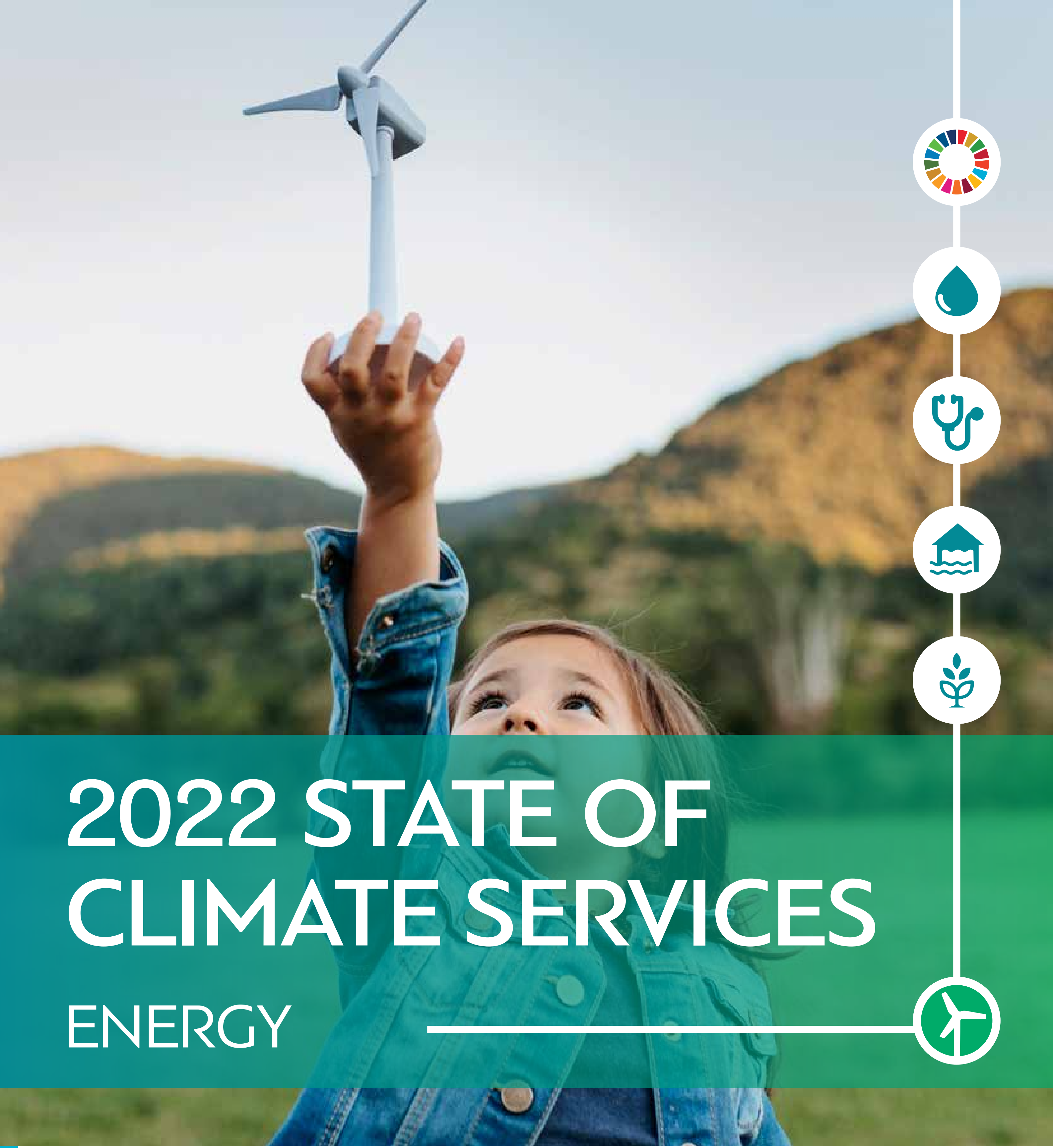

2022 STATE OF CLIMATE SERVICES

ENERGY

WEATHER CLIMATE WATER

WORLD METEOROLOGICAL ORGANIZATION

GFCS
GLOBAL FRAMEWORK FOR CLIMATE SERVICES

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WMO has issued annual reports on the state of climate services since 2019 in order to provide scientifically-based information to support climate adaptation and mitigation.

This 2022 edition of the WMO State of Climate Services report focuses on the issue of energy, a subject that continues to dominate discussion and debate as it affects every single community, business, sector and economic sector, in all parts of the world.

Energy is at the very heart of our response to the 2030 Agenda for Sustainable Development and the Paris Agreement on climate change. Given that the energy sector contributes around three quarters of global greenhouse gas emissions, switching to clean forms of energy generation, such as solar, wind and hydropower – and improving energy efficiency – is absolutely vital if we are to thrive in the twenty-first century. Net zero is the aim. But we will only get there if we double the supply of low-emissions electricity within the next eight years.

As we highlight in this report, weather, water and climate services will be increasingly important as the world transitions to net zero. As we explore – through data, analysis and a series of case studies – countries are able to improve their energy infrastructure, resilience and security through better climate services – supported by sustainable investments. Early weather warnings are safeguarding energy supply in Beijing, China. Climate stress tests are ensuring electricity is suitably distributed in the Italian Dolomites. Warning systems in Tajikistan are providing advance notice of dry conditions for hydropower operations planning.

But there are huge opportunities to go further and faster, investing in climate services to scale up our resilience to climate change, increase clean energy generation and safeguard a sustainable future.

Time is not on our side and our climate is changing before our eyes. Sustainable energy security and reaching net zero by 2050 will mean a complete transformation of the global energy system – and weather, water and climate services will play a crucial role.

Prof. Petteri Taalas,
Secretary-General,
WMO

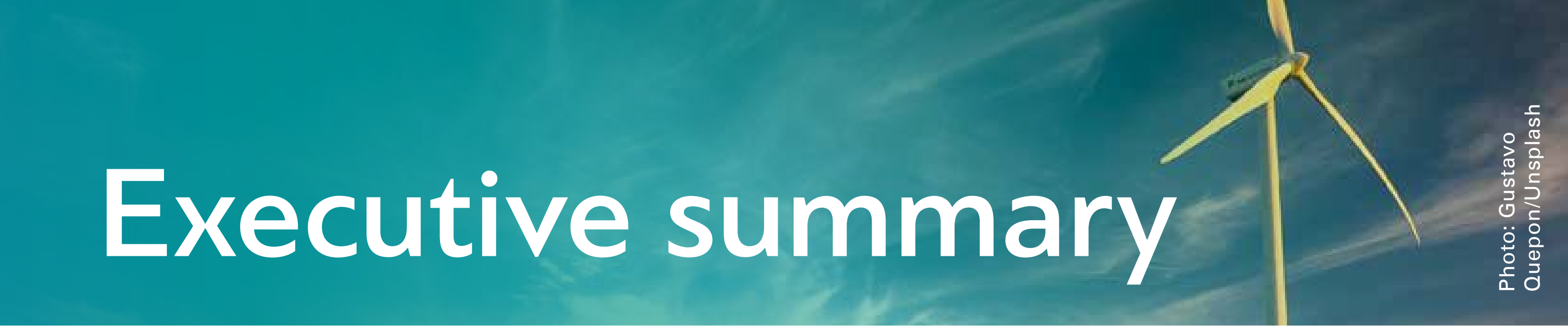

Photo: Gustavo Quepon/Unsplash

Executive summary

The past seven years have been the warmest on record.[1] According to the Intergovernmental Panel on Climate Change (IPCC), human-induced climate change is causing dangerous and widespread disruption in nature and affecting the lives of billions of people around the world.[2]

There is now consensus that without immediate and strong reductions in greenhouse gas (GHG) emissions, limiting global warming to 2 °C is beyond reach. As it accounts for almost three quarters of global GHG emissions, major transitions are required in the energy sector.[3]

Energy is at the heart of the challenges of achieving both the 2030 Agenda for Sustainable Development and the Paris Agreement on climate change. Renewable energy sources and energy efficiency play a key role in providing energy services in a sustainable manner and, in particular, in mitigating against and adapting to climate change.[4]

CLIMATE CHANGE IS PUTTING ENERGY SECURITY AT RISK GLOBALLY

In the midst of the race to net zero emissions (NZE), the impact of global temperature increase continues to raise concerns about energy security. Changes in climate pose significant risks to the energy sector, directly affecting fuel supply, energy production, physical resilience of current and future energy infrastructure, and energy demand.[5] Heatwaves and droughts associated with anthropogenic climate change are already putting existing energy generation under stress, making the net zero transition even more urgent.[6]

In 2020, 87% of global electricity generated from thermal, nuclear and hydroelectric systems directly depended on water availability.[7] Meanwhile, 33% of the thermal power plants that rely on freshwater availability for cooling are already located in high water stress areas.[8] This is also the case for 15% of existing nuclear power plants, a share expected to increase to 25% in the next 20 years.[9] Eleven per cent of hydroelectric capacity is also located in highly water-stressed areas.[10] And approximately 26% of existing hydropower dams and 23% of projected dams are within river basins that currently have a medium to very high risk of water scarcity.[11]

Most countries are likely to experience more frequent or intense extreme weather, water and climate events. This also affects nuclear power plants, which not only depend on water for cooling but are also often located in low-lying coastal areas and hence are vulnerable to sea-level rise and weather-related flooding. For example, the Turkey Point nuclear plant in Florida (United States of America), which sits right at sea level, will be threatened in the coming decades. In January 2022, massive power outages caused by a historic heatwave in Buenos Aires, Argentina affected around 700 000 people. In November 2020, freezing rain coated power lines in the Far East of the Russian Federation, leaving hundreds of thousands of homes without electricity for several days.

Despite these risks, energy security is a low priority for adaptation. Just 40% of nationally determined contributions (NDCs) submitted by Parties to the United Nations Framework Convention on Climate Change (UNFCCC) prioritize adaptation in the energy sector. The lack of recognition of the importance of climate services has led to a lack of demand and finance. Climate adaptation-focused investments in the energy sector remain very low, at just over US$ 300 million, tracked per year in 2019–2020.[12]

RENEWABLE ENERGY WILL CONTRIBUTE TO A SUSTAINABLE FUTURE

All countries should be making a concerted effort to transition to low-carbon energy. The energy sector is the largest source of GHG emissions, accounting for almost three quarters of global emissions.[13] In 2020, CO_2 concentrations reached 149% of pre-industrial levels.[14]

Supply from low-emissions sources needs to double by 2030 if the world is to reach net zero by 2050, according to the International Energy Agency (IEA).[15] Total energy supply will fall by around 7%, and around 50% (up to 65%)[16] of total energy supply will come from low-emissions energy sources by 2030, presenting significant growth from the current level of around 25%, according to IEA.[17]

1 2021 one of the seven warmest years on record, WMO consolidated data shows
2 IPCC AR6 Working Group II press release
3 Global Energy Review: CO_2 Emissions in 2021
4 Renewable Energy and Climate Change
5 Climate Resilience
6 IAEA, *Climate Change and Nuclear Power, Securing Clean Energy for Climate Resilience* (in press)
7 Climate Resilience
8 World Energy Outlook 2021
9 World Energy Outlook 2021
10 Water Stress Threatens Nearly Half the World's Thermal Power Plant Capacity
11 Using the WWF Water Risk Filter to Screen Existing and Projected Hydropower Projects for Climate and Biodiversity Risks
12 Global Landscape of Climate Finance 2021
13 Global Energy Review: CO_2 Emissions in 2021
14 WMO Greenhouse Gas Bulletin, No. 17
15 Net Zero by 2050: A Roadmap for the Global Energy Sector
16 World Energy Transitions Outlook
17 COP26 climate pledges could help limit global warming to 1.8 °C, but implementing them will be the key

The transition is all the more important when considering the water–energy nexus. The total life cycle water used to generate electricity by solar and wind is substantially lower than for more traditional technologies, such as thermoelectric power plants, either fossil-fuel- or nuclear-based.[18] A transition to renewable energy therefore constitutes an essential contribution to alleviating growing global water stresses.

Current pledges made by countries fall well short of what is needed to meet the objectives set by the Paris Agreement – limiting global warming to well below 2 °C – leaving a 70% gap in the amount of emissions reductions needed by 2030.[19] The 3.7 TW from renewables in 2030 pledged in the 56% of NDCs with quantified renewable power targets, if implemented, represent less than half of what is needed to keep the 2 °C goal alive. The pathway to reach the Paris Agreement long-term global goal on temperature requires 7.1 TW of clean energy capacity to be installed by 2030.[20]

The necessary policies and regulations to enable decarbonization in the energy sector are still particularly weak in Africa, South America and Asia, according to the World Bank.[21] And the recognition of the need for services to support renewable energy is particularly low – just 6% of NDCs mention climate services for energy for mitigation.

WEATHER, WATER AND CLIMATE SERVICES ARE CRUCIAL FOR ENERGY SECURITY AND THE GLOBAL ENERGY TRANSITION TO ACHIEVE NET ZERO

Renewable energy systems are weather and climate dependent, so the transition to clean energy calls for improved climate information and services for the energy sector.

Climate services are needed to ensure the resilience of energy systems to climate-related shocks and to inform measures to increase energy efficiency. Risk assessments addressing planning and early warning of adverse events affecting energy supply and demand can help populations to anticipate, absorb, accommodate and recover from adverse impacts. For example, early weather warnings can safeguard energy supply in Beijing (China), climate stress tests can ensure effective electricity distribution in the Dolomites region of Italy, and severe weather warnings can protect offshore wind power production in China.

Climate services are also essential for renewable energy, including for: site selection, resource assessment and financing; operations, maintenance and management of energy systems; electricity integration into the grid; and impact assessment of energy systems. For example, climate services are providing warnings ahead of dry conditions for hydropower operations planning in Tajikistan; localized wind-resource information is aiding full-value-chain wind industry decision-making; and climate services are supporting the placement of solar panels on noise barriers in Germany.

Seventy-nine per cent of WMO Members provide climate services for energy, including some particularly notable examples. However, less than 50% of Members provide tailored products for the energy sector, which shows the untapped potential of National Meteorological and Hydrological Services (NMHSs) and the efforts required to address the emerging needs of this sector.

Specialized services for renewable energy are sub-optimal. Just 25 Members maintain a dedicated observing network for energy services, and only 18 Members have access to observational or simulated data on energy from other national public, private and/or academic sector entities.

Existing climate services for energy systems need to be expanded, and climate services for the energy system transition, in particular, need strengthening.

INVESTMENTS IN RENEWABLE ENERGY NEED TO TRIPLE BY 2050, INCLUDING FOR CLIMATE SERVICES FOR ENERGY

The radical transformation of the global energy system requires a significant increase in annual investment in energy from just over US$ 2 trillion globally to almost US$ 5 trillion by 2030.[22] Current levels of investment in renewable energy need to at least triple to put the world on a net zero trajectory by 2050, according to the Climate Policy Initiative (CPI), including for climate services. In 2019–2020, the majority of renewable energy investments were made in the East Asia and Pacific region (mainly China and Japan), followed by Western Europe, and North America, mainly the United States and Canada, according to CPI. According to the International Renewable Energy Agency (IRENA) and CPI, developing and emerging economies continue to remain underrepresented when it comes to accessing clean energy finance. Further, only 2% of such investment in the last two decades was made in Africa.[23]

International public financial flows to developing countries in support of clean energy decreased in 2019 for the second year in a row, falling to US$ 10.9 billion. This level of support was 23% lower than the US$ 14.2 billion provided in 2018, 25% lower than the 2010–2019 average, and less than half of the peak of US$ 24.7 billion in 2017.[24]

18 Life Cycle Water Use for Electricity Generation: A Review and Harmonization of Literature Estimates
19 COP26 climate pledges could help limit global warming to 1.8 °C, but implementing them will be the key
20 IRENA, based on analysis of NDCs.
21 Regulatory Indicators for Sustainable Energy
22 World Energy Outlook 2021
23 Renewable Energy Market Analysis: Africa and its Regions
24 SDG7 2022 report

THERE IS A HUGE OPPORTUNITY FOR AFRICA TO HELP CLOSE THE GAP IN THE NEED FOR RENEWABLE ENERGY

Africa is already facing severe effects from climate change, including massive droughts, despite bearing the least responsibility for the problem. Africa accounts for less than 3% of the world's energy-related CO_2 emissions to date and has the lowest emissions per capita of any region. Global ambitions for cutting emissions with declining clean technology costs hold new promise for Africa's future, with increasing flows of climate finance. Achieving Africa's energy and climate goals means more than doubling energy investment this decade, with a huge increase in adaptation as well.[25]

African countries host the lowest percentage of modern renewable systems (just 7.6% of final energy consumption),[26] and only 2% of global investments in renewable energy in the last two decades were made in Africa.[27] Yet, the continent has a huge resource potential, particularly for solar[28] energy systems, but also wind[29] and hydropower.[30] The region has huge potential to deploy solar energy systems: Africa is home to 60% of the best solar resources globally, yet only 1% of installed photovoltaic (PV) capacity.[31]

According to IEA, bringing access to modern energy for all Africans calls for investment of US$ 25 billion per year, which is around 1% of global energy investment today.[32]

By 2050, global electricity needs will mainly be met with renewable energy, with solar the single largest source of supply (in terms of installed capacity), according to IEA's Net Zero Emissions by 2050 Scenario (NZE).[33] African countries have an opportunity to be major players within the market.

ENERGY POLICIES AND COMMITMENTS NEED TO BETTER ADDRESS ENERGY SECURITY IN A CHANGING CLIMATE AND PROMOTE THE TRANSITION TO NET ZERO, INCLUDING BY SCALING UP CLIMATE SERVICES

More effective climate services will not only contribute to creating attractive market conditions to scale up renewable energy infrastructure, but they will also promote clean energy system efficiency and climate resilience. Increased, sustained investments in such services, supported by recognition of the need for such services through enhanced policies, are required to achieve this.

25 Africa Energy Outlook 2022
26 SEforALL Analysis of SDG7 Progress - 2021
27 Renewable Energy Market Analysis: Africa and its Regions
28 IRENA estimates the continent's solar technical potential at 7 900 GW (assuming a 1% land-utilization factor), indicating vast potential for the generation of solar power.
29 IRENA estimates the technical potential of wind power generation in Africa at an immense 461 GW (assuming a 1% land-utilization factor), with Algeria, Ethiopia, Namibia and Mauritania possessing the greatest potential.
30 The Delft University of Technology estimates the continent's unexploited hydropower potential to be 1 753 GW (Global Potential Hydropower Locations), with Angola, the Democratic Republic of the Congo, Ethiopia, Madagascar, Mozambique and Zambia leading.
31 Africa Energy Outlook 2022
32 Africa Energy Outlook 2022
33 Net Zero Emissions by 2050 Scenario (NZE)

Photo: Firmbee.com/ Unsplash

Data and methods

WMO collects data from its Members based on a framework developed by WMO inter-governmentally appointed experts. The present report assesses the progress of WMO Member NMHSs in providing climate services for adaptation and mitigation in the energy sector based on data[34] currently available for 164 (85%) WMO Members, including 89% of the world's least developed countries (LDCs) and 56% of small island developing States (SIDS) as of May 2022. In addition, data from 87 WMO Members based on a survey of NMHSs conducted by the WMO Commission for Weather, Climate, Water and Related Environmental Services and Applications (Services Commission) are analysed in the Priorities and needs section. The results presented in the present report reflect the profiles of the countries which have provided these data.

The analysis of climate policy priorities is based on NDCs submitted to date (194 as of March 2022). The analysis is further complemented by the UNFCCC synthesis reports and IRENA NDC reports.

The data for United Nations Sustainable Development Goal 7 (SDG 7) are from the World Bank, IEA, IRENA, the United Nations Statistics Division (UNSD) and the World Health Organization (WHO). The solar and wind resource maps are from the Energy Sector Management Assistance Program (ESMAP).[35] Data on private sector delivery of climate services for the energy sector are from the World Energy & Meteorology Council (WEMC). The Investment section of the report presents information from the Green Climate Fund (GCF), Adaptation Fund (AF), French Development Agency (AFD), Climate Policy Initiative (CPI) and Global Environment Facility (GEF).

Case studies provided by partners highlight how climate information services and early warnings contribute to improved climate-related energy sector outcomes. Each case study highlights successful approaches to achieving socioeconomic benefits through climate services for the energy sector at the national, regional or global level. Some of the included case studies were supported by research by students from the Graduate Institute of International and Development Studies. The research focused on collecting data on the socioeconomic benefits of climate services for energy, through the collection of information via desktop review and structured calls with service providers and users.

34 WMO Climate Services Dashboard
35 Global Solar Atlas and Global Wind Atlas

Value

Photo: Rawfilm/ Unsplash

Energy systems are the driving force for economic and social development, and associated investments can represent a sizeable portion of a country's GDP

Energy is essential to all aspects of human welfare, including access to water, agricultural productivity, health care, education, job creation and environmental sustainability. GHGs, such as carbon dioxide (CO_2) methane (CH_4) and nitrous oxide (N_2O) from the energy sector, however, account for the largest share of global anthropogenic GHG emissions.

Emission reduction targets under UNFCCC are expected to significantly increase demand for energy from renewable sources, which, in turn, are highly sensitive to climate, as well as to lead to requirements for energy-efficiency measures.

Energy-sector planning and operations are markedly affected by weather and climate variability and change. With an ever-growing annual global energy demand – which saw an increase of about 30% in the past ten years – expanding energy systems are increasingly exposed to the vagaries of weather and climate. Electrical distribution and transmission systems, including for traditional energy sources, are also severely affected by extreme weather, water and climate events. Improved decision-making that considers weather and climate information can considerably increase the resilience of energy systems.

The power sector routinely uses weather forecasts up to 15 days.[36] Beyond this time horizon, climatological data (water and climate variables typically covering a longer reference period) are commonly used. Relying on climatology assumes that future conditions will be similar to past conditions. Because climate change invalidates this assumption, the energy sector is witnessing the use of increasingly sophisticated climate services applications, according to Barcelona Supercomputing Center.

In these new normal operating conditions, companies such as ENEL[37] are developing holistic scenarios which take into account traditional industrial and economic considerations and factor in future trends in climate variables based on the use of multiple regional climate models. Such climate services can help to support increased development and use of renewable energy sources distributed efficiently by smart resilient grids.[38]

The development and application of targeted climate products and services through the Global Framework for Climate Services can support both adaptation and mitigation:

➔ **Adaptation:**

- Greater climate resilience and adaptation across the sector, due to its fundamental importance for economic and social development.

➔ **Mitigation:**

- Efficiency and reduction of energy consumption with consequent emissions reduction in support of mitigation targets;
- Support for the growing renewables subsector, given the apparent climate sensitivity of renewables on the one hand and the policy priority afforded to them due to their GHG emissions reduction benefits on the other.[39]

In the energy sector, studies have demonstrated the value of very short-term, sub-seasonal and seasonal forecasts (e.g. for temperature, wind speed, stream flow) for fuel purchasing decisions, demand and generation forecasting, and system planning. Temperature forecasts allow managers to forecast peak loads more accurately and optimally schedule power generation plants to meet demands at a lower cost.[40] Hydropower operations benefit from daily, weekly and seasonal precipitation and streamflow forecasts, which can help to optimize operations.

For example, the use of streamflow forecasts increases energy production from major Columbia River (United States) hydropower dams by 5.5 TWh/year, resulting in an average increase in annual revenue of approximately US$ 153 million per year.[41] Similarly, the use of forecasts to manage hydropower operations in Ethiopia produces cumulative decadal benefits ranging from US$ 1 to US$ 6.5 billion, compared to a climatological (no forecast) approach.[42] In another example, the use of an El Nino Southern Oscillation (ENSO) forecast by a heating plant manager resulted in more than US$ 500 000 in savings in natural gas purchases over the course of the 1997/1998 northern hemisphere winter season (based on predictions of a warm winter, the plant manager chose to purchase natural gas on the spot market, rather than lock in a price).[43]

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36 Practices, Needs and Impediments in the Use of Weather/Climate Information in the Electricity Sector
37 Enel Integrated Annual Report 2021
38 Energy Exemplar to the User Interface Platform of the Global Framework for Climate Services
39 Energy Exemplar to the User Interface Platform of the Global Framework for Climate Services
40 Weiher, R.; Houston, L.; Adams, R. *Socio-economic Benefits of Climatological Services* (Draft). United States of America Contribution to the Update of WMO No. 424; National Oceanic and Atmospheric Administration and Oregon State University, 2005.
41 Economic Value of Long-lead Streamflow Forecasts for Columbia River Hydropower
42 Tailoring Seasonal Climate Forecasts for Hydropower Operations
43 Interactions with a Weather-sensitive Decision Maker

What are climate services for energy?

Climate services rely on the production and delivery of relevant, credible and usable climate information. The energy industry has extensive experience using weather services but less experience with climate services,[44] the latter being a more recent endeavour. However, in the context of the changing climate and the energy transition, new approaches based on climate information are required. As energy systems become increasingly dependent on weather variations, it is apparent that the information flow from weather and climate data and forecasts needs to be properly incorporated into the decision support systems (Figure 1).

