'Electricité (ONE). Developed by ONE in collaboration with the AfDB, since 2009, the plan has two key objectives: increasing Morocco's wind energy generation capacity from 1% in 2007 to 14% in 2020 and increasing access to electricity in rural areas from 93% in 2007 to 100% in 2020.

Morocco is promoting a PPP business model to develop wind farm power plants.

Project components

The project comprises two components, each with different financing sources, structures and outputs:

Component A: Wind energy generation system with hydro-storage and related transmission infrastructure, funded under a CTF concessional loan. The national government recognises the need to offset the irregularity of wind power with the consistency of hydroelectric power and create an integrated renewable energy generation system that helps make Morocco's electricity supply more reliable. ONE will design and be responsible for constructing transmission lines to evacuate the electricity produced from wind farms and the hydroelectric sites to the national grid.

Component B: Rural electrification (funded under an AfDB loan).

Table 6. Overview of financing actors and totals for the ONE project

COMPONENT	EQUITY (US$ MILLION)		DEBT COVERAGE (US$ MILLION)						TOTAL (US$ MILLION)
	ONE	Private	CTF AfDB	CTF World Bank	AfDB	EIB*	KfW**	Others	
Wind power									
Tanger II	8.93	26.76	30.73	0	62.57	24.70	24.40	0	178.09
Koudia el Baida	78.42	145.64	33.58	0	73.42	0	0	565.20	896.26
Djebel el Hadid	19.25	57.78	17.91	0	0	147.55	47.73	59.92	350.14
Midelt	13.50	40.53	12.80	0	11.12	99.82	99.82	0	277.59
Hydropower									
Abdelmoumen pumped power transfer station (STEP)	0	0	29.98	0	86.95	173.01	0	18.84	308.78
TOTAL	120.10	270.71	125.00	0	234.06	445.08	171.95	643.96	2,010.86

Notes: * European Investment Bank; ** *Kreditanstalt für Wiederaufbau*

Table 7. Overview of the ONE project in relation to the CTF's six investment criteria

CTF CRITERIA[84]	HOW DOES THE PROJECT MEET THE CRITERIA?
1. Potential for GHG emissions saving at country, regional or sub-regional levels. Priority is on the deployment, diffusion and transfer of low-carbon technologies that are at, or approaching, market take-off phase and in sectors that make major contributions to GHG emissions that are technically viable, commercially available and have strong mitigation potential.	The project calculated emissions reductions of 21 tCO_2 per year by 2020. The ancillary services the hydropower component will provide are essential to supporting the grid's extra wind power capacity. The wind technologies represent low-carbon technologies that are approaching market take-off phase.
2. Cost-effectiveness. This is based on a calculation of the CTF investment per tCO_2e reduced. It will also require an analysis of the expected reduction in technology costs due to technological progress and scale effect at a global level, and/or through organisational learning and scale effects at country level.	The CTF investment of US$125 million will leverage around US$2.2 billion – this is a leverage factor of around 17. The initiative also stimulates private sector investments through PPPs and independent power producers.
3. Demonstration potential at scale. CTF aims to support transformational investments at scale through thematic programmes and large-scale projects, at sector or sub-sector level, in a given country, sub-nationally or regionally. On this basis, the CTF assesses the potential for significant reductions in GHG emissions growth as a result of the broader demonstration, deployment and transfer of low-carbon technologies. It also assesses the **transformation** potential, or the ability to demonstrate that the project/programme constitutes a strategic effort to stimulate lasting changes in the structure or function of a sub-sector, sector or market.	The initiative supports the building of agency credibility for PPPs. Developing a transmission network will signal to private investors that wind energy is viable and that the national government is committed to developing it. Further wind power development is constrained by the lack of a dedicated transmission network, which needs public financing. Without CTF financing, this infrastructure development could be delayed by years. The project is also a good example of maintaining grid stability while increasing wind penetration – a model that can provide replicable lessons in other countries.
4. Development impact. Demonstrating the potential for low-carbon technologies to contribute to sustainable development and achieving the SDGs through: potential efficiency gains, measured by the projected reductions GDP energy intensity; accelerated access to affordable, modern energy or transport services for the poorest; environmental co-benefits from reducing air pollutants from energy-related activities; contaminant discharges in liquid effluents from energy systems; and addressing the major impacts of pollutants on health and the environment.	It contributes to energy security by building a reliable energy supply at affordable rates. The initiative aims to increase the number of households connected to the grid from 1.7 million in 2007 to 2.3 million in 2020 (an addition of 533,000 households). Estimates indicate that the wind generation component will create about 4,500 full-time jobs.
5. Implementation potential. Public policies and institutions should support deployment, diffusion and transfer of low-carbon technologies, demonstrated through: country and sector strategies that address key policy, institutional and other issues relevant to achieving sector objectives; making institutional and implementation arrangements to identify institutions responsible for implementation that either have the capacity to support technology adoption or can develop the capacity needed in the short term; evidence of commitment to and ownership of the project and relevant policies, and arrangements for long-term operations and maintenance to ensure sustainability. Based on the co-financing mobilised from domestic public and private sector sources.	The initiative strengthens government capabilities for supporting PPPs and independent power producers. It also supports national objectives by reducing Morocco's dependence on imports, promoting national expertise, developing technological know-how and protecting the environment by mitigating climate change, expanding energy access and supplying Moroccan households and businesses with a reliable energy source. The projected annual cost savings of replacing fossil fuel imports with indigenously produced and stored wind energy is US$1.25 billion. These annual savings will significantly improve macroeconomic stability.

CTF CRITERIA[84]	HOW DOES THE PROJECT MEET THE CRITERIA?
6. Additional costs and risk premium. Each project/programme needs to identify the rate of return of investment on account of reduced GHG emissions and outline how the grant element of CTF financing covers such additional costs of risk premium. CTF will consider a project/programme for co-financing in any of the following scenarios of financial viability based on rate of return without CTF concessional resources: negative rate of return; rate of return below normal market threshold; rate of return above normal market threshold but below risk premium for project type, technology, sector or country; and rate of return above normal market threshold but where accelerating low-carbon investments has higher opportunity costs.	The initiative is underwriting transmission and storage costs to ensure viable returns for private investors. Wind farms, their hydro-storage and related transmission are being subsidised with soft financing. CTF and AfDB financing enable the components to achieve the required rate of return for the private sector, allowing for financial closure of the public-private projects. Subsidising transmission, storage and enabling ONE to be a credible partner in the public-private structure decreases the cost of clean energy, which leads to greater interest from the private sector.

Sources: African Development Bank (2011)[6]; CTF (2016)[59]

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Climate funds should facilitate the transition to a low-carbon and climate-resilient future. Energy storage and ancillary grid services are critical to expanding the proportion of intermittent renewable generation on the electricity grid. Hydropower remains the largest and most cost-effective provider of bulk energy storage, offering the flexibility to provide most other recognised grid services. While *sustainable hydropower* may not broadly meet climate finance criteria, hydropower projects with the necessary characteristics for transition do meet these objectives and should attract climate finance support. Meanwhile, concerns about the social and ecological integrity of hydropower, such as the impact it may have on local communities, provide more reasons for climate finance to incentivise hydropower designs that are socially, environmentally and technically appropriate for future conditions, supporting the shift to accessible, affordable, clean, distributed smart grids.

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