From the perspective of an energy sector user (e.g. grid operator), several areas benefit from weather and climate services (see also Figure 1):

- Characterization of past weather/climate events using **historical data**. This is perhaps the most important element, as it provides a baseline, or first-order approximation, of the current risks and opportunities, and thus it is key to managing energy production and distribution at present (especially considering the increasing fraction of renewables in the energy mix and the changing patterns in energy consumption).
- **Nowcasting/short-term weather forecasts** for load balancing by maximizing the usable component of the generated power (e.g. by optimizing power generation both temporally and spatially or by reducing curtailment through use of dynamic line rating).
- **Sub-seasonal to seasonal climate forecasting** for maintenance of infrastructure and resource and risk management purposes (e.g. to ensure sufficient water reserves are available for hydropower production).
- **Decadal climate forecasting**[45] for multi-year resource risk management. These forecasts effectively extend the seasonal forecast range, typically to ten years ahead, thus allowing a longer risk assessment horizon.
- **Multi-decadal climate projections** for infrastructure risk assessment, planning and design purposes. This includes providing authoritative data on possible evolution of climate considering different emission scenarios, including those aligned with policies. Projections related to policy targets are naturally critical as they inform planning and support system design including understanding the implications of unlikely but impactful events.[46]

EXAMPLES OF APPLICATIONS OF CLIMATE SERVICES FOR ENERGY INCLUDE:

- Planning purchases of gas and electric power;
- Managing responses in emergency situations;
- Managing capacity and resources (e.g. grid/ distribution management, electricity production/ pricing);
- Optimizing renewable power plant operation, especially reservoirs and hydropower operations;
- Commercial/residential consumption decisions.[46]

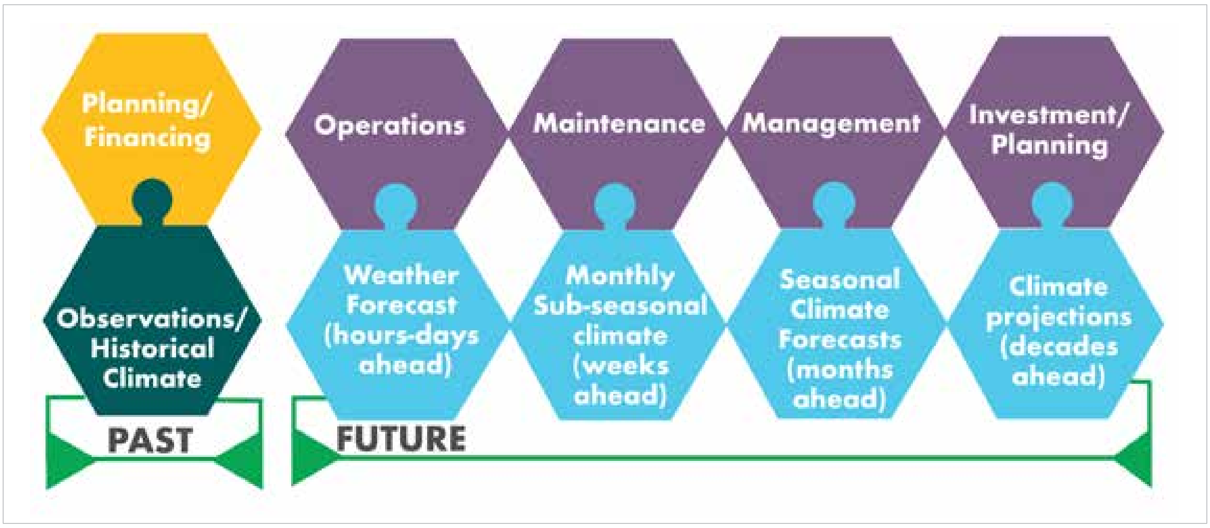


Figure 1: Past and future weather and climate data (lower row) and their typical use in the energy sector (top row)
Source: WMO Best Practices for Integrated Weather and Climate Services in Support to Net Zero Energy Transition (in press)

44 Specifically in terms of forecasting from a month ahead and beyond.
45 These are the most recent scientific development in terms of forecasting. They differ from (multi-decadal) climate projections mainly in terms of the way the initial conditions of the climate are defined, with decadal forecasting starting from a better description of the state of the climate.
46 The Value of Climate Services across Economic and Public Sectors

Photo: NASA/Unsplash

Global status

Climate change is putting energy security at risk globally

In the midst of the race to NZE, the impact of rising atmospheric GHG concentrations and accompanying changes in other indicators, such as global temperature, change in extremes (frequency, duration, intensity), precipitation, sea level and glacier mass balance, continues to raise concerns about energy security. Climate changes pose significant challenges to the energy sector, directly affecting fuel supply, electricity generation, energy infrastructure and energy demand, according to IEA.

In 2020, 87% of global electricity generated from thermal, nuclear and hydroelectric systems directly depended on water availability.[47] Meanwhile, 33% of the thermal power plants that rely on freshwater availability for cooling are already located in high water stress areas.[48] This is also the case for 15% of existing nuclear power plants, a share expected to increase to 25% in the next 20 years (Figures 2 and 3).[49] Eleven per cent of hydroelectric capacity is also located in highly water-stressed areas.[50] And approximately 26% of existing hydropower dams and 23% of projected dams are within river basins that currently have a medium to very high risk of water scarcity.[51] Nuclear power plants not only depend on water for cooling but are also often located in low-lying coastal areas and hence are vulnerable to sea-level rise and weather-related flooding.[52]

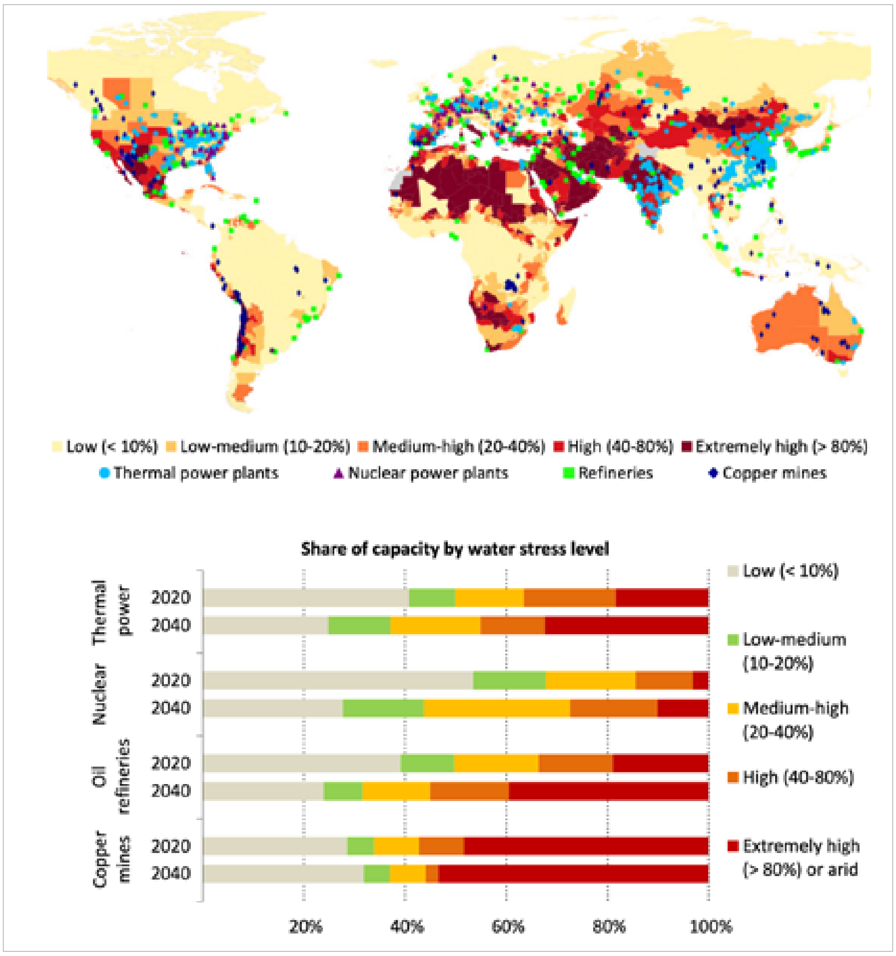


Figure 2: Location of selected energy-related infrastructure and water stress levels, 2020
Source: World Energy Outlook 2021; IEA analysis based on WRI Aqueduct 3.0 (2019) and S&P Global (2021)

47 IAEA, *Climate Change and Nuclear Power, Securing Clean Energy for Climate Resilience* (in press)
48 World Energy Outlook 2021
49 World Energy Outlook 2021
50 Water Stress Threatens Nearly Half the World's Thermal Power Plant Capacity
51 Using the WWF Water Risk Filter to Screen Existing and Projected Hydropower Projects for Climate and Biodiversity Risks
52 IAEA, *Climate Change and Nuclear Power, Securing Clean Energy for Climate Resilience* (in press)

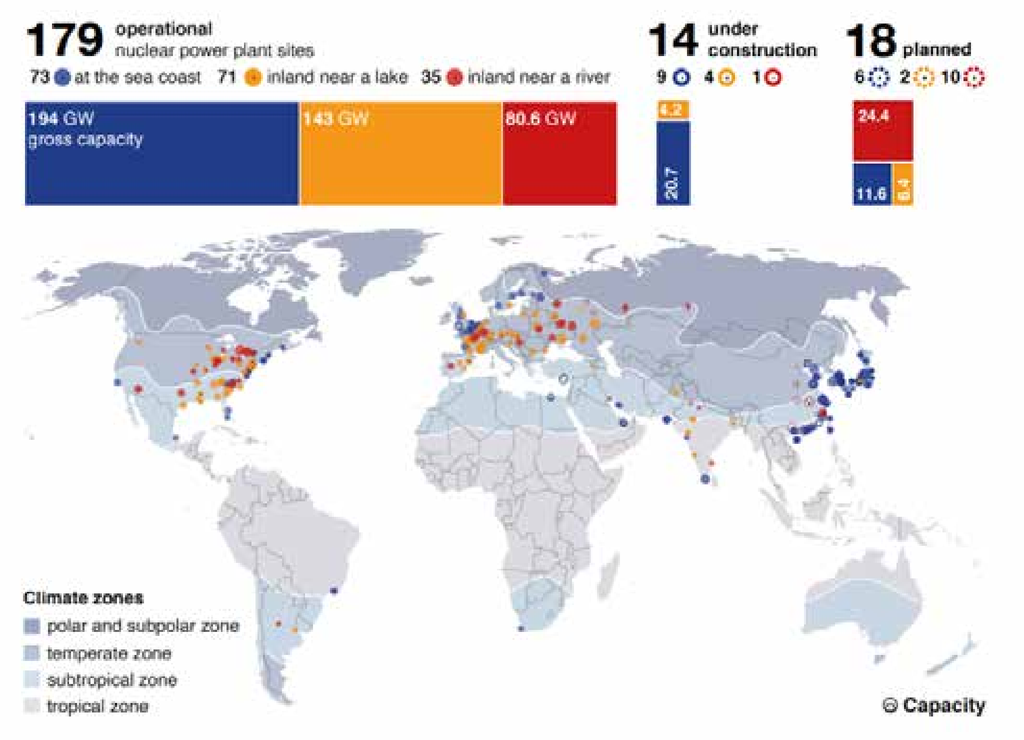


Figure 3: Location of existing nuclear sites, as well as those under construction and planned

Source: International Atomic Energy Agency (IAEA) analysis based on data from IAEA Power Reactor Information System (PRIS) database.

Note: the contours of climatic zones are indicative; their borders are likely to evolve with the changing global climate.

Most countries are likely to experience more frequent or intense extreme weather, water and climate events. For example, Turkey Point nuclear plant in Florida (United States), which sits right at sea level, will be threatened in the coming decades. In January 2022, massive power outages caused by a historic heatwave in Buenos Aires, Argentina affected around 700 000 people. In November 2020, freezing rain coated power lines in the Far East of the Russian Federation, leaving hundreds of thousands of homes without electricity for several days (Figure 4).

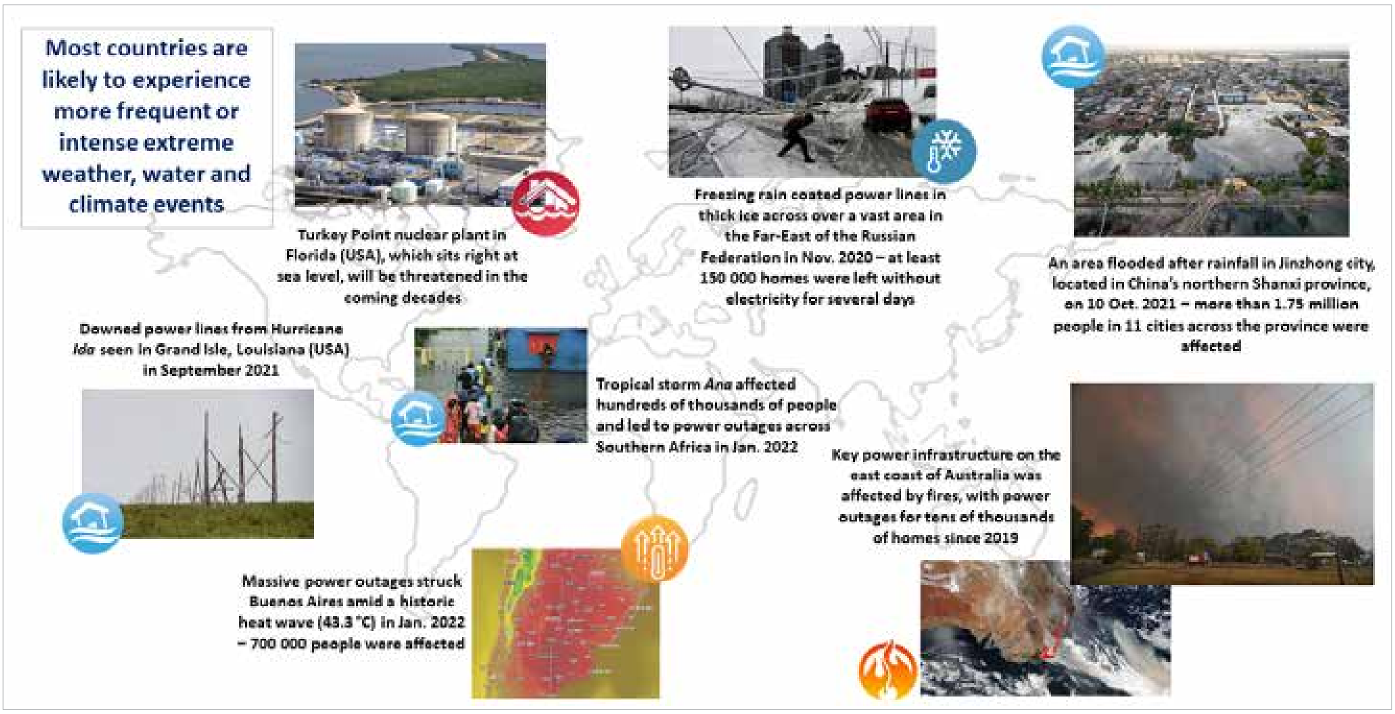


Figure 4: Impacts of extreme events on energy infrastructure

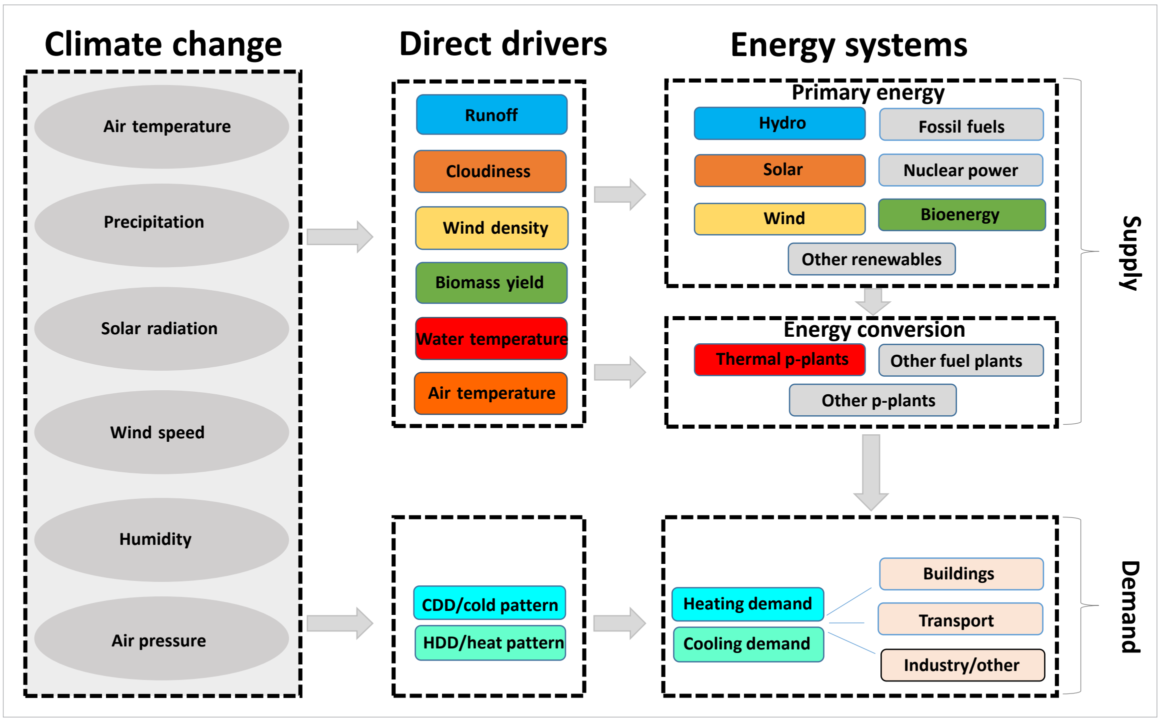


Figure 5: Conceptual framework of climate impacts on the energy sector. CDD – cooling degree days; HDD – heating degree days. *Source: Impacts of Climate Change on Energy Systems in Global and Regional Scenarios*

Because of past and future GHG emissions, a gradual and irreversible rise of the sea level will occur throughout the century and well beyond, irrespective of the future state of the climate, with consequences for the design and siting of current and future facilities located on coastlines.[53] A further increase of global sea level is certain, caused by ice loss on land and thermal expansion from deep ocean warming, with sizeable variations at the local and regional scale.[54] However, increased sea levels could exacerbate the impacts of other unpredictable but more frequent extreme weather manifestations underpinning high-emissions scenarios, such as large storms causing coastal flooding, storm surges, high-water events as well as coastal erosion and landslides. Ten per cent of dispatchable generation facilities are already exposed to severe coastal flooding.[55]

Over 70% of installed capacities in operation or under construction are in three regions – Eastern North America, Western and Central Europe and East Asia – which will face a wide variety of climate hazards in the future, including extreme heat conditions, heavy precipitation, coastal and river floods, and tropical cyclones.

On the supply side, renewables are directly dependent on the wind speed for wind power, on radiation and temperature for solar, and on water availability for hydropower. Biomass and biofuel availability is sensitive to the climate. Thermal power plants rely on water amount and temperature for their cooling systems.

On the demand side, heating and cooling demands are mostly driven by the temperature. And distribution is affected by hazards such as storms, heavy rainfall, strong wind, wet snow or frost, high temperatures, lightning or wildfires.

The cumulative impacts of weather, water and climate on all aspects of energy generation and use are therefore considerable (Figure 5).[56]

By threatening the functioning of traditional energy systems, more pronounced and severe heatwaves and droughts are potentially among the most consequential extreme climate conditions for energy. Heatwaves alter power generation and transmission efficiencies and escalate cooling demand.[57]

IAEA reports that occurrences of severe weather disrupting the operation of nuclear power plants increased five-fold in three decades, between 1990 and 2019 (Figure 6), with a notable acceleration since 2009.[58] However, the resulting impacts in term of production losses diminished appreciably in many countries thanks to regular improvements in operational practices and evolving regulatory obligations.

53 IAEA, *Climate Change and Nuclear Power, Securing Clean Energy for Climate Resilience* (in press)
54 Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities, in *The Ocean and Cryosphere in a Changing Climate: Special Report of the Intergovernmental Panel on Climate Change*; Forcing Factors Affecting Sea Level Changes at the Coast
55 World Energy Outlook 2021
56 Impacts of Climate Change on Energy Systems in Global and Regional Scenarios
57 Impacts of Climate Change on Energy Systems in Global and Regional Scenarios
58 IAEA analysis based on IAEA PRIS database.

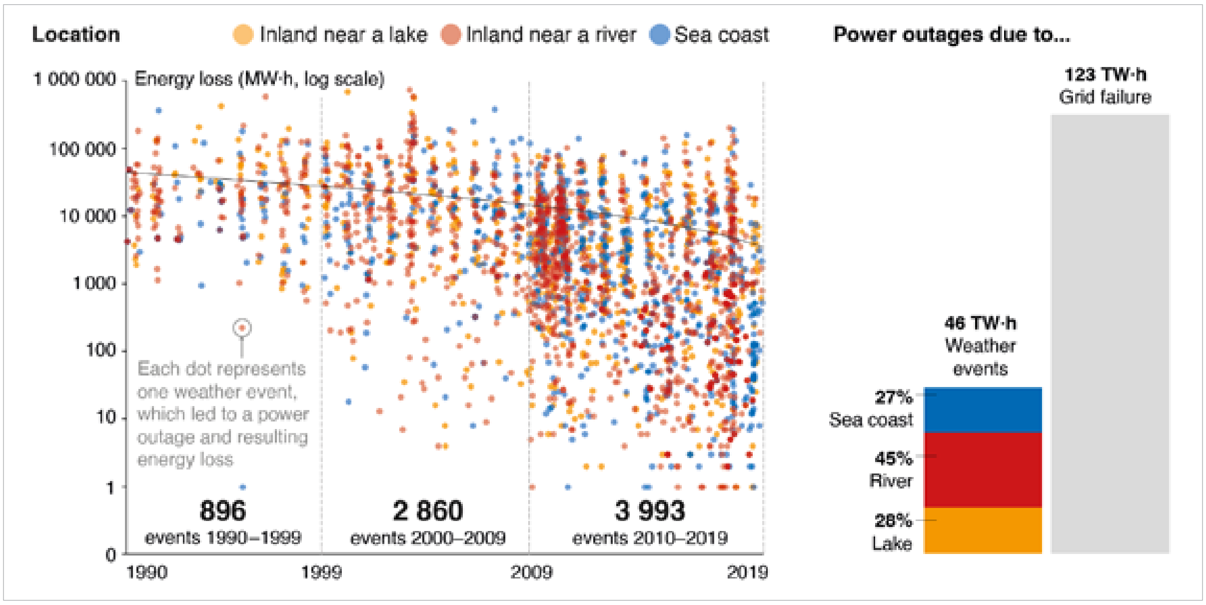


Figure 6: Reported global power outages due to weather events, 1990–2019
Source: IAEA analysis based on *IAEA PRIS database*

HYDROPOWER SECTOR CLIMATE RESILIENCE GUIDE

Hydropower facilities provide essential adaptation services that reduce the impacts of hazards exacerbated by climate change such as floods and drought. Like all infrastructure, they may be vulnerable to natural disasters, and they have a particular dependency on precipitation. To address this fact, the International Hydropower Association (IHA) launched the Hydropower Sector Climate Resilience Guide[59] in 2019. This guide offers a methodology and international good practice guidance to help project operators and developers identify, assess and manage climate risks to enhance the resilience of proposed and existing hydropower projects. It was developed over a three-year period in consultation with major hydropower developers, owners and operators, intergovernmental and not-for-profit organizations, international consultancies and independent experts. It supports lenders, operators, developers and policymakers to make informed decisions about how to plan, build, upgrade and operate hydropower assets in the face of increasingly variable hydrological conditions.

CLIMATE READi: A COMMON FRAMEWORK FOR POWER COMPANIES TO ASSESS CLIMATE RISK

As extreme weather events increase in frequency and intensity, along with society's dependence on electricity, there is an increasing need for a comprehensive and consistent approach to physical climate risk assessment. In April, the Electric Power Research Institute (EPRI) launched a new, three-year initiative, Climate READi (Power REsilience and ADaptation initiative), aiming to bring more than 50 power companies together with global thought leaders and industry stakeholders to develop a common framework to address this challenge.

The Climate READi framework produced from this effort will embody a comprehensive, integrated approach to physical climate risk assessment for the sector. The framework will provide climate data guidance, direction for assessing exposure and vulnerability across the entirety of the power system, and methods for prioritizing investment decisions. It will enable energy companies, regulators and other stakeholders to use science-informed insights in a more consistent way to better understand, plan for, and disclose future global power system challenges arising from the changing environment. Each of the three initiative workstreams will be advanced in parallel, scheduled to be completed in 2025.[60]

59 Hydropower Sector Climate Resilience Guide
60 More information about Climate READi is available at www.epri.com/READi.

Renewable energy will contribute to a sustainable future

Carbon dioxide emissions from energy combustion and industrial processes have steadily increased from 1900 to 2021 (Figure 7).[61] In 2020, atmospheric CO_2 concentrations reached 149% of pre-industrial levels.[62] The next decade will be decisive if the goals of the Paris Agreement and the SDGs are to be achieved. Any delay will lead to further warming, with profound and irreversible economic and humanitarian consequences.

A transition to low-carbon, clean energy should be at the heart of climate action in all countries. Phasing out unabated coal, limiting investments in oil and gas to facilitate a swift decline and a managed transition as well as embracing technology, policy and market solutions will put the global energy system on track for a net zero pathway.

According to IEA, the energy sector is the largest source of GHG emissions, accounting for almost three quarters of global emissions.

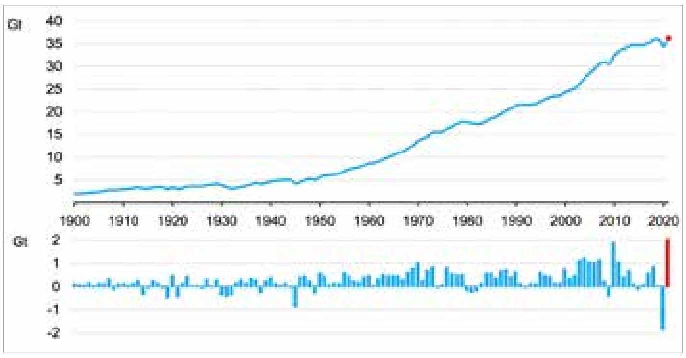


Figure 7: Total CO_2 emissions from energy combustion and industrial processes and their annual change, 1900–2021
Source: Global Energy Review: CO_2 Emissions in 2021

A massive transition in the way we produce and consume energy is required to reach NZE by 2050, according to IEA and IRENA. IEA's NZE by 2050 roadmap provides a pathway to reach this formidable and critical goal, setting out more than 400 milestones for what needs to be done, and by when, to decarbonize the global economy in just three decades.[63] IRENA's World Energy Transitions Outlook outlines priority areas and actions based on available technologies that must be realized by 2030 to achieve NZE by mid-century.[64]

On an NZE by 2050 pathway, the world economy in 2030 is some 40% larger than today but uses 7% less energy, due to a major worldwide push to increase energy efficiency. Around half of total energy supply comes from low-emissions energy sources by 2030, which represents significant growth from the current level of around one quarter. The share of renewables could be as high as 65% by 2030.[65] At the same time, energy supply from unabated fossil fuels[66] declines by 30% between 2020 and 2030, leading to no new oil and gas field development and no new coal mines (Figure 8). By 2050, almost 90% of electricity generation comes from renewable sources, up from 25% in 2018,[67] with wind and solar PV alone accounting for almost 70%. Most of the remainder comes from nuclear[68] and natural gas. Other mature renewable technologies (e.g. hydropower, bioenergy, geothermal[69]) and emerging renewable technologies (e.g. concentrating solar power, ocean energy) also play important roles in decarbonizing the world's electricity supply.[70]

The transition is all the more important when considering the water–energy nexus. The total life cycle water used to generate electricity by solar and wind is substantially lower than for more traditional technologies, such as thermoelectric generation technologies.[71] A transition to renewable energy therefore constitutes an essential contribution to alleviating growing global water stresses.

61 Net Zero by 2050
62 WMO Greenhouse Gas Bulletin, No. 17
63 Net Zero by 2050: A Roadmap for the Global Energy Sector
64 World Energy Transitions Outlook
65 World Energy Transitions Outlook
66 Consumption of fossil fuels in facilities without carbon capture, utilization and storage (CCUS).
67 World Energy Transitions Outlook
68 Net Zero by 2050: A Roadmap for the Global Energy Sector
69 GCF's Indonesia Geothermal Resource Risk Mitigation Project provides a useful example.
70 World Energy Transitions Outlook
71 Life Cycle Water Use for Electricity Generation: A Review and Harmonization of Literature Estimates

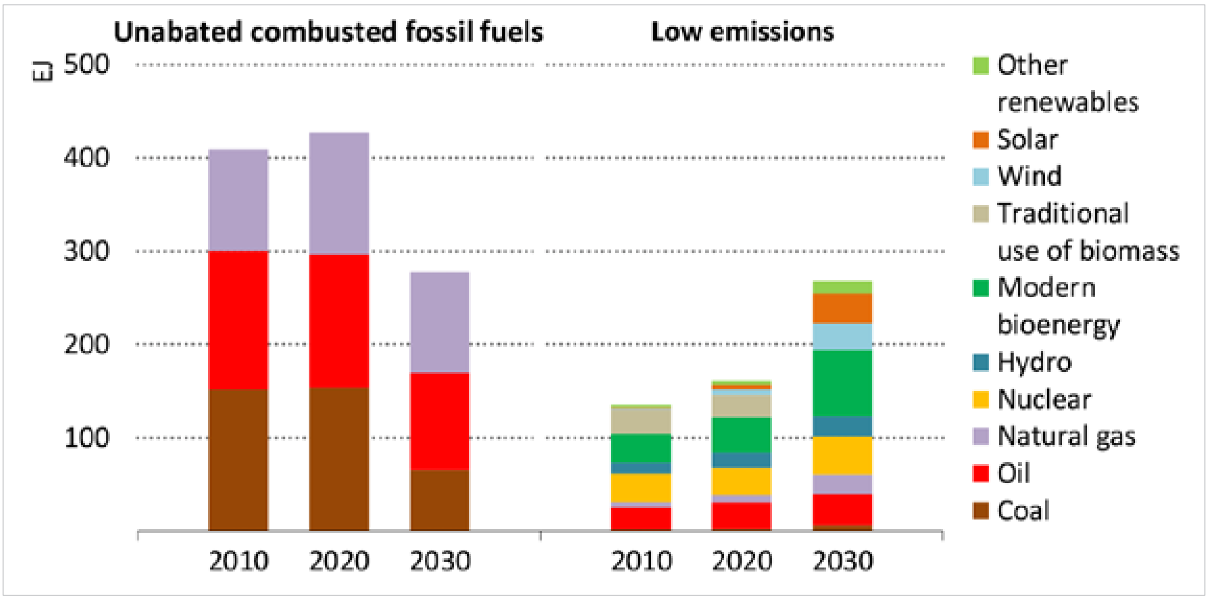


Figure 8: Transition in global total energy supply by source to 2030 in the NZE by 2050 scenario. Notes: EJ – exajoules. Other renewables include marine and geothermal energy. Modern bioenergy includes modern solid biomass, liquid biofuels and biogases derived from sustainable sources; it excludes the traditional use of biomass. Low-emissions coal, oil and natural gas include fuel combustion equipped with carbon capture, utilization and storage (CCUS), as well as fossil fuel used in non-energy purposes. Non-renewable waste use is not reported.

Source: World Energy Outlook 2021

CLIMATE SERVICES MINIMIZING EMISSIONS FROM HYDROPOWER STORAGE PROJECTS

Water storage, which is often cited as a proxy for water security, becomes even more relevant under climate change scenarios.[72] In 2018, 2.3 billion people were living in countries under water stress and 3.6 billion people faced inadequate access to water at least one month per year. By 2050, the latter number is expected to increase to more than 5 billion.[73] Studies show that regions with significant hydrological variability have lower per capita GDP. Water storage is essential for buffering intra-annual and inter-annual variations in rainfall that otherwise significantly impact economic growth.

Hydropower storage projects can deliver multiple benefits, including alleviating water scarcity. Yet, they must not contribute to the problem of climate change, which is exacerbating water insecurity. Biogenic GHG emissions caused by the impoundment of a reservoir can be significant in some cases. Although this fact has raised concerns about hydropower as a source of clean energy, studies confirm that the median life cycle emissions for hydropower facilities are as low as for other renewable technologies.[74]

While certain hydropower reservoirs can provide considerable reduction in GHG emissions because of the displacement of fossil-fuel-based generation, it is essential to identify and define strategies to tackle the GHG emissions from high-emitting reservoirs. Modelling tools can identify better locations to minimise the impact of emissions after impoundment.[75] Observations and monitoring are crucial for understanding the emissions pathways and the effectiveness of actions to reduce them. Measures can include vegetation clearance before impoundment, sediment inflow management and variable water intakes. Modern technologies can even capture methane emissions. Climate services can support minimizing fluctuations in water levels to avoid increasing GHG flux from the drawdown areas.

72 Making Water a Part of Economic Development: The Economic Benefits of Improved Water Management and Services
73 *2021 State of Climate Services: Water* (WMO No. 1278)
74 Water Security and Climate Change: Hydropower Reservoir Greenhouse Gas Emissions
75 The carbon calculator for reservoirs

Commitments from countries are falling short of what is needed

Current pledges made by countries fall well short of what is need to meet the objectives set by the Paris Agreement – limiting global warming to well below 2 °C – leaving a 70% gap in the amount of emissions reductions needed by 2030.[76] According to IRENA, 74% of countries have a quantified renewable energy target in their NDCs.[77] But it is not enough. An increase of about 16% in global GHG emissions in 2030, compared to 2010, is expected for the aggregate NDCs of all 194 Parties. This translates to a global average temperature rise of about 2.7 °C by the end of the century.[78] Just 56% of NDCs (Figure 9) include quantified renewable power targets to collectively reach 3.7 TW[79] of clean energy provision by 2030. The pathway to reach the Paris Agreement demands an additional 7.1 TW of clean energy by 2030.[80]

Most of the countries that have committed to 100% renewables in their electricity mix by 2030 are SIDS.[81] Although climate is a major driver for renewables deployment in these countries, increased ambition is also driven by energy security and other socioeconomic benefits, which are adversely affected by importing fossil fuels. However, these targets remain conditional on international support in the form of financing, technology transfer and technical assistance.

Among the G20 and other high emitters, only seven Parties included targets related to increased power supply from renewables. Of these, only two presented them as a share of electricity mix, and those shares were less than 25%.[82]

Although renewable energy systems are weather and climate dependent, which calls for improved climate information and services for the energy sector, the value of climate services for mitigation is only recognized by 6% of NDCs (Figure 10). This is in sharp contrast to the frequency with which climate services are recognized as a priority for supporting adaptation in agriculture and food security (85%),[83] disaster risk reduction (88%)[84] and water resource management (50%)[85,86] in Parties' NDCs.

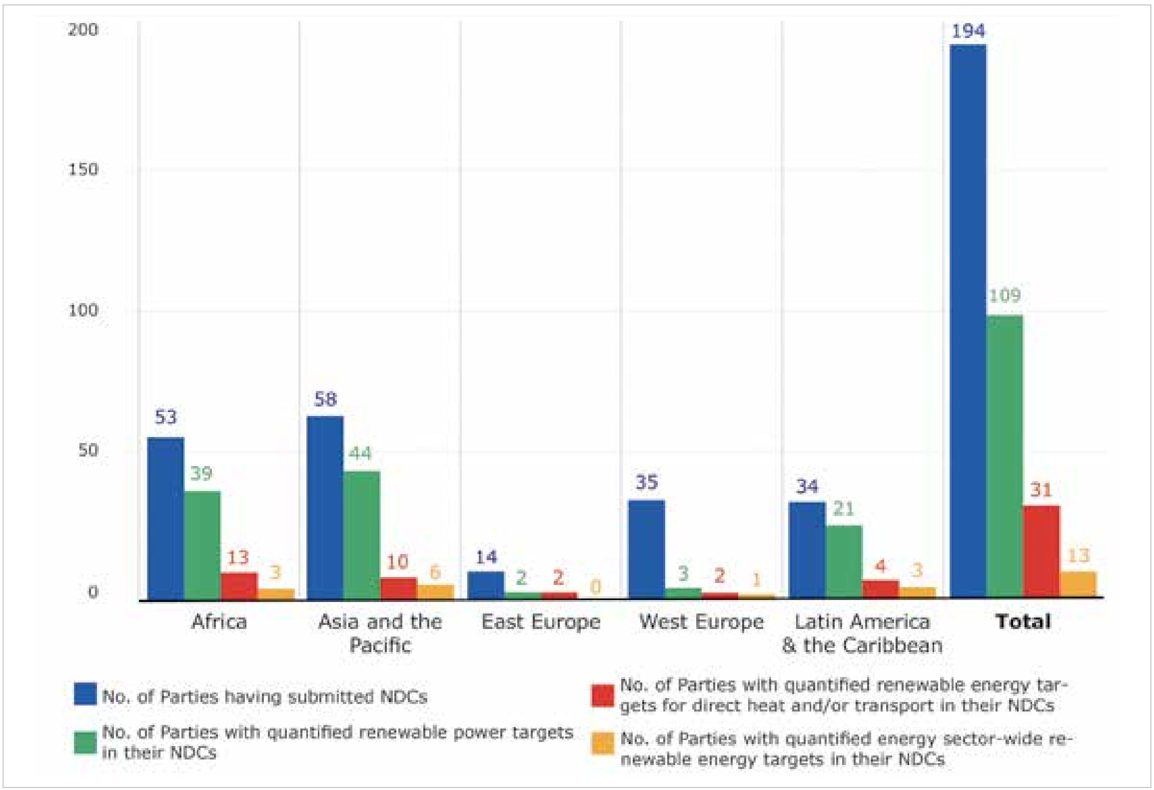


Figure 9: 2030 renewable energy targets in the NDCs
Source: IRENA's Energy Transition Support to Strengthen Climate Action

76 COP26 climate pledges could help limit global warming to 1.8 °C, but implementing them will be the key
77 NDCs and Renewable Energy Targets in 2021
78 UN Reports Find Updated Climate Commitments "Fall Far Short" of Paris Goal
79 This quantification is based on targets in national policy documents (including policies, roadmaps, plans, energy strategies, etc.), according to IRENA.
80 IRENA, based on analysis of NDCs.
81 NDCs and Renewable Energy Targets in 2021
82 NDCs and Renewable Energy Targets in 2021
83 *2019 State of Climate Services: Agriculture and Food Security* (WMO No. 1242)
84 *2020 State of Climate Services: Risk Information and Early Warning Systems* (WMO No. 1252)
85 Based on updated NDCs submitted as of August 2021.
86 *2021 State of Climate Services: Water* (WMO No. 1278)

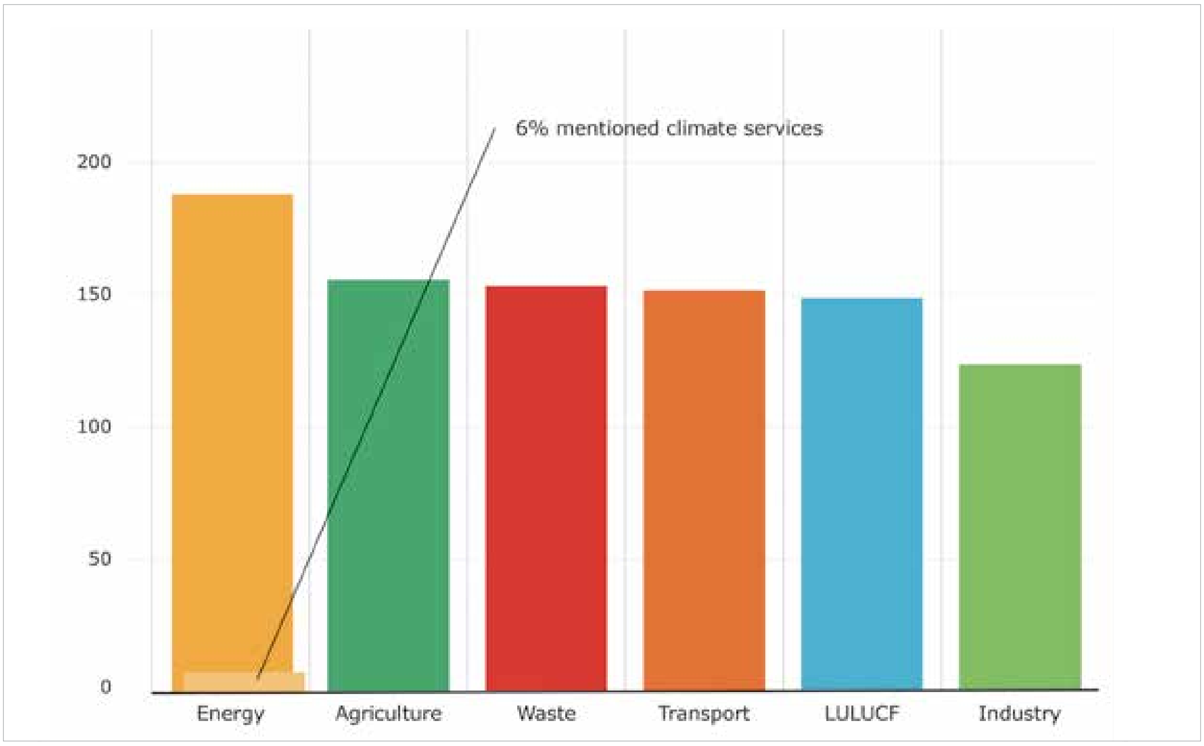


Figure 10: Sectors covered by NDC mitigation targets, in number of Parties from 2016 to March 2022. LULUCF – land use, land-use change and forestry.

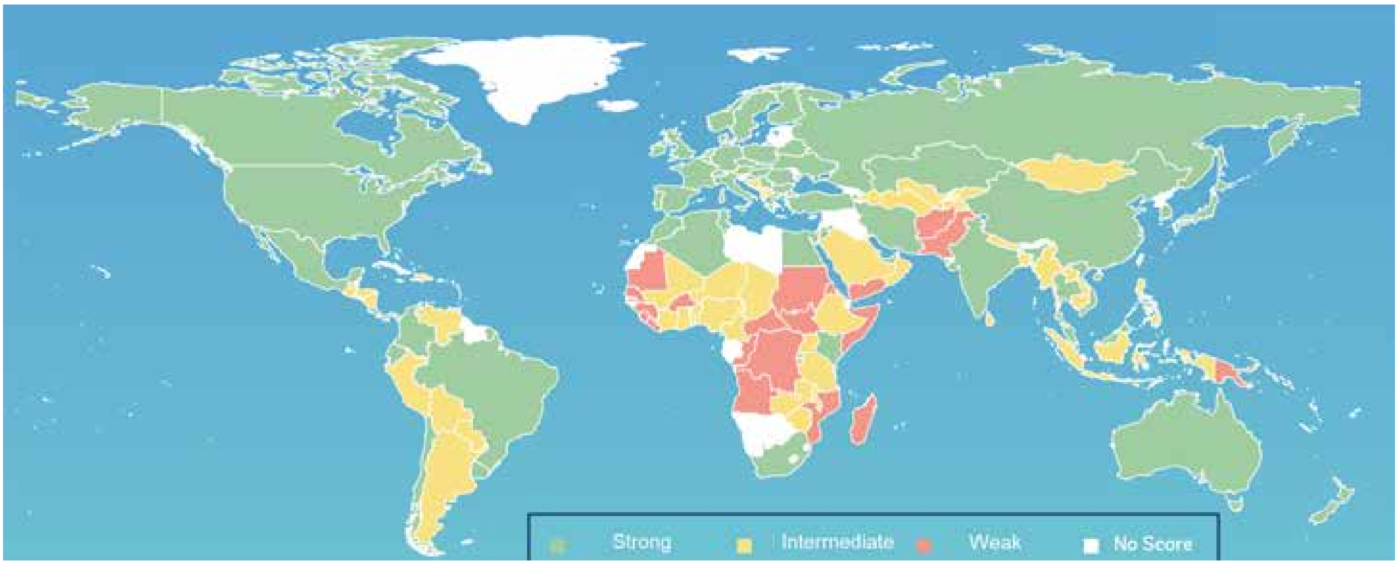


Figure 11: RISE scores reflecting a snapshot of countries' policies and regulations in the energy sector, organized by the four pillars of sustainable energy: electricity access, clean cooking, energy efficiency and renewable energy (as of June 2022)

Adoption of the policies and regulations necessary to enable decarbonization in the energy sector is still particularly weak in Africa, South America and Asia; however, there are disparities between different countries in those regions, according to the World Bank's Regulatory Indicators for Sustainable Energy (RISE) (Figure 11). RISE scores reflect a snapshot of a country's policies and regulations in the energy sector, organized by the four pillars of sustainable energy: electricity access, clean cooking, energy efficiency and renewable energy.[87]

Despite the exposure and vulnerability of the sector to climate variability, extremes and change, of the 194 NDCs submitted by Parties to the secretariat of the UNFCCC (as of March 2022), just 40% of NDCs prioritize adaptation in the energy sector, failing to recognize that climate change is putting the energy sector at risk. Energy is only the ninth most frequent adaptation priority in Parties' NDCs, with most Parties identifying agriculture and food security, water, health, and ecosystems and biodiversity as the top adaptation priorities (Figure 12). Of the minority of Parties that do prioritize energy for adaption, only 64% mention the climate services that will be needed for that purpose

87 RISE

(Figure 12), with most climate-services-related activities not directly mentioned under the energy sector, but rather mentioned in cross-cutting activities. For example, Equatorial Guinea highlighted the need to identify the locations of rain gauge stations in hydroelectric plants to monitor the changes in precipitation. Therefore, although the gap is not as stark as in the case of the exceedingly low level of recognition of the need for climate services to support renewable energy as a mitigation measure reviewed earlier, there is clearly a low level of recognition in the NDCs of both the need for adaptation in the energy sector and of the need for climate services providing the necessary support.

The relatively low priority given to adaptation in the energy sector is particularly striking given the generally high recognition by Parties of energy as an underpinning, cross-cutting sector supporting the achievement of adaptation in other climate-sensitive sectors, such as water (51%), infrastructure (36%) and agriculture (26%) (Figure 13). For example, Cabo Verde highlighted in its NDC, in the water-associated measures, the need to increase its installed renewable capacity as an energy source for the production of desalinated water. The importance of energy in this regard strengthens the case for ensuring that adaptation in the sector is adequately supported.

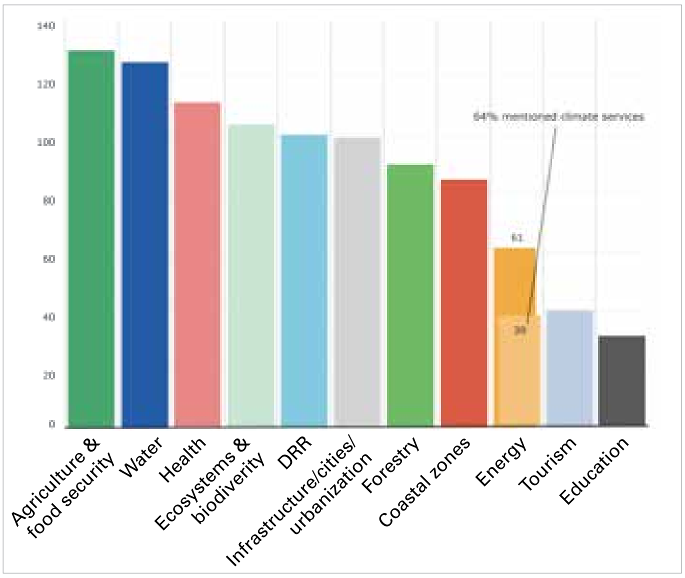


Figure 12: Sectors identified as priorities for adaptation in the 194 NDCs submitted from 2016 to March 2022

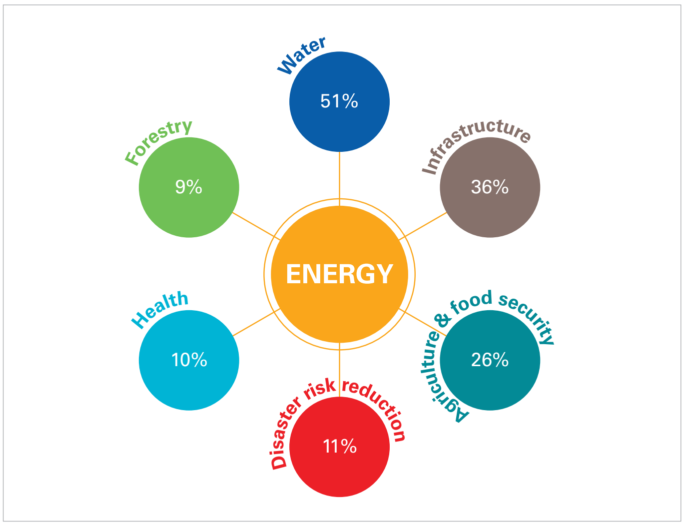


Figure 13: Overview of the interaction between energy and the other sectors indicated in the NDCs of 70 Parties which mentioned energy in relation to other sectors

PROGRESS IN ACHIEVING SDG 7 ON ENERGY[88]

The world is set to fall short of achieving the goal of universal access to affordable, reliable, sustainable and modern energy by 2030, as set out in SDG No. 7, by a wide margin. Based on current trends, the world is not on track to achieve SDG Target 7.1 (Figure 14).

Projections show an increase in the share of renewables in the energy mix[89] to between 18% and 22% by 2030.[90] These expected moderate gains in the share of renewables in the energy mix by 2030 notwithstanding, renewable energy systems need to be expanded to meet these needs.

In 2019, the share of renewable energy sources in total final energy consumption (TFEC) amounted to 17.7% – only 0.4% points higher than the year before. Renewable energy consumption increased by 2.8% from the year before, as TFEC expanded by 0.7%.

Africa has the highest share of renewables in its TFEC overall, at 54.2%; of that, only 7.6%[91] is from modern renewables – the lowest percentage among all regions.

Energy efficiency improvements continue to remain below the target set under the SDGs for 2030. Between 2010 and 2019, the average annual rate of improvement in global energy efficiency was 1.9%. Although better than the rate of 1.2% between 1990 and 2010, it was well below the level of 2.6% specified in SDG Target 7.3.[92] The average annual rate of improvement now has to reach 3.2% to make up for lost ground. This rate would need to be even higher – consistently over 4% for the rest of this decade – if the world is to reach NZE from the energy sector by 2050, as envisioned in IEA's Net Zero Emissions by 2050 Scenario.[93]

88 Tracking SDG7: The Energy Progress Report 2022
89 Share of renewable energy in total final energy consumption.
90 SEforALL Analysis of SDG7 Progress – 2021
91 SEforALL Analysis of SDG7 Progress – 2021
92 Revisions of underlying statistical data and methodological improvements explain the slight changes in historical growth rates from previous editions. The SDG 7.3 target of improving energy intensity by 2.6% per year in 2010–2030 remains the same, however.
93 Net Zero Emissions by 2050 Scenario (NZE)

Figure 14: Primary indicators of global progress toward the SDG 7 targets

Source: IEA, IRENA, UNSD, World Bank, WHO. *Tracking SDG 7: The Energy Progress Report*. World Bank, Washington DC. ©2022 World Bank. License: Creative Commons Attribution – Non-Commercial 3.0 IGO (CC BY-NC 3.0 IGO).

UN-ENERGY COMMITTED TO TRANSLATE COMMITMENTS INTO IMPACT

UN-Energy is the United Nations mechanism for inter-agency collaboration in the field of energy. The UN-Energy Plan of Action Towards 2025,[94] launched in May 2022, sets out a framework for collective action by nearly 30 United Nations and international organizations, in order to achieve the goals of the UN-Energy pledge.[95]

To tackle these large-scale challenges, the Plan identifies seven work areas, including catalysing multi-stakeholder partnerships by scaling up ‘Energy Compacts’. By mobilizing voluntary commitments from all stakeholders and providing an effective tool for driving holistic and inclusive action, the Energy Compacts are a key vehicle to translate the Global Roadmap for Accelerated SDG7 Action – delivered by the United Nations Secretary-General as an outcome of the High-level Dialogue on Energy held in September 2021 under the auspices of the General Assembly – into concrete actions and partnerships.

To date, over 200 Energy Compacts have been announced that amount to investment commitments of over US$ 600 billion by governments and the private sector alone. Supported by UN-Energy, an Energy Compact Action Network[96] has also been established to match those governments seeking support for their clean energy goals with governments and businesses that have pledged to support implementation of these commitments. A number of coalitions have already been formed, including to support energy access and transition in Nigeria and the city of Santiago, Chile, showcasing the Network’s potential, as well as to advance or expand coalitions supporting green hydrogen and a stronger role for women in leading and benefiting from the energy transition.

94 UN-Energy Plan of Action Towards 2025
95 The UN-Energy Pledge
96 Energy Compact Action Network Brochure

Priorities and needs

Photo: Alexei Scutari/ Unsplash

Weather, water and climate services are crucial for energy security and the global energy transition to achieve net zero

Meeting the world's ever-growing energy demand, coupled with an imperative to transition to greener, and renewable, sources and more sustainable and resilient energy systems, creates new needs. As with traditional energy generation, renewable energy systems are weather and climate dependent, so the transition to clean energy calls for improved climate information and services for the energy sector.

Climate services are needed to ensure the resilience of energy systems to climate-related shocks and to inform measures to increase energy efficiency. Risk assessments addressing planning for and early warning of adverse events affecting energy supply and demand can help populations to anticipate, absorb, accommodate and recover from adverse impacts. For example, early weather warnings can safeguard energy supply in Beijing, China, climate stress tests can ensure effective electricity distribution in the Dolomites region of Italy, and severe weather warnings can protect offshore wind power production in China.

Climate services are also essential for renewable energy, including for: site selection, resource assessment and financing; operations, maintenance and management of energy systems; electricity integration into the grid; and impact assessment of energy systems. For example, climate services are providing warnings ahead of dry conditions for hydropower operations planning in Tajikistan; localized wind-resource information is aiding full-value-chain wind industry decision-making; and climate services are supporting the placement of solar panels on noise barriers in Germany.

Given the need for an unprecedentedly rapid transition of the sector, and the current very low levels of recognition of what will be required to achieve that rapid transition in terms of climate services compared to other sectors – such as agriculture, water resource management and disaster risk reduction – where the role of climate services is well established and understood, the transition to clean energy also requires a new paradigm for a more effective exchange of information between weather, water and climate specialists and energy-sector stakeholders. And specifically, the energy transition will require improved communication and collaboration between climate services providers and energy industries.[97]

According to a survey of NMHSs conducted by the WMO Study Group on Integrated Energy Services, 79% of WMO Members provide climate services for energy, including some particularly notable examples. Also, less than 50% of Members provide tailored products for the energy sector (Figure 15), which shows the untapped potential of NMHSs and the efforts required to address the emerging needs of this sector.

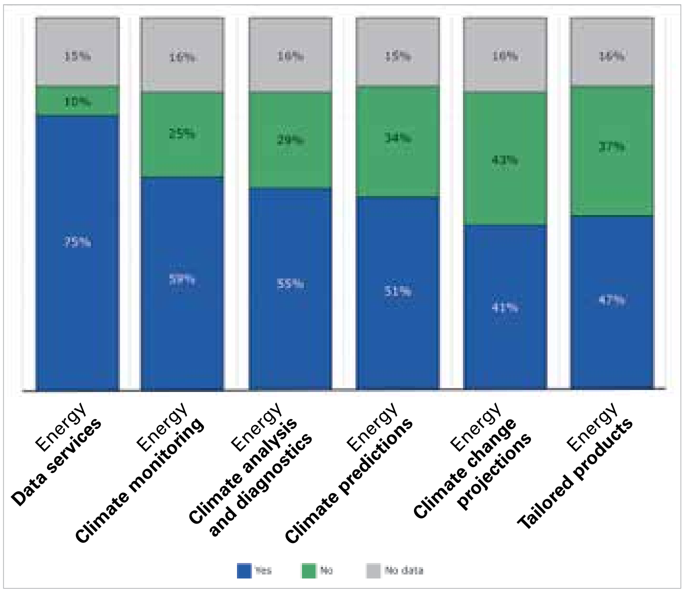


Figure 15: Percentage of WMO Member NMHSs providing climate services to the energy sector globally and by type of product

Overall, WMO found that climate services for energy are not performing well. The global average rating given by Members is just three out of six[98] potential levels of service representing increasing user engagement. Future activities should focus on better addressing the needs of end users, according to Climate Investment Funds (CIF). Only 16%[99] of Members reported having a national working group for the energy sector. Thirty-six Members highlighted adequate organizational structures within NMHSs as one of the top three enabling factors to improve uptake of climate services for energy transition towards NZE.

Specialized services for renewable energy are sub-optimal. Further increases are needed in the density of meteorological observations to address significant monitoring gaps and improve data coverage according to CIF, a conclusion confirmed by WMO data. As of 14 July 2022, 87 WMO Members had responded to the NMHS energy-sector survey.[100] The majority (69) reported not having access to energy observational or simulated data on energy from other national public, private and/or academic sector entities, while only 18 Members reported having access, with the majority of these (10 Members) being from Europe. Additionally, 62 Members (Figure 16) reported not maintaining a dedicated

97 Weather & Climate Services for the Energy Industry
98 Six levels of sophistication of climate services to the energy sector: 1 = initial engagement with sector; 2 = definition of needs; 3 = co-design of products; 4 = tailored products accessible for use; 5 = climate services guide policy decisions and investment plans in sectors; 6 = documentation of socioeconomic benefits.
99 Based on 193 WMO Members.
100 Of the Members that responded, 36% are high-income, 26% upper-middle-income, 25% lower-middle-income, and 13% low-income.

observing network for energy services. Installation of weather stations near energy assets was identified as top priority by 60 Members (Figure 17). Fifty-eight Members reported providing climate hazard early warnings to the energy sector.

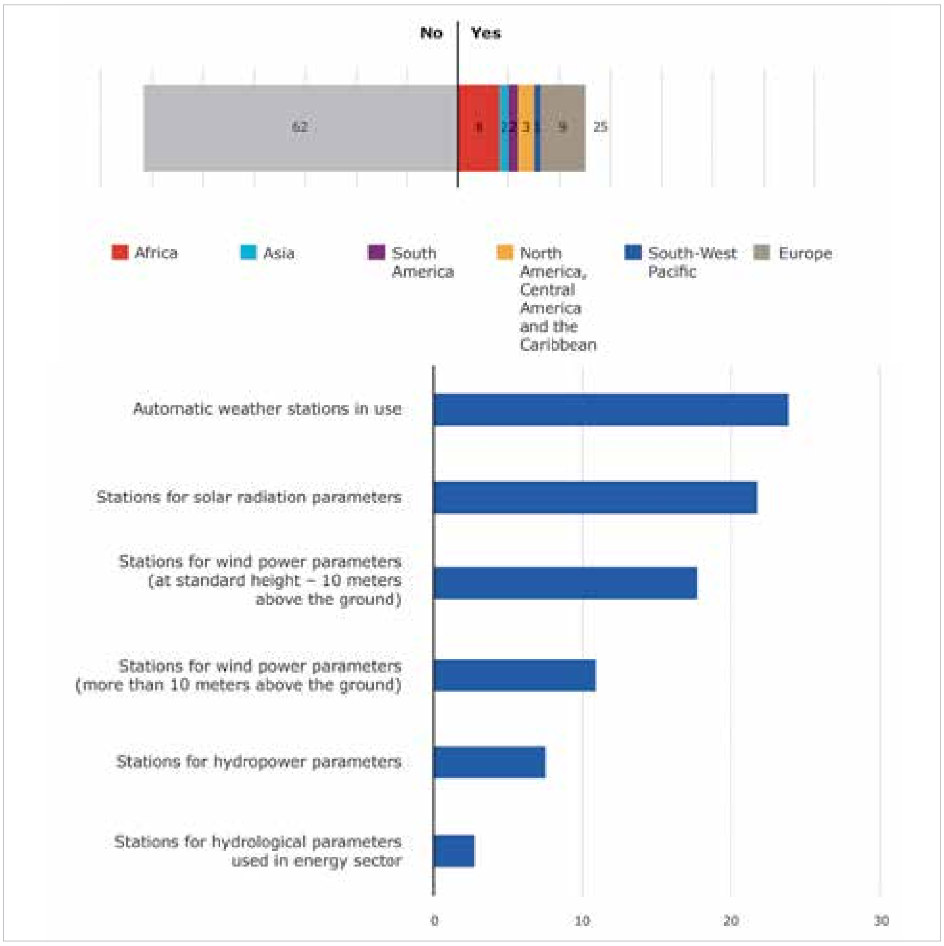


Figure 16: WMO Member NMHSs maintaining dedicated observing networks for energy services (top) and details of networks being maintained (bottom)
Source: WMO Best Practices for Integrated Weather and Climate Services in Support of Net Zero Energy Transition (in press)

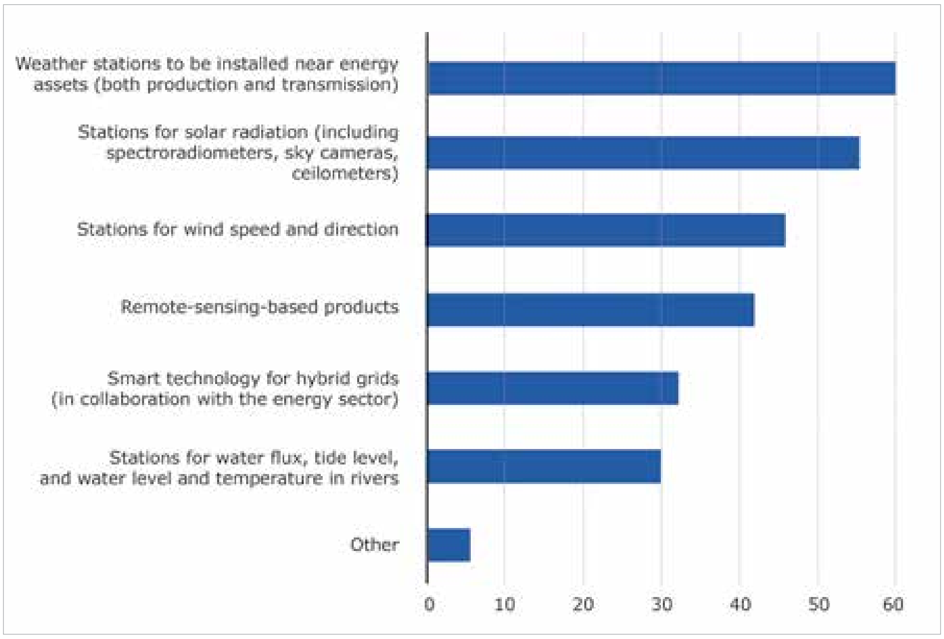


Figure 17: Infrastructure equipment and services needs highlighted by WMO Member NMHSs
Source: WMO Best Practices for Integrated Weather and Climate Services in Support of Net Zero Energy Transition (in press)

THE ROLE OF PUBLIC–PRIVATE PARTNERSHIPS IN ENHANCING CLIMATE SERVICES

The public sector plays a prominent role in the development of climate services for the energy sector (Figure 18). The private sector is rapidly developing such services, however, resulting in a healthy mix of public and private climate service providers. The numbers of organizations providing climate services to the energy sector that responded to a 2015/2016 survey by WEMC,[101] by type, were as follows:

- Public: 21 (including government and research institutes);
- Private: 10 (including private and consultancy);
- Other: 4;
- International organizations: 2.

The climate services market is rapidly growing, attracting private players[102] of different sizes – from the largest corporations to start-ups – in varying segments of the value chain – from modelling to smart sensors – with the private sector generally ready to respond to clients' needs more quickly than public institutions. Private companies can lower the risks associated with innovation by partnering with research institutions.

Bilateral collaborations and contracts (in the context of public–private partnerships) are a solution to limit these risks and respond to specific user needs in a timely fashion, as highlighted by 52 WMO Member NMHSs. Strengthening partnerships and collaboration through demand-led and co-created project design processes across regions, government agencies, key sectors, the private sector and vulnerable communities, to promote buy-in and collaboration, emerges as a solution from the 2021 Learning Review of CIF-Supported Hydromet and Climate Services Projects.[102]

These partnerships have an added value later in research and innovation projects that aspire to produce climate services, according to the Barcelona Supercomputing Center. By working closely with industrial partners, researchers better understand user needs, language and ways of working. This interaction enables researchers to address more ambitious and relevant societal challenges by involving users as partners. This engagement benefits all partners, including by producing relevant results and by limiting risks to the private sector, as mentioned previously.

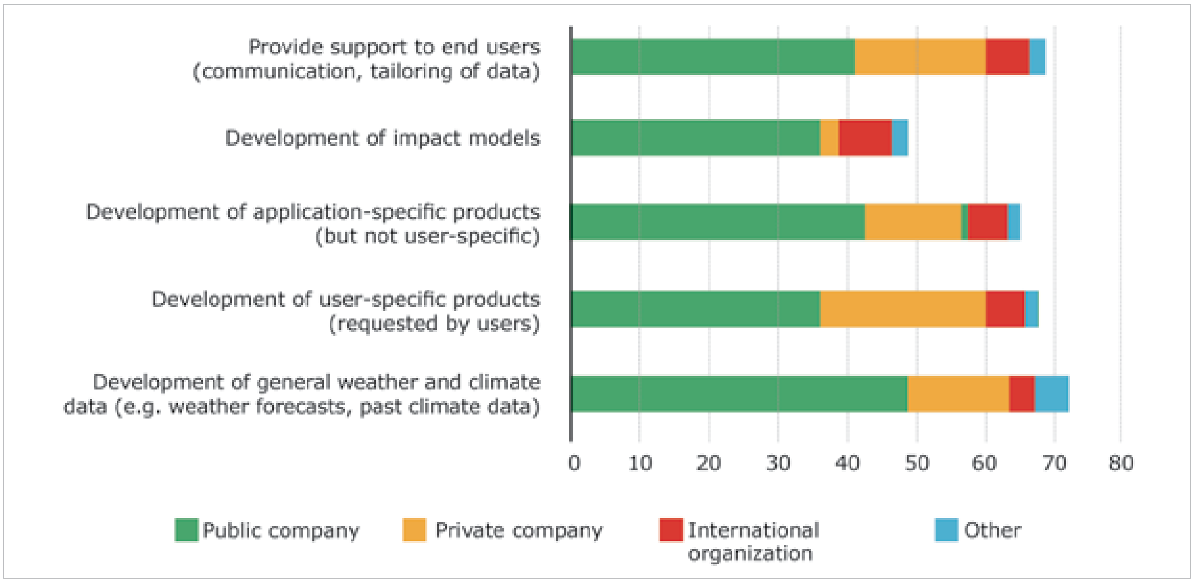


Figure 18: Scope of activities in organisations operating in meteorology and climate that responded to the WEMC survey
Source: Weather & Climate Services for the Energy Industry

101 Weather & Climate Services for the Energy Industry
102 Systematic Analysis of EU-based Climate Service Providers
103 Learning Review of CIF-Supported Hydromet and Climate Services Projects

Investment

Investments in renewable energy need to triple by 2050, including for climate services for energy

Global climate finance reached US$ 632 billion a year in 2019–2020, increasing just 10% compared to 2017–2018. Analysis carried out by CPI indicates that current levels are falling far short of estimated needs. Mitigation finance totalled US$ 571 billion in 2019–2020, while adaptation finance commitments were US$ 46 billion. A further US$ 15 billion went to projects with dual benefits (both mitigation and adaptation).

Climate investments in energy supply reached an average of US$ 334 billion a year in 2019–2020, representing 58% of total mitigation finance and 53% of total climate finance. At US$ 324 billion, renewable energy represented 57% of total mitigation finance in 2019–2020.[104] Despite the impact of the Covid-19 pandemic on the global economy, average annual renewable energy investments remained stable in 2019–2020 compared to 2017–2018 (Figure 19). The average costs for electricity generated by solar and wind technologies could decrease by between 26% and 59% by 2025, according to IRENA. With the right regulatory and policy frameworks in place, cost reductions can continue to be realized in solar and wind technologies until 2025 and beyond.[105]

PV and wind (both onshore and offshore) attracted 91% of total renewable energy investments in 2019–2020. Other technologies, such as bioenergy, hydropower and geothermal accounted for much smaller shares, between 0.3% and 3%.

In line with overall mitigation finance flows, in 2019–2020, the majority of renewable energy investments were made in the East Asia and Pacific region, mainly China and Japan, followed by Western Europe, and North America, mainly the United States and Canada. Since 2013, these three regions have consistently attracted 65%–75% of global investments, while developing and emerging economies continue to remain underrepresented.[106] While renewable energy investments have increased over time, the current level of investment needs to at least triple to put the world on a net zero trajectory by 2050.

Developing and emerging economies continue to remain underrepresented when it comes to accessing clean energy finance, according to IRENA and CPI. Only 2% of such investments in the last two decades were made in Africa.[107]

Climate-adaptation-focused investments in the energy sector remain very low, at just over US$ 300 million, tracked per year in 2019–2020. Investments in dual benefits projects for the energy sector – targeting both mitigation and adaptation – were somewhat higher at US$ 1.5 billion a year in 2019–2020.

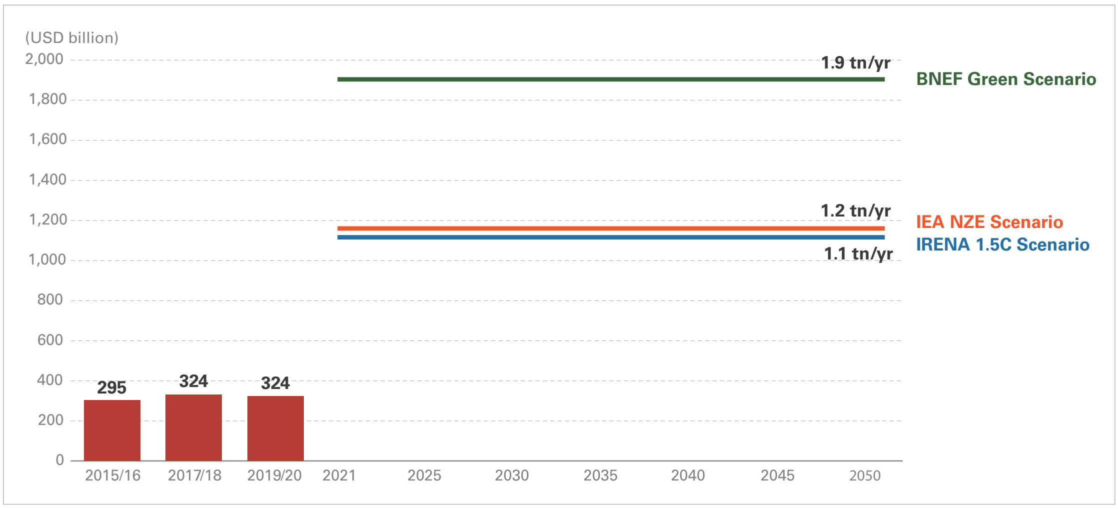


Figure 19: Annual renewable energy investments (2015–2020) versus average investment needs through 2050
Source: Global Landscape of Climate Finance 2021

104 Global Landscape of Climate Finance 2021
105 The Power to Change: Solar and Wind Cost Reduction Potential to 2025
106 Global Landscape of Renewable Energy Finance 2020
107 Renewable Energy Market Analysis: Africa and its Regions

FINANCING TO SUPPORT ACHIEVING SDG 7 IN DEVELOPING COUNTRIES[108]

International public financing commitments for energy projects that support achieving SDG 7 in developing countries are still insufficient to mobilize the larger volumes of investment required to meet the target. International public financial flows to developing countries in support of clean energy decreased in 2019 for the second year in a row, falling to US$ 10.9 billion at 2019 prices and exchange rates. This level of support was 23% less than the US$ 14.2 billion provided in 2018, 25% less than the 2010–2019 average, and less than half of the peak of US$ 24.7 billion in 2017.

CLIMATE FINANCE INSTITUTIONS SUPPORTING CLIMATE SERVICES FOR ENERGY

The Adaptation Fund has invested over US$ 65 million of its US$ 908 million portfolio in climate information services. The funding supports creation of infrastructure for climate information services, as well as capacity-building activities for key government institutions and other relevant actors, and as such, generates the potential to build resilience in the energy sector as well. However, due to low country demand to-date, the number of funding requests received by the Adaptation Fund so far in the energy sector has been small.

CIF has invested over US$ 220 million of its US$ 1.2 billion of climate-resilience funding in activities to strengthen hydrometeorology and climate services in selected countries.[109] This investment addresses the full weather and climate information services value chain, including: observations and monitoring; data and information management; research, forecasting and modelling; and the development and provision of improved services, as well as the training and capacity building underpinning all four components.

GEF, through the Least Developed Countries Fund (LDCF) and the Special Climate Fund (SCCF), has provided more than US$ 850 million in grant finance to date for projects that include climate information services. The systemic capacity building in key institutions and creation of infrastructure for climate information services under these projects will benefit multiple sectors, including in some cases the energy sector. Some LDCF- and SCCF-financed projects include a specific focus on enhancing the climate resilience of the energy sector.

The GCF was established under the Cancún Agreements in 2010 as a financial mechanism of the Paris Agreement and UNFCCC. The total current (May 2021) GCF portfolio amounts to US$ 10.1 billion[110] in committed funding, of which energy-access and power-generation projects constitute 25% (US$ 2.5 billion). Energy efficiency and low-emission transport account for US$ 1.3 billion and US$ 0.5 billion, respectively. The area of cities, buildings and urban systems also to a large degree includes energy optimization, and this result area amounts to US$ 0.9 billion. Hence, half of the GCF commitments are allocated to projects in the energy sector. The bulk of energy-sector-related commitments are devoted to the Asia–Pacific region (US$ 2 billion (39%)) and Africa (US$ 2 billion (38%)). Commitments to energy-sector projects in Latin America and the Caribbean amount to US$ 0.8 billion (16%), and US$ 0.3 billion (6%) is devoted to Eastern Europe.[111]

108 Tracking SDG7: The Energy Progress Report 2022
109 Learning Review of CIF-Supported Hydromet and Climate Services Projects
110 US$ 39 billion, when both GCF and non-GCF co-financing are included.
111 The information on the climate services for energy portfolio is not available.

Regional overview

Photo: Kyle Glenn/ Unsplash

SDG 7 overview[112]

In 2019, the share of renewable energy sources in TFEC amounted to 17.7% – only 0.4% higher than the year before. Significant regional disparities lie behind these global improvements (Figure 20). Africa has the largest share of renewable sources in its energy supply, though modern renewables represent only 7.6% of the renewable total. Excluding traditional uses of biomass, South America is the region with the largest share of modern renewables in TFEC, thanks to significant hydropower generation, the consumption of bioenergy in industrial processes and the use of biofuels for transport. In 2019, 44% of the global year-on-year increase in modern renewable energy consumption took place in Eastern Asia, where hydropower, solar PV and wind dominated growth.

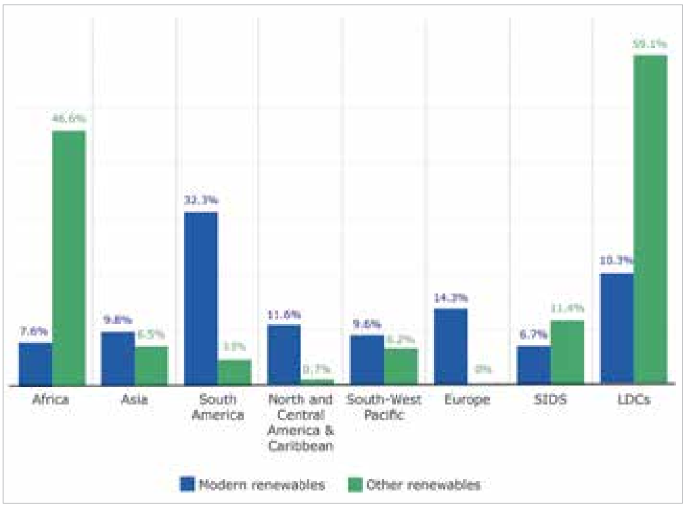


Figure 20: Percentage share of modern renewable energy systems[112] and other renewable systems, by region
Source: SDG 7.2 data are sourced from IEA, IRENA and UNSD and analysed by WMO to fit its regional classification.

The rate of improvement in global primary energy intensity[114] has slowed in recent years, and differences are observable across regions (Figure 21). Eastern Asia and South-East Asia surpassed the SDG 7.3 target between 2010 and 2019, with energy intensity improving by an annual average rate of 2.7%, driven by strong economic growth. Average annual improvement rates in Oceania (2.2%), Northern America and Europe (2%), and Central Asia and Southern Asia (2%) were also above the global average and historical trends. Energy intensity in Africa is the highest among all other regions, highlighting differences in economic structure, energy supply and access rather than energy efficiency.

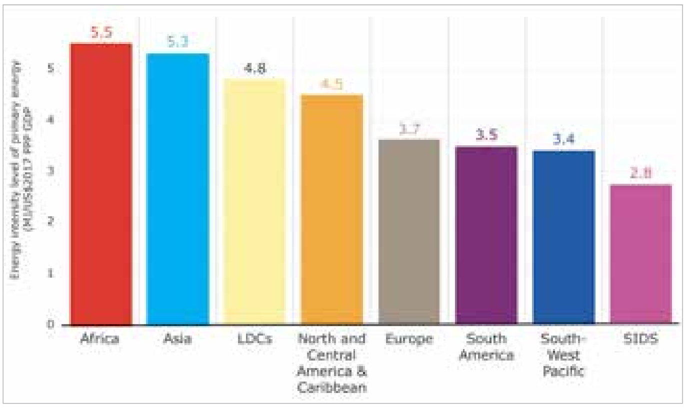


Figure 21: Energy intensity level of primary energy (MJ/$ 2017 purchasing power parity (PPP) GDP) by WMO region including SIDS and LDCs
Source: SDG 7.3 data are sourced from IEA and UNSD and analysed by WMO to fit its regional classification.

Investment

In line with overall mitigation finance flows, in 2019–2020 the majority of renewable energy investments were made in the East Asia and Pacific region, mainly China and Japan, followed by Western Europe, and North America, mainly the United States and Canada. Since 2013, these three regions have consistently attracted 65%–75% of global investments, while developing and emerging economies continue to remain underrepresented,[115] despite their potential renewable energy resources (Figures 22–24).

Renewable energy potential

The power sector presents a significant opportunity for transformation through the increased deployment of renewable energy technologies.

Renewable energy resources are plentiful in Africa, especially solar, but also wind, biomass, geothermal and hydropower.[116] **Africa** could meet nearly a quarter of its energy needs from indigenous and clean renewable energy by 2030. Modern renewables amounting to 310 GW could provide half the continent's total electricity generation capacity. This corresponds to a sixfold increase from the capacity available in 2021, which amounted to 56 GW.[117]

112 This is an adaptation of an original work by IEA, IRENA, UNSD, World Bank and WHO. Views and opinions expressed in the adaptation are the sole responsibility of the author or authors of the adaptation and are not endorsed by IEA, IRENA, UNSD, World Bank and WHO.
113 Modern renewables include all uses of renewable energy with the exception of traditional use of solid biomass.
114 Energy intensity is the ratio of total energy supply to the annual GDP created – in essence, the amount of energy used per unit of wealth created. It drops as energy efficiency improves.
115 Global Landscape of Renewable Energy Finance 2020
116 Africa Power Sector: Planning and Prospects for Renewable Energy
117 Scaling Up Renewable Energy Deployment in Africa: Impact of IRENA's Engagement

According to IRENA, the share of renewables in the generation mix could grow to 50% by 2030 in Africa. The total installed renewable energy generation capacity would reach 310 GW. Hydropower and wind capacity could reach 100 GW each, and solar capacity could reach over 90 GW. This would be an overall tenfold renewable energy capacity increase from 2013 levels for the power sector in Africa.[118]

According to IEA, **South-East Asia** has considerable potential for renewable energy, but (excluding the traditional use of solid biomass) renewables currently meet only around 15% of the region's energy demand. Hydropower output has quadrupled since 2000, and the modern use of bioenergy in heating and transport has also increased rapidly.[119] A recent study assessed the national potential of wind and PV to help China achieve its goal of carbon neutrality by 2060.[120] The results showed that, under the current technological level, the wind and PV installed capacity potential of China is approximately nine times that required under the carbon-neutral scenario.

Latin America is a region of rapid growth for renewable energy, with interest in developing those resources growing even faster.[121] Additionally, according to IRENA, the region hosts some of the world's most dynamic renewable energy markets, building on the historical role of hydropower – the cornerstone of the region's power sector development – and liquid biofuels, driven by Brazil's early determination to diversify its transport fuel mix.[122]

North America features some of the world's richest wind, solar, geothermal, hydropower and biomass resources.[123] The region relies on renewable energy for large-scale power generation, particularly in the form of hydropower.[124]

The **South-West Pacific** region is rich in renewable energy resources, with potential for hydropower in Fiji, Papua New Guinea, Samoa, Solomon Islands, the Federated States of Micronesia and Vanuatu, and strong potential for solar and, to a lesser extent, wind throughout the region.[125] The Pacific islands are endowed with a rich variety of renewable energy resources, providing a viable and attractive alternative to fossil fuel imports. The people of the Pacific islands are cognizant of the fact that universal access to secure, robust, sustainable and affordable electricity, transport fuel and household energy services is crucial for their sustainable development efforts and that energy supplies must be resilient to climate change and natural disasters and increasingly supplied by renewable resources, with improved energy efficiency, upgraded energy infrastructure and improved technologies. In their resolve to contribute to achieving the Paris Agreement goal, Pacific islands energy Ministers have reaffirmed their commitment to 100% renewable energy generation for the Pacific islands region.[126]

In **Europe**, the share of renewable energy more than doubled between 2004 and 2020, reaching 22.1% of gross final energy consumption in 2020. Wind and hydropower each accounted for more than two thirds of the total electricity generated from renewable sources (36% and 33%, respectively). The remaining third was generated from solar power (14%), solid biofuels (8%) and other renewable sources (8%). Solar power has been the fastest-growing source since 2008.[127]

SIDS face a range of pressing challenges, from coping with the effects of climate change to dependence on costly fuel imports to meet their energy needs. To address these challenges, SIDS have resolved to harness their vast renewable energy potential, with a view to strengthening climate resilience and improving energy security.[128] Most SIDS are well placed geographically and geomorphologically to benefit from solar and wind potentials, tidal and oceanic energy sources, and sometimes geothermal and hydropower.[129] Through the SIDS Lighthouses initiative (LHI), most of the targets for 2020 and 2023 have been met or exceeded ahead of schedule. Taking into account the success in surpassing the previous targets, the SIDS LHI has revised its target to 10 GW of total renewable energy installed capacity in all SIDS by 2030. This new target has formed the basis of the IRENA-AOSIS Energy Compact and the Ambitious SIDS Climate Action Summit Package, which are operationalized by the SIDS LHI.[130]

According to the Least Developed Countries Renewable Energy and Energy Efficiency Initiative for Sustainable Development, while most LDCs are endowed with significant renewable energy resource potentials, the majority of their people, productive sectors and development efforts suffer from energy deficits.[131] Renewable energy sources, such as solar and wind power, could have a revolutionary effect in rural areas, home to 82% of those without power in LDCs, and help to overcome the historical obstacles to rural electrification.[132] Access to energy in the LDCs remains a major challenge despite the extraordinary growth potential for energy transformation in these countries. Appropriate financing is needed more than ever to transform livelihoods and economies to build a future based on climate-resilient, low-emission development.[133]

118 Africa 2030: Roadmap for a Renewable Energy Future
119 Southeast Asia Energy Outlook 2019
120 Assessment of Wind and Photovoltaic Power Potential in China
121 Renewable Energy in Latin America 2015: An Overview of Policies
122 Renewable Energy Market Analysis: Latin America
123 North America
124 North America
125 The Pacific Islands: The Push for Renewable Energy
126 Framework for Energy Security and Resilience in the Pacific (FESRIP) 2021–2030
127 Renewable Energy Statistics
128 Transforming Small-island Power Systems: Technical Planning Studies for the Integration of Variable Renewables
129 Renewables and Energy Transitions in Small Island States
130 SIDS Lighthouses initiative
131 LDC REEEI Framework
132 LDC - Progress in Least Developed Countries Hinges on Access to Modern Energy, new United Nations Report Says
133 High-level Briefing to LDCs Group on Accelerating Sustainable Recovery with Renewable Energy

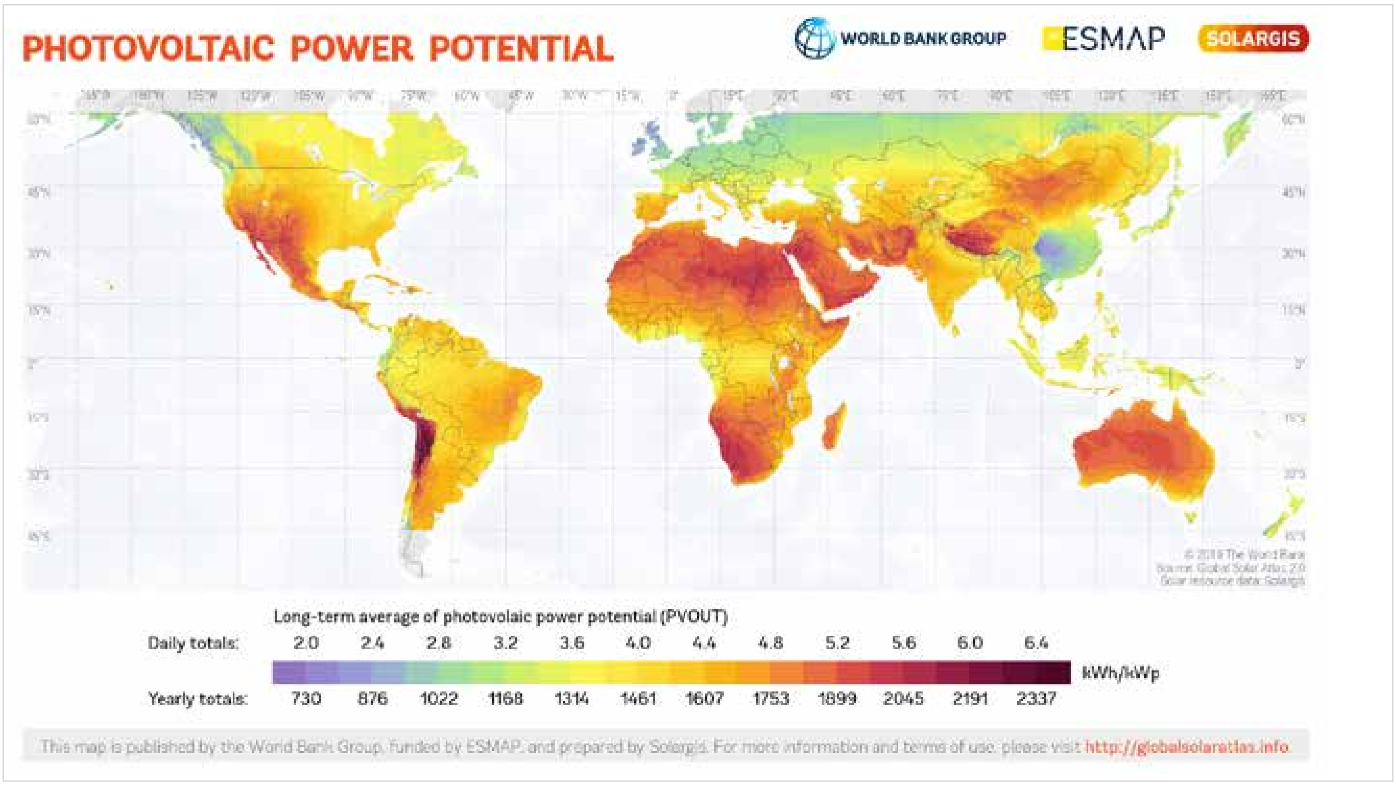


Figure 22: Long-term average daily/yearly sum of electricity production from a 1 kW peak grid-connected solar PV power plant
Source: Global Solar Atlas 2.0; Solar resource data: Solargis, from 1994 to 2018 for some regions

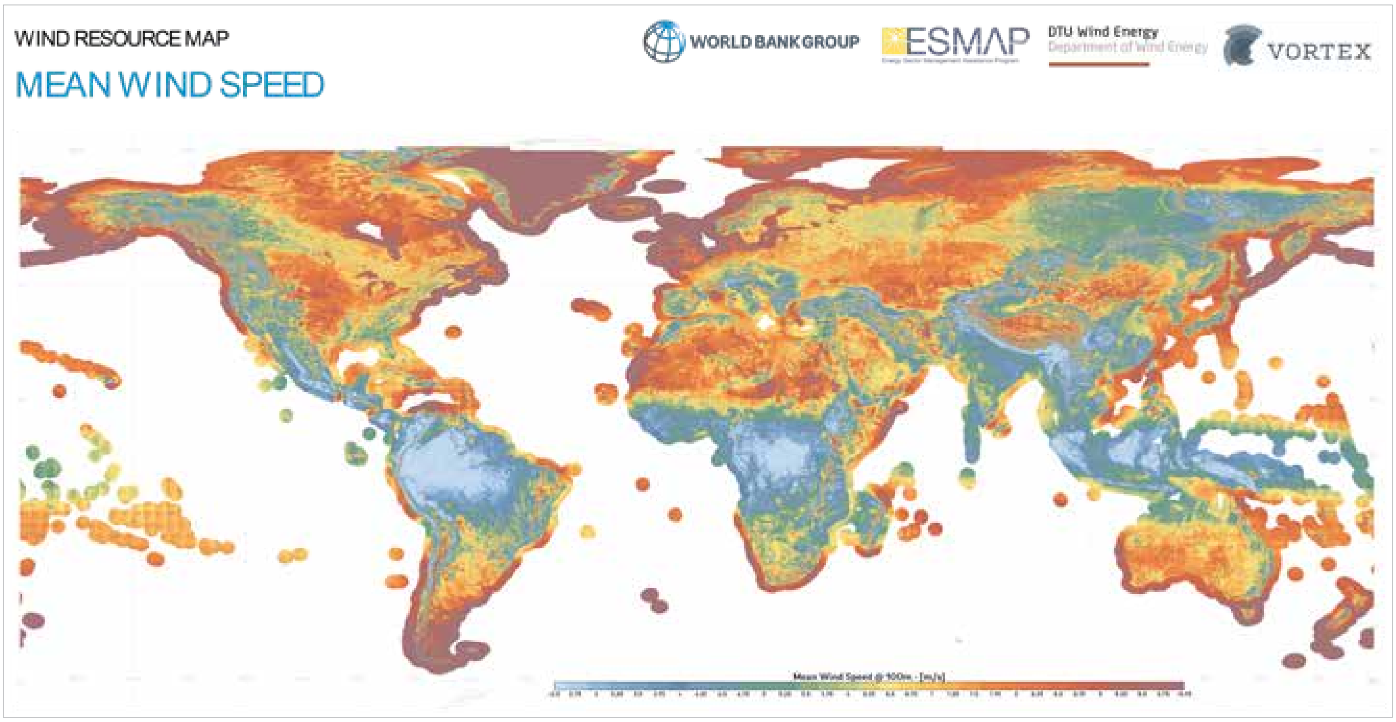


Figure 23: An estimate of mean power density at 100 m above surface level globally. Power density indicates wind-power potential, part of which can be extracted by wind turbines. The map is derived from high-resolution wind-speed distributions based on a chain of models, which downscale winds from global models (~30 km) to mesoscale (3 km) and to microscale (250 m). The Weather Research and Forecasting (WRF) mesoscale model uses data from the European Centre for Medium-Range Weather Forecasts ECMWF Reanalysis v5 (ECMWF ERA5) reanalysis data for atmospheric forcing, sampling from the period 1998–2017.
Source: Global Wind Atlas, v. 3, from 1998 to 2017

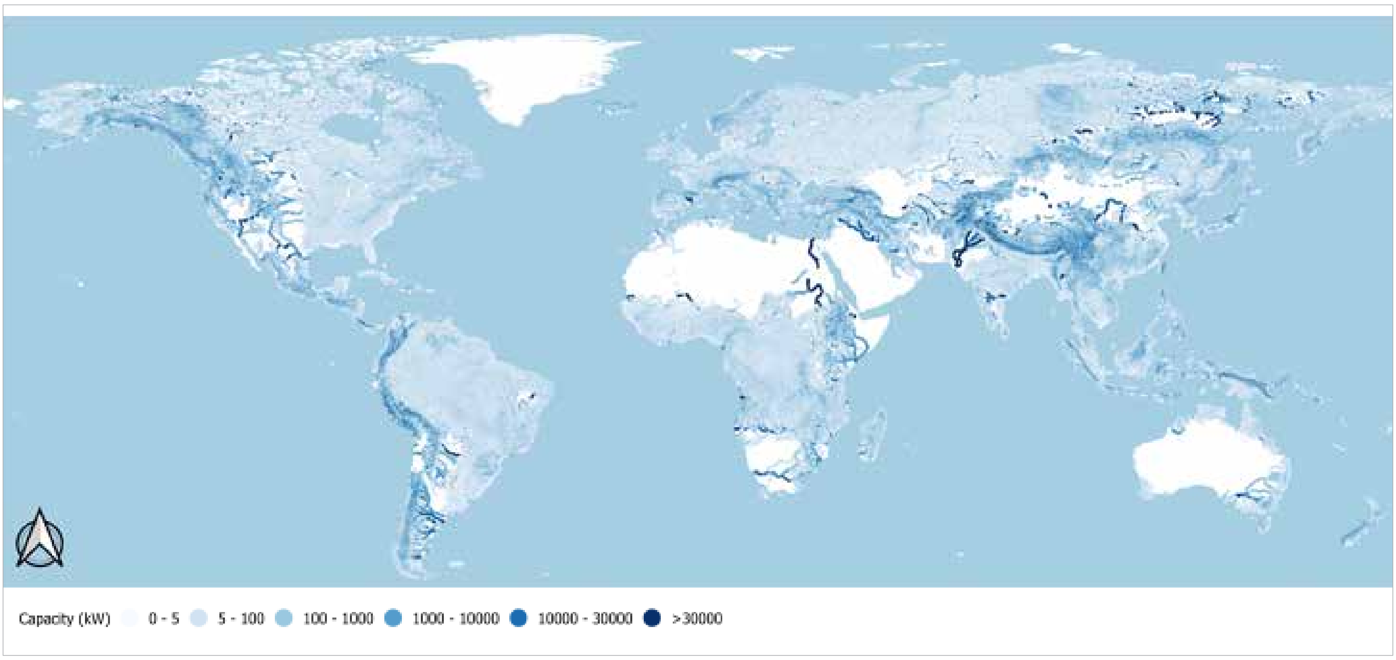


Figure 24: An estimate of potential hydropower plant locations (for microhydropower to large-sized plants) based on the Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010) break line datasets (elevation) and runoff data from the Global Runoff Data Centre

Source: Global Potential Hydropower Locations Research Dataset

OVERVIEW OF CLIMATE SERVICES FOR ENERGY

With regard to the provision of climate services, data show that all regions have a high number of Member NMHSs providing those services to the energy sector. Regional disparities exist when it comes to the provision of the different products, with climate projections provided by the lowest percentage of NMHSs across all regions, except Europe (Figure 25).

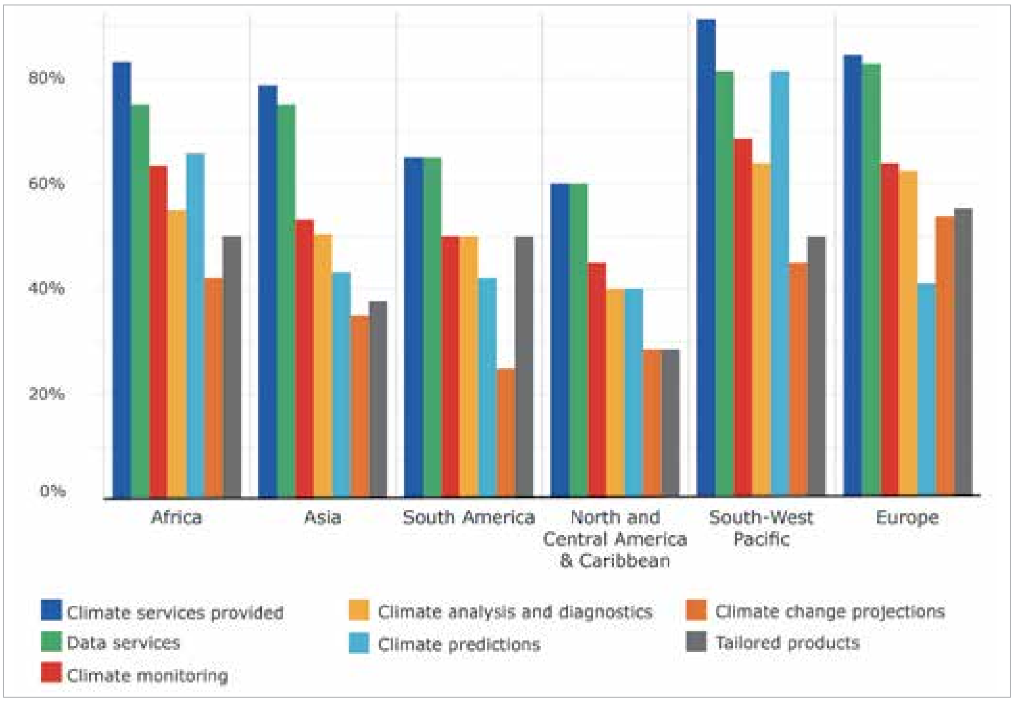


Figure 25: Percentage of WMO Member NMHSs in each region providing climate services (CS) for energy, by type of product. Information collected from 2020 to May 2022.

Gaps

Photo: Matthew Henry/Unsplash

1. **THE IMPACT OF INCREASING CONCENTRATIONS OF GHGs IN THE ATMOSPHERE CONTINUES TO RAISE CONCERNS ABOUT ENERGY SECURITY.**

   Heatwaves and droughts associated with anthropogenic climate change are major hazards for energy systems. Systems dominated by renewable energy are highly climate sensitive, yet recognition of the need for climate services to support expansion of renewable energy and other forms of mitigation remains extremely low compared with other climate-sensitive sectors.

2. **JUST 40% OF NDCs SUBMITTED BY PARTIES TO THE UNFCCC PRIORITIZE ADAPTATION IN THE ENERGY SECTOR.**

   This is despite the fact that in 2020, 87% of global electricity generation provided by nuclear, thermal and hydroelectric systems directly depended on water availability. A third of the thermal power plants that rely on freshwater availability for cooling are already located in high water stress areas. This is also the case for 15% of existing nuclear power plants, a share expected to increase to 25% in the next 20 years.[134] Eleven per cent of hydroelectric capacity is located in highly water-stressed areas.[135] And approximately 26% of existing hydropower dams and 23% of projected dams are within river basins that currently have a medium to very high risk of water scarcity.[136] Heatwaves and droughts associated with climate change are already putting existing energy generation under stress.[137] Because of past and future greenhouse gas emissions, a gradual and irreversible rise of the sea level will occur throughout the century and well beyond, irrespective of the future state of the climate, with consequences for the design and siting of current and future facilities located on coastlines.[138] Seventy-three nuclear powerplants are located near the seacoast, according to IAEA.

3. **CURRENT GHG REDUCTION COMMITMENTS MADE BY COUNTRIES ARE STILL WELL SHORT OF WHAT IS NEEDED TO ACHIEVE THE LONG-TERM TEMPERATURE GOAL OF THE PARIS AGREEMENT.**

   Supply from low-emissions energy sources needs to double, according to IEA. Just 56% of NDCs include quantified targets for renewable power to collectively reach 3.7 TW of clean energy provision by 2030. The pathway to reach the Paris Agreement goal, limiting temperature rise to well below 2 °C, demands 7.1 TW of clean energy by 2030, according to IRENA.

4. **MORE THAN 70% OF WMO MEMBER NMHSs PROVIDE CLIMATE SERVICES FOR ENERGY. CURRENT CLIMATE SERVICES ARE NOT PERFORMING WELL AND THERE IS A SIGNIFICANT MISMATCH BETWEEN THE POTENTIAL FOR SERVICE DELIVERY AND THE ACTUAL DEMAND FOR SUCH SERVICES.**

   Climate services are crucial in enabling the global energy transition, ensuring the resilience of energy systems to climate-related shocks and to inform measures to increase energy efficiency. The global average rating given by Members is just three out of six[139] potential levels of service representing increasing user engagement. Moreover, just 6% of NDCs mention climate services for energy for mitigation, versus 64% for adaptation, indicating under-recognition of the need for such services to support the energy transition.

5. **DEVELOPING AND EMERGING ECONOMIES CONTINUE TO REMAIN UNDERREPRESENTED WHEN IT COMES TO ACCESSING CLEAN ENERGY FINANCE.**

   The majority of renewable energy investments are being made in the East Asia and Pacific region – mainly China and Japan, followed by Western Europe, and North America, mainly the United States and Canada, according to CPI. Least developed countries receive only a fraction of international financing for renewable energy, and only 2% of such investments in the last two decades were made in Africa.[140]

134 World Energy Outlook 2021
135 Water Stress Threatens Nearly Half the World's Thermal Power Plant Capacity
136 Using the WWF Water Risk Filter to Screen Existing and Projected Hydropower Projects for Climate and Biodiversity Risks
137 IAEA, *Climate Change and Nuclear Power, Securing Clean Energy for Climate Resilience* (in press)
138 IAEA, *Climate Change and Nuclear Power, Securing Clean Energy for Climate Resilience* (in press)
139 Six levels of sophistication of climate services to the energy sector: 1 = initial engagement with sector; 2 = definition of needs; 3 = co-design of products; 4 = tailored products accessible for use; 5 = climate services guide policy decisions and investment plans in sectors; 6 = documentation of socioeconomic benefits.
140 Renewable Energy Market Analysis: Africa and its Regions

Recommendations

THERE IS A HUGE OPPORTUNITY FOR AFRICA TO HELP CLOSE THE GAP IN THE NEED FOR RENEWABLE ENERGY.

To put the world on a trajectory to reach NZE by 2050, current levels of investment in renewable energy, including in associated climate services, need to at least triple.[141] Given current low levels of investment in Africa, there is great potential for clean energy investments in that region.

African nations host the lowest percentage of modern renewable systems (just 7.6% of final energy consumption), and only 2% of global investments in renewable energy in the last two decades were made in Africa.[142] The region has huge potential to deploy solar energy systems; Africa is home to 60% of the best solar resources globally, yet only 1% of installed solar PV capacity.[143] It also has large resource potential in wind and hydropower.

According to IEA, bringing access to modern energy for all Africans calls for investment of US$ 25 billion per year.[144]

By 2050, the global power sector will consist mainly of renewable energy, with solar the single largest source of supply, according to IEA's Net Zero Emissions by 2050 Scenario.[145] African countries have an opportunity to be major players within the market.

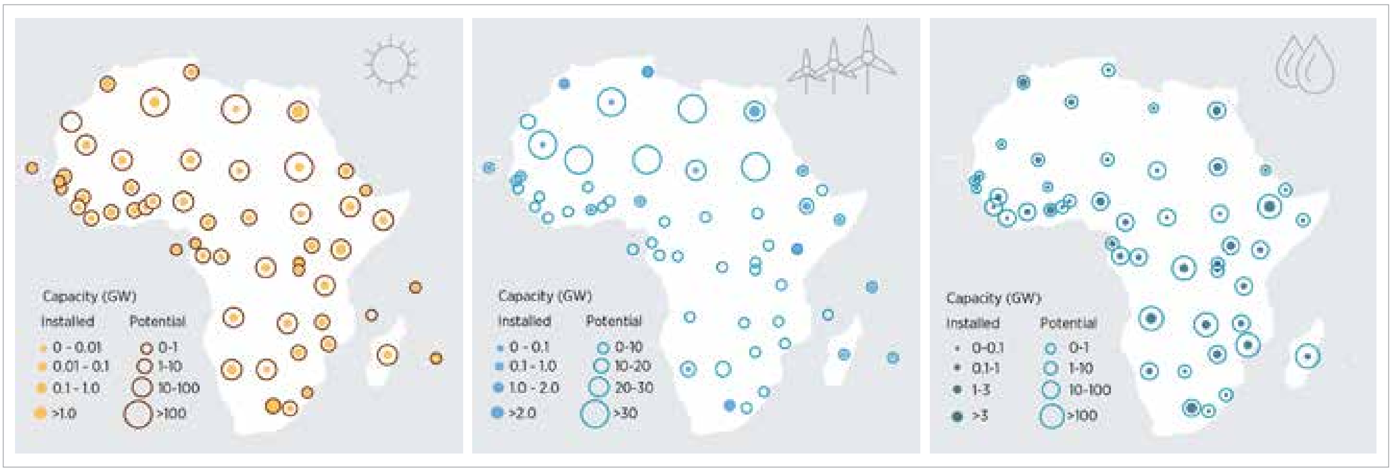


Figure 26: Renewable energy potential and capacity installed in Africa, for wind, solar and hydropower
Source: IRENA, 2022

ENERGY POLICIES AND COMMITMENTS NEED TO BETTER ADDRESS ENERGY SECURITY IN A CHANGING CLIMATE AND PROMOTE THE TRANSITION TO NET ZERO, INCLUDING BY SCALING UP CLIMATE, WATER AND WEATHER SERVICES.

More effective climate services for energy will not only create attractive market conditions to scale up renewable energy infrastructure, but they will also ensure that clean energy systems are efficient and resilient to climate change. Increased, sustained investments and enhanced policies are required to achieve this goal. There is currently little recognition of the need for such services in NDCs, in which the need for adaptation in the energy sector is under-recognized in relation to the exposure and vulnerability of the sector, along with its importance for other sectors, and in which the recognition of the need for climate services for mitigation, including for energy, is almost absent.

141 As compared to annual renewable energy investments (2019–2020), according to CPI.
142 Renewable Energy Market Analysis: Africa and its Regions
143 Africa Energy Outlook, IEA, 2022
144 Africa Energy Outlook, IEA, 2022
145 Net Zero Emissions by 2050 Scenario (NZE)

SPECIALIZED SERVICES FOR RENEWABLE ENERGY ARE SUB-OPTIMAL. GIVEN THE INCREASING RATE OF NEW RENEWABLE GENERATION, THERE IS A NEED TO CONSIDERABLY STRENGTHEN THESE SERVICES.

Future activities should focus on better addressing the needs of end users, according to CIF. Strengthening partnerships and collaboration through demand-led and co-created project design processes across regions, government agencies, key sectors, the private sector and vulnerable communities, to promote buy-in and collaboration, emerges as a solution from the 2021 Learning Review of CIF-Supported Hydromet and Climate Services Projects.[146] This is further confirmed by WMO data from 52 Members. Furthermore, increases are needed in the density of meteorological observations to address significant monitoring gaps and improve data coverage according to CIF, a conclusion confirmed by WMO data. Fifty-six WMO Member NMHSs confirmed the need for training courses and workshop to strengthen their capacity to improve delivery of climate services to the energy sector.

146 Learning Review of CIF-Supported Hydromet and Climate Services Projects

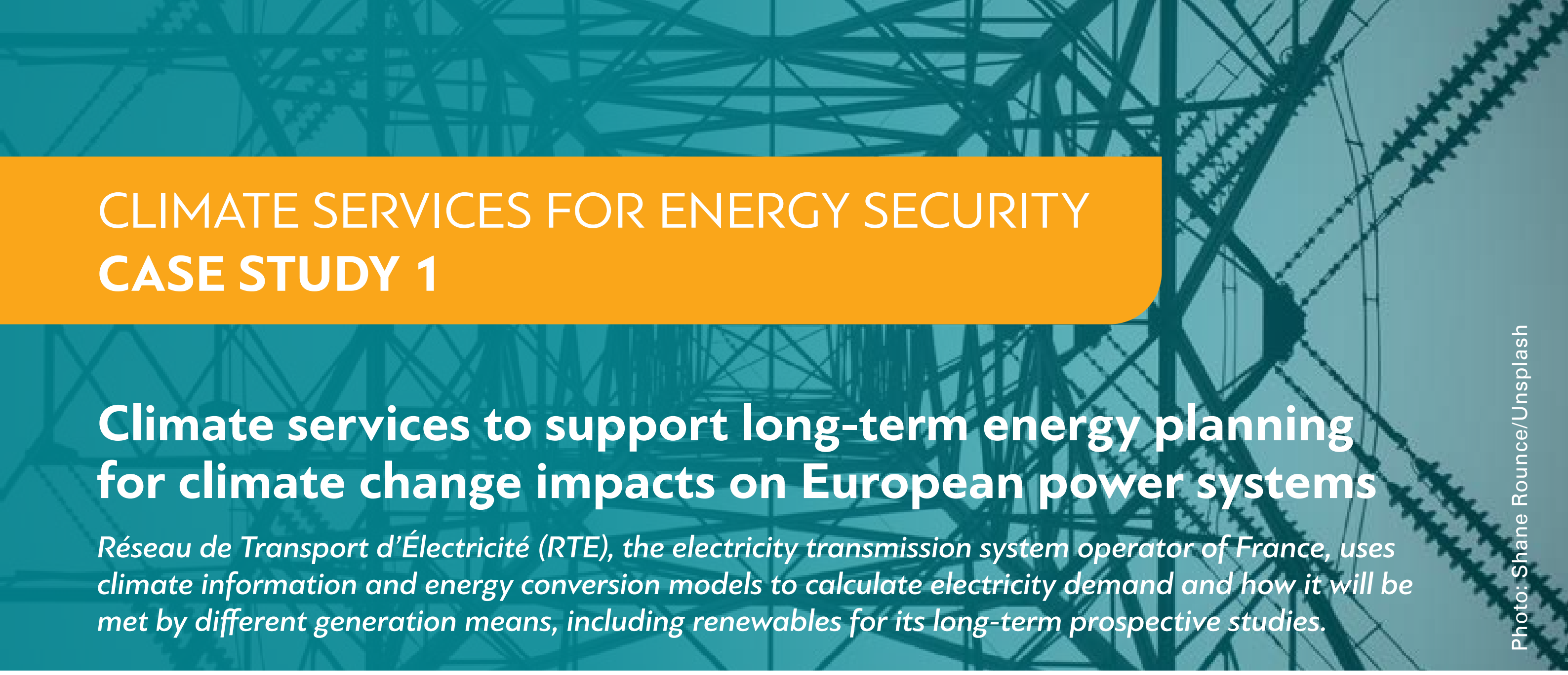


Photo: Shane Rounce/Unsplash

CLIMATE SERVICES FOR ENERGY SECURITY
CASE STUDY 1

Climate services to support long-term energy planning for climate change impacts on European power systems

Réseau de Transport d'Électricité (RTE), the electricity transmission system operator of France, uses climate information and energy conversion models to calculate electricity demand and how it will be met by different generation means, including renewables for its long-term prospective studies.

CHALLENGE

Long-term planning for the transition to generating a higher percentage of energy from renewable sources is particularly dependent on climate information. Climate change obviously has significant impacts. A major concern is temperature, which in France may increase on average from 12.0 °C in 2000 to 13.6 °C in 2050 under the RCP4.5 climate change scenario (14.0 °C under RCP8.5). According to climate projections, winter cold waves will become less intense and less frequent. A significant increase in the number and duration of summer heat waves is also expected. Wind speed and solar irradiance show light changes, however these are an order of magnitude lower than the current interannual variability. Precipitation, river flow and consequently hydropower generation capacity show a moderate annual decrease, which hinders a stronger seasonal change, with increased generation in winter and decreased generation in summer and early autumn.

In compliance with its legal obligations and at the request of the Government of France, RTE initiated a two-year study on the evolution of the power system, Energy Pathways 2050, published in February 2022. This project was undertaken at a crucial point in the public debate about energy and the climate, shaping the strategies that will be adopted to move away from fossil fuels and achieve carbon neutrality in 2050, as per the long-term global goal of the Paris Agreement.

APPROACH

This study assessed climate change through high-resolution time series for several variables (air temperature, precipitation, river discharge, wind speed and solar irradiance), for the current and projected future climate, at hourly and 20 km resolution, over the whole of Europe. The study included climate simulations designed building on a long-term collaboration with Météo-France, France's National Meteorological Service. The resulting dataset consists of three sets of 200 climate years. The first one represents the climate of the 2000s, while the other two represent the climate of the 2050s under RCP4.5 and RCP8.5, respectively. These simulations were compared to other sources of data, including EURO CORDEX, Copernicus and some CMIP6 simulations, which established that they are in line with other climate simulations.

RTE then designed energy conversion models to calculate the corresponding time series of electricity demand, and generation from wind, solar and hydropower, as well as nuclear power plant availability based on cooling system constraints. All these data fed RTE's power system model that provides results related to technical, economic, environmental and societal aspects.

RESULT

As expected, the major change is related to the increase in temperature. While currently the power system is very sensitive to extreme cold, the future energy mix will be more sensitive to cold (but not extreme) events associated with wind drought, that is, reduced wind energy generation. However, the analysis showed that most extreme cold events are not associated with the lowest wind speeds. On the other hand, summer stress tests showed that late-summer hydrological drought and heat waves might become more problematic for riverside thermal generation plants.

Future activities will include consideration of upgrading the climate database to take into account more recent climate projections, additional RCP scenarios and additional climate models. A more dynamic representation will also be explored, by considering the models' outputs throughout the twenty-first century.

While currently the power system in France is very sensitive to extreme cold, the future energy mix will be more sensitive to cold events associated with wind drought and resulting reduced production of wind energy.

PARTNERS

RTE, Météo-France and Institut Pierre-Simon Laplace (IPSL).

Photo: Nazrin Babashov/Unsplash

CLIMATE SERVICES FOR ENERGY SECURITY
CASE STUDY 2

EDF is coordinating climate adaptation at a group level

Using the Copernicus Climate Change Service (C3S), the global energy business EDF has created an internal climate service to access global climate observations and projections in a consistent way.

CHALLENGE

Electricity generation, load and transmission are highly dependent on the weather conditions. Therefore, EDF, one of Europe's major electricity companies, launched a research programme devoted to climate change in 1990. The 2003 heat wave underscored the necessity of adapting to the ongoing changes in the climate, and a series of climate change impact projects were launched starting in 2004. Because the demand for climate impact studies kept growing, coming from more and more branches of the group, it became necessary to ensure consistency between the different studies, in order to appropriately inform the adaptation strategy at the group level.

APPROACH

At the European level, C3S provides valuable information on the current climate status and its projected evolution. EDF R&D contributed from the beginning to the development of the sectoral service devoted to energy. At the national scale in France, the portal 'DRIAS les futurs du climat' makes available climate information and projections downscaled to France at 8 km spatial resolution, and EDF R&D set up a user's group which oriented the development in the starting phase. While France and Europe are the main regions for EDF's business, it operates worldwide. Therefore, the need for consistent access to global climate observations and projections to answer various questions soon arose. This led in 2014 to the creation of an internal climate service organized around three pillars: the gathering and provision of data, the development of tools and the development of expertise in climate change science.

RESULT

Relying on scientific partners and on international data portals like the Copernicus Climate Data Store (CDS), a subset of around 20 models was selected among all the contributors to the Coupled Model Intercomparison Projects, and the corresponding projections were downloaded and stored internally. In terms of emission scenarios, the largest number of scenarios available for most of the models was considered. The selection was based on various criteria, including the model dependency, the IPCC AR6 best estimate equilibrium climate sensitivity range and the need to best cover the projection spread. Sub-ensembles of EURO CORDEX projections were also retrieved.

Basic tools devoted to the manipulation of the datasets have been proposed and shared: calendar management, search for available variables, extraction of selected variables over a chosen region or for selected grid points, bias adjustment and downscaling. Dedicated studies have been devoted to the comparison of different downscaling approaches, as well as to temporal downscaling to hourly timesteps. For nuclear power plant adaptation, a methodology has been proposed to select four combinations of a climate model and an emission scenario projecting, respectively, one low-change scenario, two intermediate-change scenarios and a high-change scenario at the 2050 horizon. Furthermore, some dedicated studies necessitate the development of targeted methodologies. For example, nuclear power plant safety continuity involves the estimation of very rare extreme levels in taking climate change into account. Original approaches have been proposed and published to estimate future return levels of high temperatures based on the extremes of a standardized variable and the changes in mean and standard deviation,[147] or future extreme low flows using stochastic modelling.[148] This allows EDF to regularly update knowledge about the sensitivity of its assets, especially nuclear power plants, and take adaptation measures to ensure resilience or inform decisions on the design and location of future power plants.

EDF is a global business. Therefore, there is a need for consistent access to global climate observations and projections.

PARTNERS

EDF and C3S.

147 Future High-temperature Extremes and Stationarity
148 Extreme Low Flow Estimation under Climate Change

Photo: Carrie Borden/Unsplash

CLIMATE SERVICES FOR ENERGY SECURITY
CASE STUDY 3

Climate-proofing of local development and investment plans in the Dolomites

The Socio-Economic Regional Risk Assessment (SERRA) method can map historical and future climate risk to multiple sectors in Italy's Belluno Province.

CHALLENGE

The uncertain evolution of climatic hazard, related to different factors such as internal uncertainty, model uncertainty and scenario uncertainty,[149] calls for policy preparedness, prompt adaptation strategies and the integration of potential climatic impacts into national and regional planning. Considering this, practitioners in multiple economic sectors – from infrastructure to finance – are becoming more and more aware of the importance of climate-proofing in strategic planning and decision-making, to cope with climate risk. Climate change is recognized as a new source of risk to financial and economic stability, negatively affecting productive capacity and social well-being.

APPROACH

In this regard, a climate stress test has been developed to assess how climate risk might propagate through the financial system and showing how policy timing might help reduce negative effects of hazardous events.[150]

The study focused on the Alpine region, where climate change has already shown remarkable effects in terms of temperature rise (2 °C over the last 120 years) at a pace that is as much as twice the global average, with dramatic consequences in terms – for example – of glacier retreat and disappearance.

The approach adopted derives from the SERRA method developed by the European Union Kulturisk Project.[151] It combines high-resolution regional climate model (RCM) data, custom-tailored to the characteristics of the studied area and the hazards to be analysed, with a solid analysis of the four main economic activities: tourism, winter sports, the eyewear industry and the electricity supply. This integrated approach allows estimation of the potential damages associated with risks of different kind and magnitude, offering a concrete application of the adopted methodology and potentially supporting stakeholders and policy makers in future decision and investments.

RESULT

The SERRA integrated approach combines classical spatial risk assessment with socioeconomic analysis, enabling estimation of the damages associated with potential risks of different types for different economic activities. By aggregating historical and future risk maps over the whole of Belluno Province, we found an increase of up to 6.2% in the direct climate risk and a 10.2% increase in the indirect climate risk for wet snow events in the 2036–2065 period.

A series of sectoral sets of maps and tabular syntheses provides private and public decision makers with extensive documentation that can be considered when making strategic decisions for investments and planning with medium to long-term perspectives.

Results show that some areas have combinations of multiple risks at higher levels, which should be carefully considered in planning. This is the case in key areas for eyewear production (Longarone, Sedico, Agordo), where risks for winter sports are also present. Even more relevant is the combination of high risks for summer tourism with moderate to high risks for both electricity distribution and winter sports in the area of Cortina.

Historical and future risk for the whole of Belluno Province shows a 6.2% increase in the direct climate risk for wet snow events in the 2036–2065 period.

PARTNERS

Venice International University (VIU), the CMCC Foundation – Euro-Mediterranean Center on Climate Change, Ca' Foscari University of Venice and Enel Foundation.

149 On the Interpretation of Constrained Climate Model Ensembles; The Potential to Narrow Uncertainty in Regional Climate Predictions; Robust Adaptation to Climate Change
150 A Climate Stress-test of the Financial System
151 The Socio-economic Dimension of Flood Risk Assessment: Insights of KULTURisk Framework

CLIMATE SERVICES FOR ENERGY SECURITY

CASE STUDY 4

Integrated weather services for offshore wind power production in China

An early warning system aims to address risks to human life, energy stability and company assets via an online platform which issues warnings and recommendations regarding weather events posing risks to offshore wind farm operations.

Photo: Luo Lei/Unsplash

CHALLENGE

Offshore wind farm operations face high risks to human life, as well as high operational costs and risks. Users determined their need for this service due to losses of around RNB 100 million that resulted from the cutting of an underwater construction cable in a dangerous weather event. The July 2022 sinking of the *Fujing* 001 offshore wind installation ship, located near facilities owned by a user of this service, further highlights the ongoing need for life-saving technologies such as this.

APPROACH

The Beijing JiuTian Meteorological Technology Co. has developed a predictive early warning system which integrates various types of meteorological data into a visualization product used by decision makers on offshore wind farms to inform their practices in a way which preserves human life and prevents financial losses due to accidents harming company assets. Such decisions include when to remove workers from plants before dangerous weather situations occur, and which periods are safest for conducting maintenance.

The service improves on existing weather forecasting services in that it offers recommendations on what action to take for the specific weather event, tailored to the specific situation and needs of each individual user. Prior to the deployment of the system, departure decisions were made mainly by captains, based on their experience and best judgment. Now, operation plans are better informed by wind and wave predictions, so that the client can tell exactly which ships are in danger, and what should be done to mitigate the situation.

RESULT

The service provider estimates that it provides around 100 early warning notices per wind farm per year. Warnings are received by the users in time for stakeholders to react immediately and to a sufficient degree, and wind farms owned by users of this service report no losses of human life or company assets since its implementation in late 2020.

As equipment used for the construction of new offshore wind farms is rented, accurate and reliable information on when weather conditions will be ideal for construction helps reduce the costs of construction. The service user CGN New Energy experienced a reduction in construction costs of RNB 11 million (0.5%) per year across its eight wind farms.

Accurate predictions of when weather conditions will be ideal for maintenance also help decrease the amount of time that wind turbines are inactive (and not generating electricity), thereby increasing the maximum amount of power generated per turbine per year. Thanks to the precise maintenance window prediction provided by the service, "trouble-free operation time" of wind turbines has increased by 10 hours per year. In turn, increased reliability of wind power generation allows for greater penetration of wind power into the country's energy mix, and decreases energy costs.

CGN New Energy has experienced a reduction in construction costs of RNB 11 million (0.5%) per year across its eight wind farms.

PARTNERS

China Meteorological Administration.

CASE STUDY 5

Early weather warnings to safeguard electricity supply for Beijing

To better safeguard Beijing's electricity supply security, the Energy Service Team under the China Meteorological Administration (CMA) has worked with the Beijing Branch of State Grid[152] to create a precise early warning system.

Photo: Jinyang Liu/Unsplash

CHALLENGE

As a megacity, Beijing requires a continuous and highly reliable power supply. Extreme weather events, such as rainstorms, floods, gales, hail, and cold waves have caused great threats to the operation of Beijing's power grid. In recent years, various meteorological disasters and their derivative factors caused more than 50% of all distribution network failures.

APPROACH

Using advanced information technologies, such as multisource data analysis and power grid lean geographic models, CMA established a precise early warning system for targeted prevention of meteorological disasters. Through in-depth integration of meteorological and power grid considerations at the data, system, business and organization levels, the system has realized accurate disaster warning for more than 10 types of disasters, such as wire icing, conductor galloping and flooding of transformer substations.

The project team established a series of differentiated early warning models or algorithms for each substation and each base tower. To achieve accurate monitoring and forecasting, weather information needs to be updated every 10 minutes, and a mobile operation application was also developed to rapidly transmit monitoring, forecasting and early warning information. Forecasts of disaster events and the deduced conclusion of their impact on the power grid are also crucial. Project team members must comprehensively consider meteorological conditions, topography and landform, and historical extreme weather conditions to determine whether the power grid equipment will be affected by mountain torrents, mudslides and urban water logging. The system has detailed analysis reports for the historical climate conditions for each element of equipment based on the climatological data.

RESULT

Using this system, the power grid has obtained significant economic benefits, residents have enjoyed stable power transmission, and power grid operators have better safety protection. The system helps achieve accurate disaster prevention for the grid and flexible dispatch during disasters, thereby helping avoid or reduce serious disaster losses for the grid (equipment losses, power outage losses, casualties, etc.). It also reduces the cost of emergency management and disaster prevention. In addition, pressure on power-grid employees during disaster prevention has been reduced. While it is difficult at present to quantify the economic benefits the system creates, these are still increasing. Social benefits are also significant. The system helps improve the efficiency of and reduce costs of disaster prevention. This effectively solves the past problem of the coexistence of excessive disaster prevention costs and insufficient prevention of power cuts. It helps to effectively improve dependability of regional power supply, greatly reducing social and economic impacts from power outages.

> The system has been fully applied in the Beijing Branch of State Grid, and has become essential for emergency management, disaster prevention deployment, and operation and maintenance of the capital's power grid.

PARTNERS

CMA and State Grid Beijing Electric Power Company.

152 State Grid

Photo: Solimpeks/Unsplash

CLIMATE SERVICES FOR RENEWABLE ENERGY
CASE STUDY 6

A solar atlas to guide energy management and planning in Egypt

A solar atlas developed by the Government of Egypt, with support from the Group on Earth Observations (GEO) CRADLE initiative, is being used by the Government to plan future national investments and the efficient exploitation of solar energy.

CHALLENGE

Egypt's economic development is heavily reliant on the energy sector. To tackle growing energy demand, the Integrated Sustainable Energy Strategy (ISES) to 2035 aims to ensure security and stability of supply in Egypt, emphasising the role of renewable energy and energy efficiency. The Government of Egypt has set renewable energy targets of 20% of the electricity mix by 2022 and 42% by 2035, to be achieved through new investments as well as rehabilitation and maintenance programmes in the power sector.[153]

The continuous provision of accurate and timely information, through coordinated and sustained Earth observation activities, is considered a key enabler for informed decision-making in response to challenges such as increasing access to energy in the face of climate change. In this context, large international initiatives such as GEO and Copernicus are promoting the integration and coordination of Earth observation capacities at regional, national and international levels. Despite continuous progress, further potential remains for improving the uptake of Earth observations for energy applications, including in North Africa and the Middle East.

APPROACH

The GEO CRADLE pilot activity Solar Energy Nowcasting SystEm (SENSE) was built on freely-accessible data from Copernicus and Copernicus Atmosphere Monitoring Service (CAMS), innovative modelling and state-of-the-art real-time solar energy calculating systems, and delivered reliable and high-resolution solar atlases and broader climatology studies. The pilot aimed to stimulate the interest of relevant stakeholders, decision makers and investors from the private sector.

At the asset level, applications have been developed with a focus on historical datasets, such as spatiotemporal mapping of solar resources. Nowcasting and forecasting systems for solar radiation/energy, such as the forecasting system NextSENSE, have been developed through the EuroGEO Showcases EU project. These applications provide key information for the operation of solar systems and farms in real time and with high spatiotemporal resolution.

RESULT

Based on the analysis of Egypt's ISES, IRENA recommended undertaking comprehensive measurement campaigns at areas with a high potential for renewable energy, to prepare for large-scale solar and wind investments in the country.[154] Subsequent large-scale projects have included the Benban Solar Park, which started its operation in 2018 and is currently the fourth largest solar power plant in the world, with a total capacity of 1 650 MW nominal power. In 2014, there were 4 or 5 companies working on solar energy; now, there are more than 250.

The collaboration between GEO CRADLE and the Government of Egypt led to the development of the Solar Atlas of Egypt, which has been used by the Government to plan future national investments and the efficient exploitation of solar energy for the implementation of ISES 2035. Data from the Solar Atlas and the website have helped secure funding for these solar projects as well – close to US$ 2.2 billion in Egypt. The collaboration also included the nowcasting of the solar energy potential in real time in order to support the Egyptian energy authorities to better plan solar energy demand.

Notably, the Solar Atlas provided information on the climatology of the solar resources and its application for management of solar-based electricity power plants and grid integration strategies across three subregions (Cairo, Alexandria and Southern Egypt).

> "The Ministry of Electricity and Renewable Energy together with the New and Renewable Energy Authority of Egypt considers this Solar Atlas as an excellent addition, complementing the Government's efforts in finding other venues of electricity production."
>
> *Mohamed Shaker El-Markabi, Minister of Electricity and Renewable Energy*

PARTNERS

WMO, GEO, GEO CRADLE, EuroGEO, e-shape, Copernicus, EUMETSAT, Ministry of Electricity and Renewable Energy of Egypt, NREA, National Observatory of Athens (NOA), Physical Meteorological Observatory in Davos/World Radiation Center, and Center for Environment and Development for the Arab Region and Europe.

153 Renewable Energy Outlook: Egypt
154 Renewable Energy Outlook: Egypt

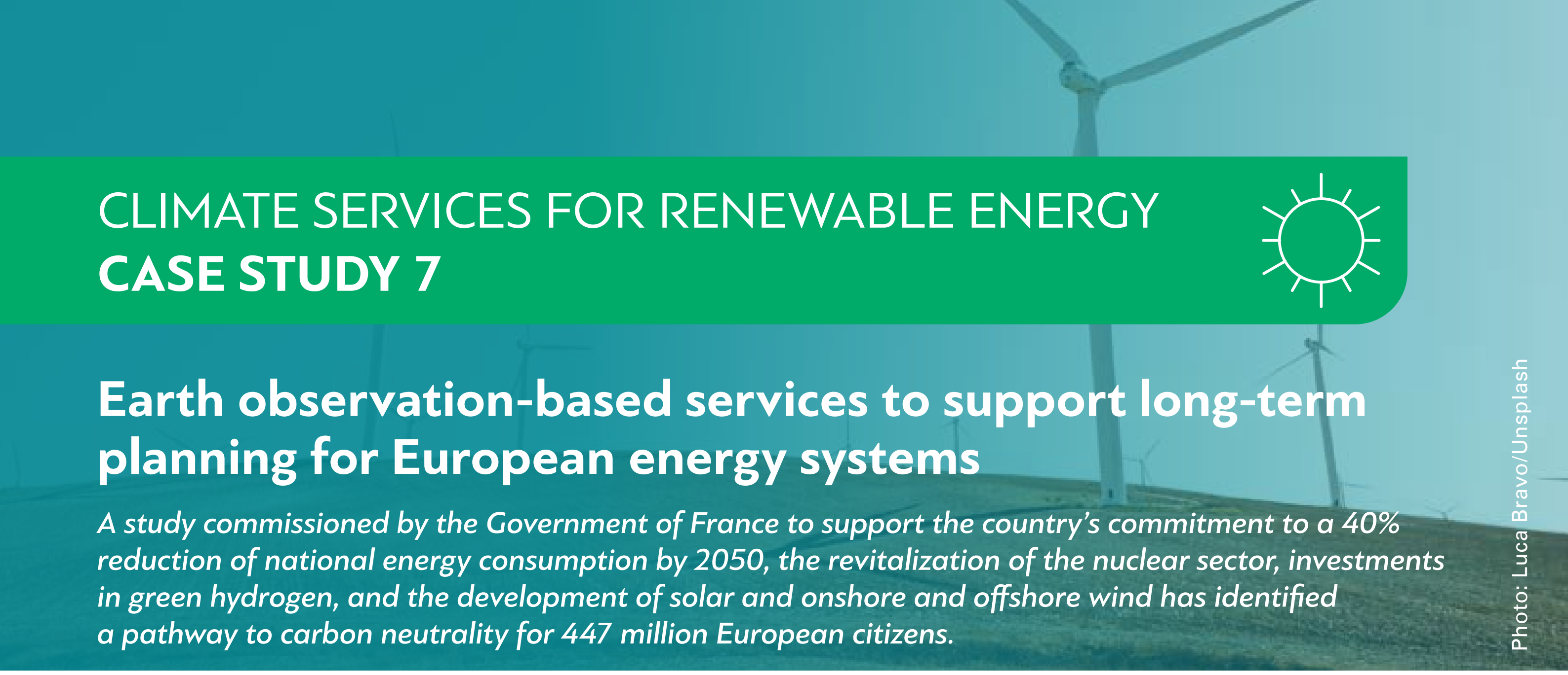


Photo: Luca Bravo/Unsplash

CLIMATE SERVICES FOR RENEWABLE ENERGY

CASE STUDY 7

Earth observation-based services to support long-term planning for European energy systems

A study commissioned by the Government of France to support the country's commitment to a 40% reduction of national energy consumption by 2050, the revitalization of the nuclear sector, investments in green hydrogen, and the development of solar and onshore and offshore wind has identified a pathway to carbon neutrality for 447 million European citizens.

CHALLENGE

The transition to clean energy requires climate services to demonstrate the benefits of renewables for CO_2 reduction and to improve the efficiency of renewable energy systems by optimizing their performance. Such services also help with planning the development and integration of renewables at local, national and regional scales, today, tomorrow and for future decades.

APPROACH

A national-level collaboration was initiated following a request by the Government of France to the country's transmission system operator (RTE) to identify pathways towards carbon neutrality in 2050. A comprehensive study was carried out in 2019–2021, covering the following:

- Technical aspects, such as different climatic scenarios and the description of the electricity network and its evolution;
- Economic aspects, such as cost to society, sensitivity analysis, and the cost of relocation and re-industrialization for each scenario;
- Environmental aspects, such as the carbon footprint including life cycle analysis, material balance for each scenario, land use for the network and production, and volume of waste and pollutants;
- Societal aspects, such as impact on lifestyle and scenario validity conditions including electric mobility, telework, flexibility of usage.

The study also covered the production of energy and electricity, consumption and evolution of networks and in situ data for consumption, and demography. The end users of its findings include state-owned and private energy transmission system operators (TSOs) and distribution system operators (DSOs), national ministries, decision- and policy-makers at regional and local level, households, individual citizens and researchers dealing with renewable energy technologies.

Methods and tools used for the study were drawn from the GEO Vision for Energy (GEO VENER) initiative, notably the European Climate Energy Mixes (ECEM) demonstrator for modelling of renewable energy production in climate scenarios implemented by C3S. GEO VENER aims to serve a large variety of users with Earth observation data to inform decisions intended to substantially increase the share of renewable energies. Historical datasets, as well as nowcasted and forecasted solar radiation and energy data, made available through the SENSE and NextSENSE forecasting systems, developed through the e-shape project funded by the European Union's Horizon 2020 programme, provided key information for the operation of solar systems and farms in real time and with high spatiotemporal resolution. E-shape also includes a dedicated service for supporting the large-scale deployment of PV systems in urban areas. The e-shape tools build on solar cadastres developed by MINES Paris in collaboration with InSunWeTrust. These tools simulate spatial and temporal variability of the electric energy load and the yield productions of rooftop PV systems. Based on these tools, an additional service was developed to provide business-oriented information about PV self-consumption and management and planning of grid source points for distribution operators.

RESULT

The findings of the feasibility study were endorsed by the Ministry of Ecological Transition of France. The study, and a similar study undertaken at European level through the European Network of Transmission System Operators for Electricity (ENTSO-E), set the scene for future carbon neutrality for 447 million European citizens, and many more if market interconnections are taken into account.

> "Thanks to this very important work, we have for the first time objective scientific and technical bases to decide on our energy future until the middle of the century."
>
> *Barbara Pompili, Minister of the Ecological Transition of France*

PARTNERS

WMO, GEO, GEO VENER, EuroGEO, e-shape, C3S, MINES Paris, and RTE.

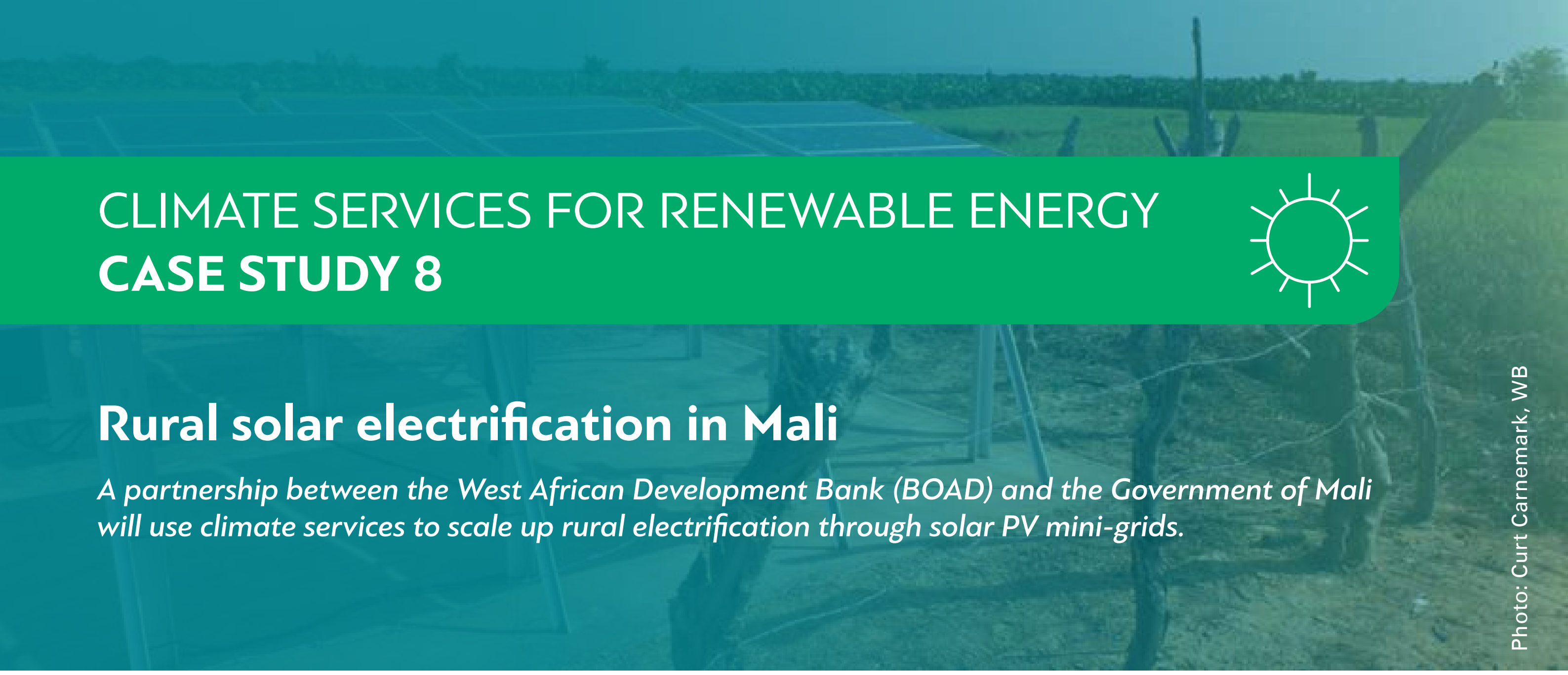


Photo: Curt Carnemark, WB

CLIMATE SERVICES FOR RENEWABLE ENERGY
CASE STUDY 8

Rural solar electrification in Mali

A partnership between the West African Development Bank (BOAD) and the Government of Mali will use climate services to scale up rural electrification through solar PV mini-grids.

CHALLENGE

In Mali, 70% of the population lives in rural areas, and 80% of the rural population lacks electricity. The solar potential (PV and concentrated solar power (CSP)) of the whole of Africa was analysed by IRENA in 2014.[155] According to this study, Mali is situated in a region with high solar potential, and the country is considered to have resources particularly conducive to the development of solar technologies. Despite the immense potential of the country, only 3% of electricity is produced from renewable sources (excluding hydroelectric production). Though Mali has a high potential for solar energy, grid extension to all is currently not feasible due to myriad technical and financial challenges. Thus, mini-grids have the potential to bridge the energy access gap while greening Mali's electricity supply.

Under the Paris Agreement, Mali committed to reduce emissions in its energy sector by up to 31%. Its National Adaptation Plan of Action (NAPA) and 2011 national climate change policy and strategy feature renewable energy as a key component for achieving its climate targets.

APPROACH

Mali has limited planning processes, domestic financial institutions and frameworks for public–private partnerships. Renewable energy technology has a high up-front cost and consumers cannot afford modern renewables without subsidies. There is limited human resource capacity in the sector, and a lack of research on impacts and market conditions challenges the ability to create a standardized programmatic approach to energy.

To address these challenges the Government of Mali and BOAD initiated a project, funded by GCF, with the following components:

- Capacity building and technical assistance. The project will support rural electrification institutions through training and sharing lessons learned. It will provide technical assistance to operations and maintenance companies that will operate the mini-grids.
- Installing solar mini-grids. This component will install mini-grids in 70 different localities, chosen based on engineering studies and specific environmental and social analysis for each site. With a mix of grants and highly concessional loans, the project takes a public–private partnership approach wherein the government owns the mini-grids, while a competitive bidding process will determine the private-sector actors responsible for their construction, maintenance and operation.
- Providing microfinance for productive use of electricity. The project will partner with local financial institutions to provide small loans to consumers who wish to purchase tools and appliances that use electricity to improve economic productivity, such as refrigeration, processing of agricultural products, or power tools for small industry.

RESULT

The project is expected to install 3.78 MW of power in its first tranche, providing emissions reductions of 821.8 kt of CO_2 equivalent over its lifetime. It will improve access to electricity for 28 300 households and encourage investment in tools and appliances that improve economic productivity.

Beyond increasing energy access, the project's public–private partnership model allows for the de-risking of energy access by improving commercial viability while encouraging the participation of the private sector. The project's technical assistance component will strengthen the capacity of institutions to engage with private sector stakeholders in the future.

With funding from GCF, the project will improve access to electricity for 28 300 households and encourage investment in tools and appliances that improve the economy.

PARTNERS

BOAD and the Government of Mali.

155 Estimating the Renewable Energy Potential in Africa: A GIS-based Approach

Photo: Andreas Gücklhorn/Unsplash

CLIMATE SERVICES FOR RENEWABLE ENERGY

CASE STUDY 9

Climate services supporting renewable energy applications in Germany's transport infrastructure

Climate data provided evidence in support of a potential significant expansion of solar power generation capacity.

CHALLENGE

One limiting factor for the extension of renewable energies can be the available land for installation of either PV or wind energy systems, especially in densely populated regions. The identification of further suitable areas and structures can therefore promote the expansion of renewable energies.

APPROACH

The 'Network of Experts' of Germany's Ministry for Digital and Transport (BMDV) is a network of German government agencies covering a variety of research topics related to Germany's transport infrastructure. One topic area focuses on the identification of potential contributions of infrastructure to the reduction of GHG emissions. In order to develop suitable suggestions for the ministry, the network brings together the expertise of the German meteorological service (Deutscher Wetterdienst (DWD)) as a climate service provider and the specialized authorities for road, rail and waterways.

A specific case study was the electricity generation potential from PV systems that could be installed on existing noise barriers and noise-protection walls along roads and railways in Germany. Information on possible locations and technical assumptions, for example on occupiable surfaces and orientation of the noise protection facilities, was provided by the partner authorities.

RESULT

Using high-quality climate data, the potential installation of PV panels on noise barriers was investigated. This revealed an annual generation potential of more than 1 400 GWh, enough to cover the average annual electricity demand of 450 000 households in Germany.

In order to estimate the potential energy yield and the associated GHG reduction, these data were linked with DWD climatological information. The yield mainly depends on solar radiation, but the efficiency of PV modules also depends on their temperature, which is not only influenced by the ambient temperature, but also by the wind speed. Therefore, a model that takes these dependencies into account is used to estimate the yield. It was driven by high-resolution climatological data in order to make a reliable overall assessment taking into account long-term site-specific details. High-resolution surface radiation data are now available from satellites for several decades, including the SARAH 2 data set (second edition of the Surface Solar Radiation Data Set – Heliosat) used in the study. SARAH 2 is provided by EUMETSAT's Satellite Application Facility on Climate Monitoring (CM SAF) and based on data from the METEOSAT satellites. It provides solar surface irradiance data for the period from 1983 onwards at a temporal resolution of 30 minutes.

Other meteorological parameters derive from the regional reanalysis COSMO REA6. The quality of both data sets has been extensively evaluated in previous studies and they are openly available for similar applications. The high temporal resolution of the data was also helpful to investigate further details, for example whether the energy can be provided to consumers in the infrastructure in a demand-oriented manner. In particular, the temporal profile of pumping requirements of the waterways was considered. The regional reanalysis also provides several other parameters, for example, including wind speed at hub height of wind energy converters, which is also used in further activities of DWD in support of wind energy extension in Germany's offshore regions in the North Sea and Baltic Sea.

Using high-quality climate data, the potential installation of PV panels on noise barriers was investigated, showing an annual generation potential of over 1 400 GWh.

PARTNERS

DWD, Federal Railway Authority, Federal Highway Research Institute, Federal Institute of Hydrology and CM SAF.

CLIMATE SERVICES FOR RENEWABLE ENERGY
CASE STUDY 10

Sector-specific localized wind resource information to aid wind industry decision-making process

Using reanalysis data, Vortex, a private sector entity serving the wind-power sector, has reduced the error in wind products by 3%–4%. A 1% reduction of the error in the wind, for a typical project of 100 MW with a 35% capacity factor for an installed wind power capacity of 50 GW per year, implies savings of approximately US$ 100 million per year.

Photo: Arteum.ro/Unsplash

CHALLENGE

Wind power generation is a key technology in the global pathway toward the NZE objectives of the European climate strategy and for European Union energy independence, with demand expected to lead to the ramping up of both onshore and offshore production systems by 2050.

The wind energy industry requires climate-derived information at different timescales, depending on the specific project and application. High-resolution, high-quality information about the past climate is crucial to assess the viability of wind sites for development, and/or to monitor sites under construction or expansion.

Energy traders, independent power producers and wind-farm operators use predictions of wind speed, direction and power production. They also use downscaled predictions of wind resources at different stages of their wind farm project development. Those users also need data to safeguard and maintain their assets and monitor energy production.

APPROACH

A new generation of private climate services has emerged to address the wind industry demand for high-fidelity wind resource data needed to facilitate energy supply prediction and project design. Such private sector entities are providing value-added products, building on publicly available data, tailored to meet wind-energy entities' requirements for climate information and services.

Vortex is an atmospheric modelling technology company focused on providing high-resolution wind resource data up to 100 m height for wind industry users to support decision-making throughout the life cycle of a wind farm project. Vortex downscaling technology relies heavily on the use of C3S ERA5 reanalysis. Vortex operates a cloud-based fully automated downscaling chain based on a multiscale weather model that uses ERA5 reanalysis as a key input to reconstruct site-specific time series and maps of the wind resource parameters required for energy resource analysis and project design.

The latest version of the Global Wind Atlas uses a global layer of ERA5-based atmospheric data at 3 km resolution developed using Vortex downscaling technology. The Atlas is a free online web-based resource, built to help policymakers, planners, and investors identify high-wind areas for wind power generation virtually anywhere in the world.

Climate Scale, a spinoff project of Vortex, provides on-demand high-resolution climate change projections for anywhere in the world to help a range of sectors, including the wind energy industry, to evaluate and manage the physical risks of climate change.

Lautec has built web-based tools (ESOX and the more powerful version ESOX+) for supporting offshore wind power generation projects, based on the C3S ERA5 reanalysis. The tool provides information on mean wind speed at 10 m and 100 m height, significant wave height and peak wave period.

Based on previous proofs of concept, C3S has built an operational energy service designed to address the needs of users who want to assess the impact of climate on energy operations, management and planning, and for energy modelers needing datasets for their assessment studies.

RESULT

Reanalysis products are now part of the wind resource toolkit, used for early-stage site screening as well as for finance close/due diligence energy and site assessment final analysis. Solutions like the one offered by Vortex are crucial as the wind energy market expands into new regions and offshore wind development approaches global scale.

Using ERA5 data, Vortex has improved wind products by reducing the error by 3%–4%. A rough estimation of the impact of a 1% reduction of the error in the wind, for a typical project of 100 MW with a 35% capacity factor for an installed wind power capacity of 50 GW per year, implies savings of around US$ 100 million per year.

High-resolution, high-quality information about the past climate is crucial to assess the viability of wind sites for development.

PARTNERS

C3S, Vortex, Climate Scale and Lautec.

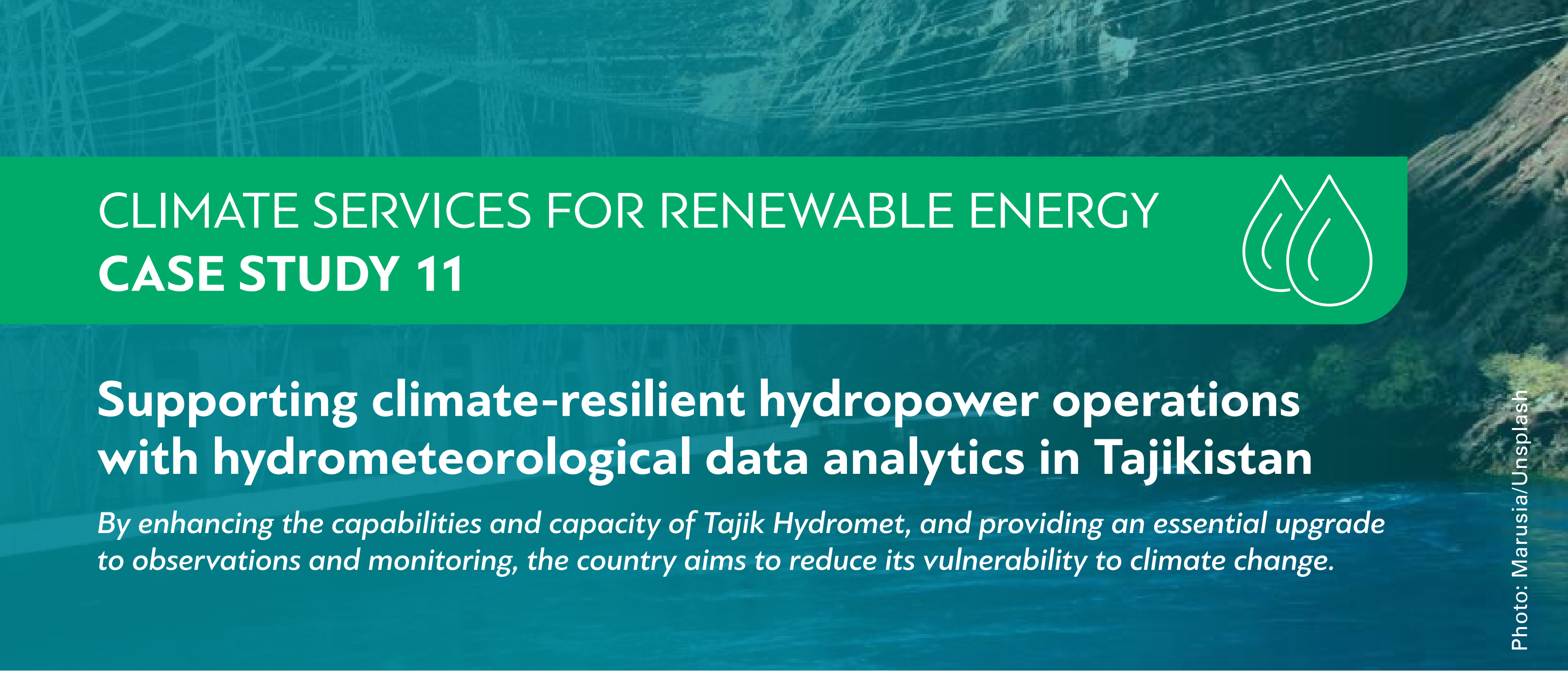


Photo: Marusia/Unsplash

CLIMATE SERVICES FOR RENEWABLE ENERGY
CASE STUDY 11

Supporting climate-resilient hydropower operations with hydrometeorological data analytics in Tajikistan

By enhancing the capabilities and capacity of Tajik Hydromet, and providing an essential upgrade to observations and monitoring, the country aims to reduce its vulnerability to climate change.

CHALLENGE

Over the past decade, Tajikistan has made steady progress in reducing poverty and growing its economy. However, its high vulnerability to climate change and recurring disasters continue to challenge to sustainable economic growth. Between 1992 and 2016, almost seven million people were affected and US$ 1.8 billion, equivalent to around 1% of GDP, was lost.

APPROACH

The European Bank for Reconstruction and Development, CIF and the Government of Tajikistan have cooperated to strengthen the NMHS of Tajikistan, Tajik Hydromet, to ensure it has the infrastructure and capability to observe, forecast and deliver weather, water and climate services that meet the country's identified economic and societal needs. The project supported modernization of observations and monitoring, enhanced institutional capacity, and improved delivery of weather and climate services. It aimed to shift the focus towards the development of improved services while providing an essential upgrade to observations and monitoring.

The project was the first focused specifically on improving hydrometeorological services in Tajikistan, previous projects having provided piecemeal support. Thus, the project provided the country its first opportunity to upgrade its observations and monitoring network. This aspect formed the largest part of the project, although it also addressed data and information management, along with the development of improved services, particularly in the water sector.

RESULT

Fully recognizing the importance of timely and accurate hydrometeorological data and forecast analytics for the safe and efficient operation of hydropower plants, one of the project's accomplishments was to help develop procedures for using hydrometeorological information and forecasts in dam operations and flood management plans. Tajik Hydromet has applied new techniques to provide more targeted information to Barqi Tojik, a state-owned power utility, while the latter offers additional hydrological data back to Tajik Hydromet to further improve forecasts. The power of data and analytics was evident when Tajik Hydromet gave advance warning of a dry year to Barqi Tojik, which afforded precious time to enable the company to plan ahead.

Overall, the project raised the awareness of the importance of weather and climate services in Tajikistan and delivered a major upgrade to the observation and monitoring network, laying the foundations for further improvements in service delivery. In addition to upgrading the observations network, the project increased the sustainability and performance of Tajik Hydromet, as well as increased the capacity of stakeholders in the hydrometeorological value cycle, including through the provision of technical assistance from advanced NMHSs, such as the Finnish Meteorological Institute (FMI).

Moreover, on a regional level the project promoted greater cooperation between the five NMHSs in Central Asia. These agencies possess a wide range of capabilities and are all Russian speaking, which provided the opportunity for knowledge sharing among countries. For example, colleagues in Kazakhstan were able to support training in Tajikistan and the Hydrometeorological Centre of Russia was also able to provide some technical assistance.

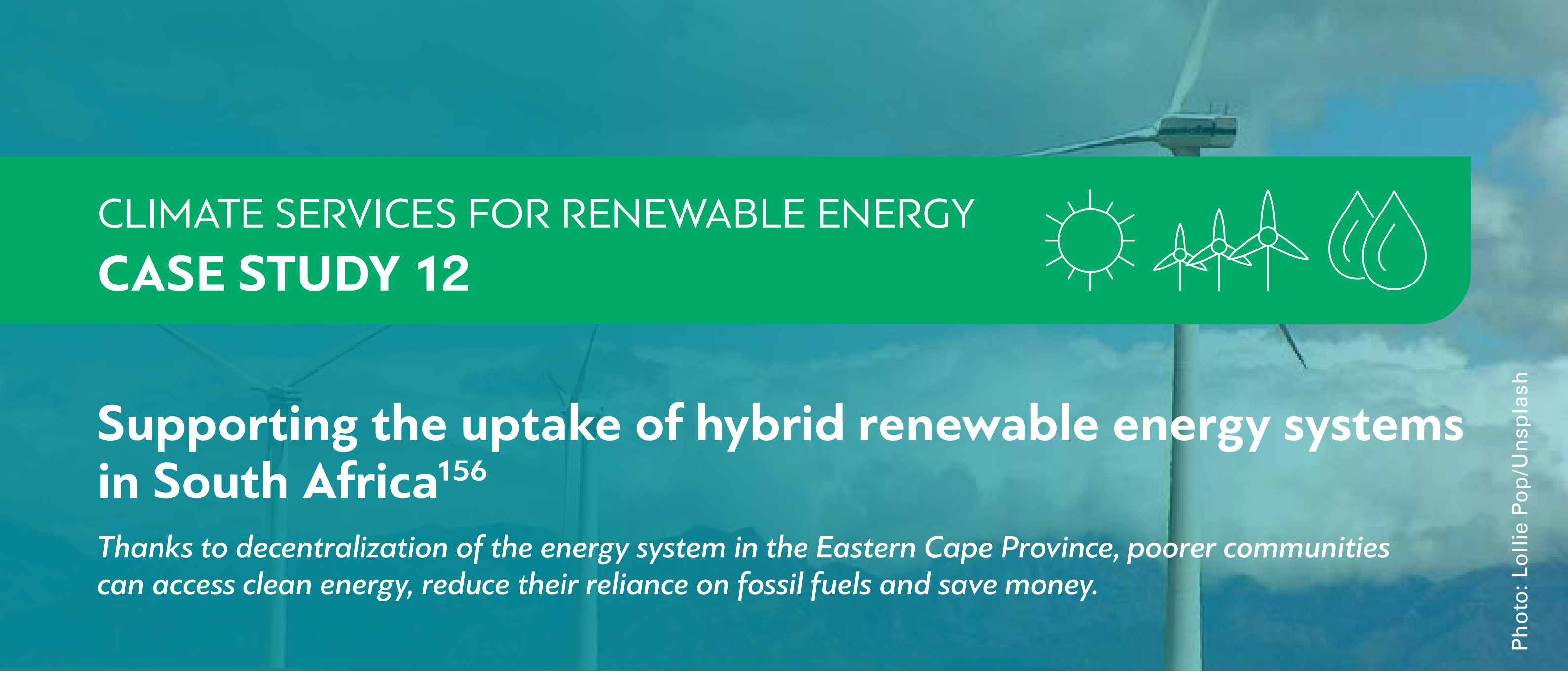
> The power of data and analytics was evident when Tajik Hydromet gave advance warning of a dry year to Barqi Tojik, a state-owned hydropower operator, enabling the company to plan ahead.

PARTNERS

European Bank for Reconstruction and Development and CIF.

CLIMATE SERVICES FOR RENEWABLE ENERGY

CASE STUDY 12



Supporting the uptake of hybrid renewable energy systems in South Africa[156]

Thanks to decentralization of the energy system in the Eastern Cape Province, poorer communities can access clean energy, reduce their reliance on fossil fuels and save money.

Photo: Lollie Pop/Unsplash

CHALLENGE

The Eastern Cape Province in South Africa has been engaging in several renewable-energy initiatives to improve access to electricity, create jobs and alleviate poverty. One of the initiatives is the Upper Blinkwater Smart Project, developed to provide a decentralized, sustainable and hybrid mini-grid system.[157] The system is based on renewable energies and diesel backup. It provides electricity access for poor rural households, which are also vulnerable to extreme weather events. The provision of renewable energy has facilitated community development, increased job opportunities within the community and reduced beneficiaries' consumption of fossil fuels.

APPROACH

The project was made possible by collaboration between the Eastern Cape Province, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and the German federal state of Saxony. Other key partners included: the community of Upper Blinkwater; South Africa's Department of Mineral Resources and Energy; the provincial Department of Economic Development, Environmental Affairs and Tourism; South Africa's Council for Scientific and Industrial Research; the South African National Energy Development Institute and the Universities of Fort Hare and Nelson Mandela. Co-production with users is a key success factor in the implementation of renewable energy systems. In this instance, communities in the Upper Blinkwater were engaged before and during the process to ensure their buy-in through the use of questionnaires and workshops as well as continuous monitoring of system performance to provide feedback and support.

The project demonstrates that renewable technologies can play an important role in enabling energy access to off-grid communities, improving living conditions and economic opportunities, and slowing rural-to-urban migration. Challenges encountered during the project included delays due to administrative and procurement processes, as well as policy requirements to obtain licences as determined by the National Energy Regulator of South Africa. Cooperation and participation of various stakeholders in project design and implementation were critical success factors that helped overcome these barriers.

RESULT

Benefits from the hybrid energy system included community access to clean and affordable energy that is used for economic activities such as goat cheese production and processing of fruits and vegetables. This was possible because the renewable energy system assisted with the production of water that was then utilized in farming activities. Households saved between R 30 and R 800 (US$ 2 and US$ 49) per month, which was previously used to purchase paraffin and candles. Other benefits include reduced deforestation and health risks associated with the use of firewood. The use of renewable energy also contributed to achieving SDG Goal 4 on education, as it relieves women and children from the burden of spending valuable time collecting firewood, which can then be used for other productive activities and education. The hybrid energy system also created opportunities for the community members to enhance their technical skills, as they received training on how to attend to electrical issues within the households.

Renewable technologies can help to enable energy access for off-grid communities, improve living conditions and slow rural-to-urban migration.

PARTNERS

GIZ, Deutsche Zusammenarbeit, Province of the Eastern Cape and Raymond Mhlaba Municipality.

156 *WMO Best Practices for Integrated Weather and Climate Services in Support to Net Zero Energy Transition* (in press)
157 The Upper Blinkwater Minigrid

CLIMATE SERVICES FOR RENEWABLE ENERGY

CASE STUDY 13

A global platform assessing the potential installed capacity of hydrology, wind and solar energy

The Global Renewable-energy Exploitation Analysis (GREAN) platform aims to alleviate the problem of inconsistent and incomprehensive data on and evaluation of clean energy potential.

Photo: Gary Yost/Unsplash

CHALLENGE

Transformations towards low-carbon and green growth are accelerating in energy industries all over the world. Some international organizations have assessed the theoretical potential of wind, solar and hydropower. However, the assessment approaches show disadvantages such as incomprehensive data, inconsistent evaluative criteria and lack of investment cost forecast. These assessments can hardly provide practical solutions for renewable energy base site selection or power transmission planning.

APPROACH

Global Energy Interconnection Development and Cooperation Organization (GEIDCO) established the GREAN platform to carry out the systematic calculation and quantitative analysis of the theoretical, technical and economic potential installed capacity of wind, solar and hydropower from a global perspective.

The comprehensive database of renewable energy assessments cuts across 32 categories and 20 types, including geographic and human activity economic data, with hour-level time resolution and 100-meter-level spatial resolution. GREAN also provides global power-grid data, covering backbone transmission grids with voltage above 110 kV in 147 countries.

Quantitative assessments of wind, solar and hydropower resources are analysed in terms of their theoretical, technical and economic potential, providing a series of scientific, systematic and comprehensive assessment results. The platform includes an accurate quantitative model and harmonized parameters, integrating with geographical information system (GIS) and engineering survey data. A parallel computing framework and ant colony and neural network algorithms are adopted innovatively. Assessment and calculation on the national scale could be completed online.

GEIDCO developed software for renewable energy base site selection, proposing digital solutions for development of hydropower, wind and PV power stations.

RESULT

Theoretical, technical and economic potential for global renewable energy are being evaluated. So far, site selection for 35 hydropower bases, 94 wind power bases and 90 PV bases, based on development potential and resource character analysis, has been developed, providing guidance for large-scale development and utilization of global renewable energy.

Power transmission schemes for major global renewable energy bases are being put forward, based on the development of power supply and demand around the world. Considering the distribution of large-scale energy bases and major power consumption centres, the grid planning realizes the ambition of multi-energy inter-regional outbound transmission, mutual complementarity across time zones, and cross-seasonal and global allocation.

The GREAN platform provides systematic information about locations, potential, price and efficient utilization approaches for renewable energy development.

PARTNER

GEIDCO.

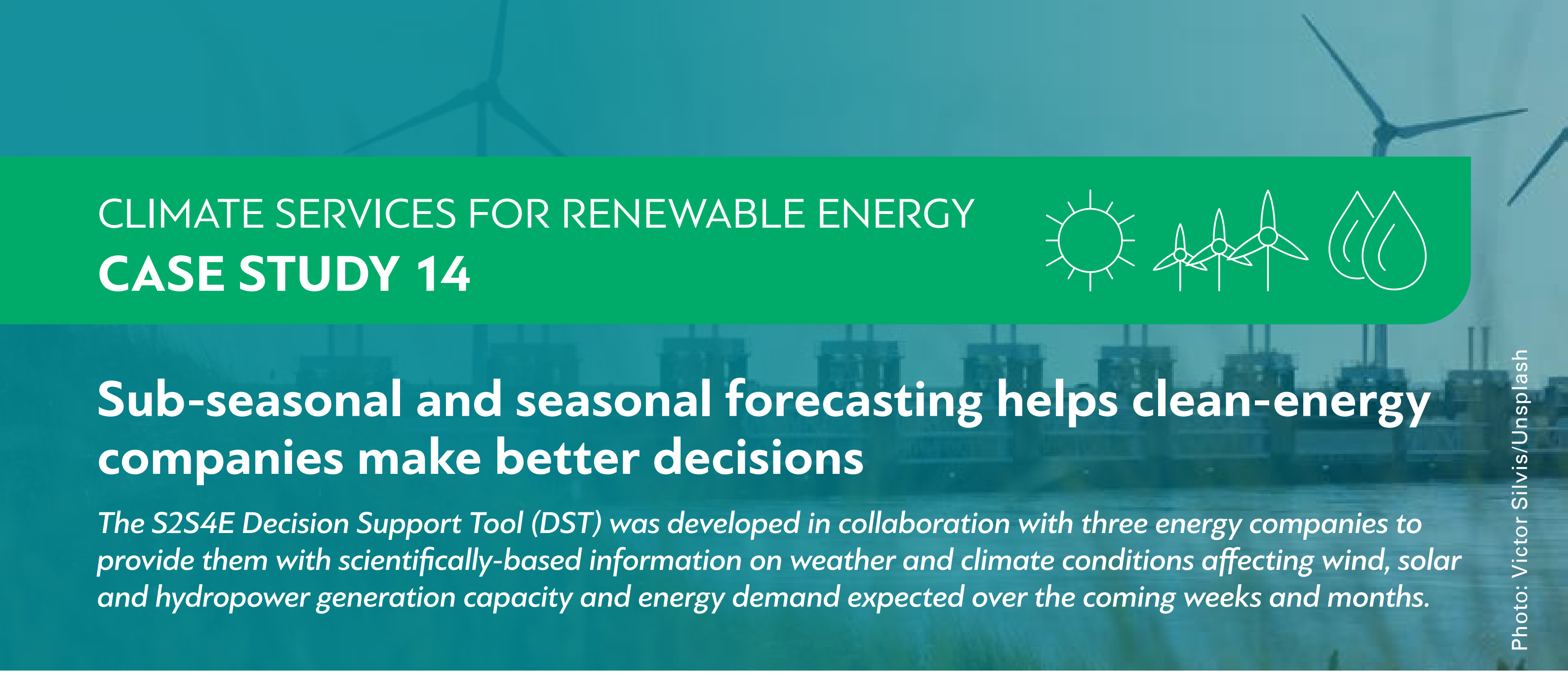


Photo: Victor Silvis/Unsplash

CLIMATE SERVICES FOR RENEWABLE ENERGY

CASE STUDY 14

Sub-seasonal and seasonal forecasting helps clean-energy companies make better decisions

The S2S4E Decision Support Tool (DST) was developed in collaboration with three energy companies to provide them with scientifically-based information on weather and climate conditions affecting wind, solar and hydropower generation capacity and energy demand expected over the coming weeks and months.

CHALLENGE

The future energy system is envisaged to rely primarily on renewable energy. Renewable energy supply and demand operations are affected by the evolution of atmospheric conditions at different time scales. Increasing integration of renewables into the power mix is making the electricity supply more vulnerable to climate variability.

To address an increase in renewable energy demand it is important to have flexibility in the system and smart technologies to anticipate and better manage changes in energy generation. Scientists and operational centres and services have been investing considerable effort and resources to improve sub-seasonal and seasonal forecasts over the past decade and have made substantial progress. Such forecasts are now able to predict the evolution of some large-scale extreme weather events several weeks in advance and to show whether the upcoming season is likely to be drier or wetter, or hotter or colder, than normal. Yet it remains challenging to link the complex probabilistic information these forecasts provide to industry-specific applications.

APPROACH

The energy system encompasses many different actors which have to make specific decisions and have specific needs. When sub-seasonal and seasonal forecasts are skilful and accurate, they can help producers of wind, solar and hydropower get better-informed estimates of how much electricity their plants are likely to generate in the weeks and months ahead. Improved estimates of future power output can enable them to make better decisions on issues such as when to sell electricity to the market, how much to sell, what price levels to expect, and when to schedule maintenance of power plants. Sub-seasonal and seasonal forecasts can therefore contribute to reducing the risks involved in investing in renewable energy and help companies to improve their risk management and production planning activities.

The S2S4E DST is a climate service that features scientifically-based climate information intended to enhance energy users' knowledge of the weather conditions expected over the coming weeks and months. The tool was developed by the S2S4E Climate Services for Clean Energy project, which has been funded by the European Union's research and innovation programme Horizon 2020 and coordinated by the Barcelona Supercomputing Center.

The first half of the project was dedicated to the co-design of the tool, with the key collaboration of three energy companies and the contribution of other energy actors. During the operational phase, the second half of the project, the DST was modified based on users' feedback. The DST was openly accessible during the second half of the project providing updated sub-seasonal and seasonal climate predictions tailored for the energy sector, including not only the prediction of weather variables (such as temperature or wind speed) but also energy indicators (e.g. wind and solar capacity factors, electricity demand and hydropower indicators).

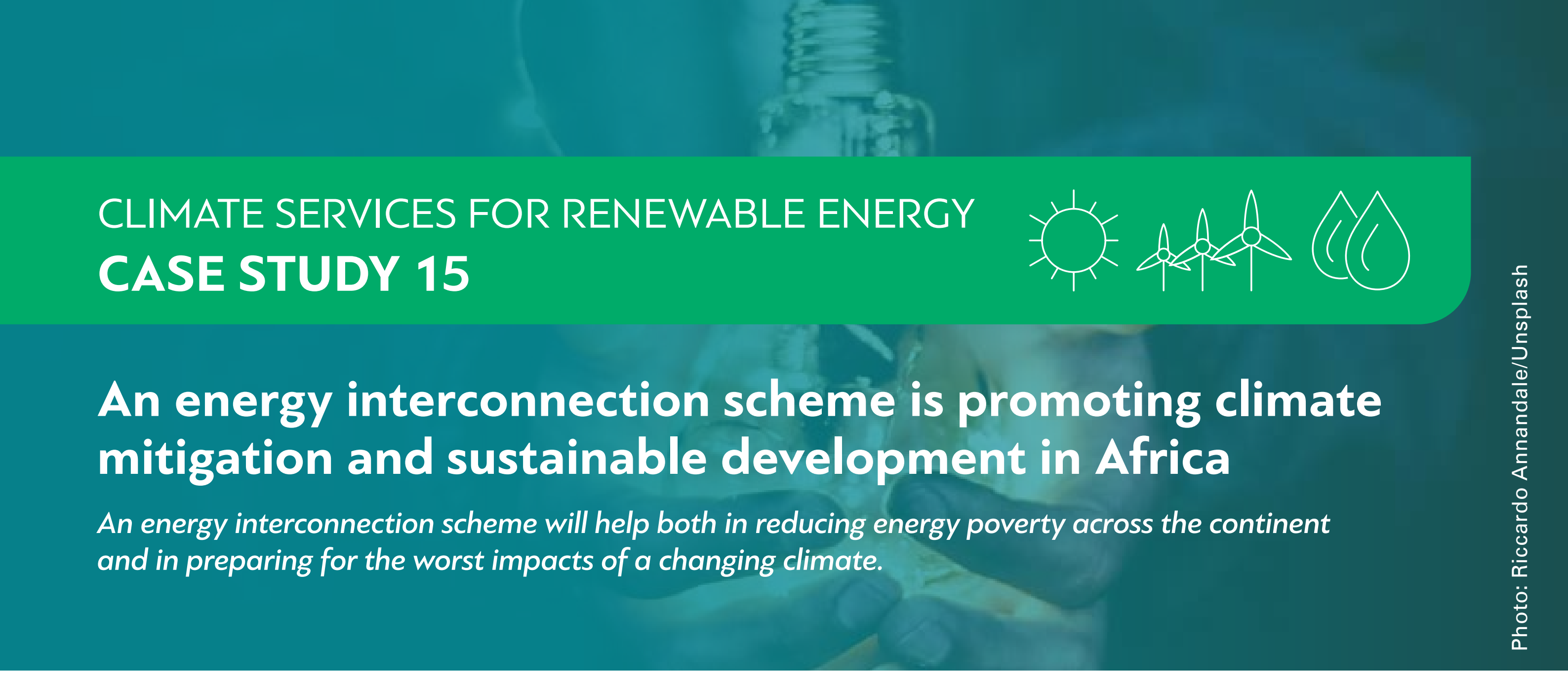
RESULT

An analysis verifying the usefulness of the tool was conducted by regularly assessing users' applications and challenges. Economic evaluations of past events and assessments under real-time forecast conditions documented user benefits and potential risks. Through these collaborative efforts, the DST has showed that it can deliver tailored services with demonstrated benefits.

Sub-seasonal and seasonal forecasts can contribute to reducing the risks involved in operating renewable energy systems and investing in renewable energy.

PARTNERS

S2S4E Climate Services for Clean Energy Horizon 2020 project: Barcelona Supercomputing Center, Center for International Climate Research (CICERO), University of Reading, Swedish Meteorological and Hydrological Institute (SMHI), Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile (ENEA), EDF, EDP Renewables (EDPR), Energie Baden-Württemberg (EnBW), The Climate Data Factory (TCDF), LGI, Nnergix and Capgemini.



CLIMATE SERVICES FOR RENEWABLE ENERGY

CASE STUDY 15

An energy interconnection scheme is promoting climate mitigation and sustainable development in Africa

An energy interconnection scheme will help both in reducing energy poverty across the continent and in preparing for the worst impacts of a changing climate.

Photo: Riccardo Annandale/Unsplash

CHALLENGE

At present, Africa faces energy poverty and climate risks. The percentage of people with access to electricity in Africa was 48.4% in 2020.[158] The average electricity price in African countries is as high as US$ 0.14/kWh, which is two to three times the worldwide average cost in developing countries.

In addition, 70% of energy for household heating and cooking and other basic domestic use comes from traditional biomass, such as firewood, charcoal and animal manure, resulting in serious indoor air pollution and GHG emissions. Hence, it is necessary to consider the energy–climate nexus and provide clean energy as well as sustainable development for Africa.

APPROACH

GEIDCO's energy interconnection scheme aims to reduce energy poverty and promote climate mitigation in Africa. First, the scheme aims at accelerating large-scale development of renewable energy, such as solar and wind, mainly in North Africa, as well as hydropower in the basins of the Congo, Nile and Zambezi rivers. Second, for optimal allocation of green power, it is essential to improve the backbone power grid infrastructure and achieve grid interconnections in Africa. Third, to promote electricity trading between countries, it is necessary to establish a unified electricity market and trading mechanism for regional power pools in Africa. Fourth, the power grids, and concentrated and distributed power sources such as PV, wind and hydropower, need to be developed to improve electricity access. Finally, to achieve robust power systems in Africa, the power sources and grid infrastructure should be designed and improved according to climate resilience standards. Real-time meteorological services should be applied to provide accurate renewable and disaster forecasts, so as to improve the electricity trading, dispatching and climate resilience of the power system.

RESULT

The scheme helps accelerate electricity access and energy transition, so as to achieve multiple SDGs in Africa. Regional power pools in Africa are improving the power systems under the scheme. The total installed renewable energy capacity in Africa has grown by over 24 GW since 2013.[159] Solar, wind and hydropower capacity increased by over 10% annually. The costs of solar PV and wind electricity fell 82% and 55%, respectively, between 2010 and 2019.[160] As a result, the number of people without access to electricity in Africa decreased from 613 million in 2013 to around 572 million in 2019.[161]

The energy interconnection scheme can help increase access to electricity, reduce poverty and achieve carbon neutrality in Africa.

PARTNERS

GEIDCO, International Institute for Applied Systems Analysis (IIASA).

158 Access to electricity (% of population) - Sub-Saharan Africa
159 This is the state of renewable energy in Africa right now
160 Key findings: Renewable power generation costs in 2019
161 Access to electricity – SDG7: Data and Projections

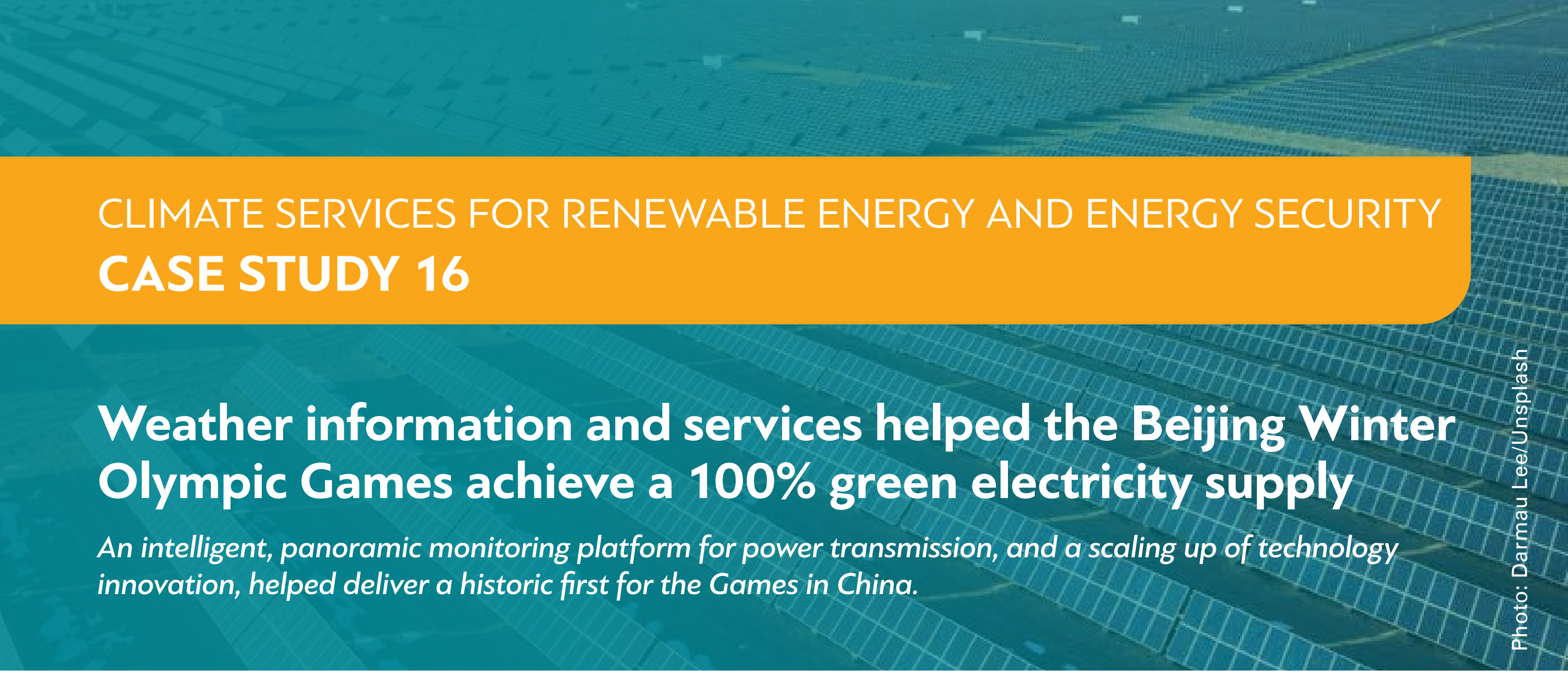


Photo: Darmau Lee/Unsplash

CLIMATE SERVICES FOR RENEWABLE ENERGY AND ENERGY SECURITY

CASE STUDY 16

Weather information and services helped the Beijing Winter Olympic Games achieve a 100% green electricity supply

An intelligent, panoramic monitoring platform for power transmission, and a scaling up of technology innovation, helped deliver a historic first for the Games in China.

CHALLENGE

The phrase '100% green power' refers to all venues of the Beijing Winter Olympics achieving reliable supply of green power throughout their entire life cycle. However, renewable energy resources are greatly affected by natural conditions, and there are uncontrollable factors such as randomness, volatility and intermittency. The safe and stable operation of the power grid faces three major challenges: low green electricity prediction accuracy, difficulty in load peak regulation and high risk of meteorological disasters. It is urgent to provide reliable support from meteorological services.

APPROACH

The approach taken was three-pronged. The first step focused on promoting renewable energy dispatch technology innovation. This included researching key technologies and developing key systems such as multiscale renewable energy resource forecasting, power forecasting and scheduling strategy optimization that consider meteorological factors to ensure renewable energy scheduling and consumption. The resource forecasting system integrating large-scale climate effects and small-scale local effects can achieve a forecast duration of 72 hours, a temporal resolution of 15 minutes and a local spatial resolution of 30 m × 30 m, with the forecast error reduced from 25% to 10%.

The next step was to build an intelligent panoramic platform for power transmission. This involved addressing the microtopography and micrometeorological information around the important power lines at the Beijing Winter Olympics, using observation information from sources such as meteorological satellites, weather radar and ground meteorological station for monitoring and early warning, and building an early warning platform to warn of short-term risks of meteorological disasters that could affect power lines. The platform achieves full coverage of 118 Olympic-related transmission lines, and the intelligent visualization device takes snapshots at time intervals ranging from 5 minutes to 20 minutes, perceives equipment abnormalities in real time and discovers potential external risks before they can impact the system.

The final step was to establish a power security system and strengthen the coordination and communication between the power industry and the meteorological department. This meant establishing a meteorological security system specifically for Olympic-related equipment, and focusing on providing fine meteorological analysis, early warning and information sharing in the core area, providing accurate guidance for equipment operation and maintenance, and proposing corresponding operation and inspection strategies based on the meteorological warning information.

RESULT

The Beijing Winter Olympics became the first Olympic Games in history that achieve 100% green electricity supply. About 400 million kWh of green electricity was consumed during the Games, which is equivalent to avoiding the combustion of 128 000 tons of standard coal and 320 000 tons of carbon dioxide emissions.

> Through the in-depth integration of power and meteorology systems, supported by meteorological information and services, a 100% green electricity supply was guaranteed for the Games.

PARTNERS

State Grid Corporation of China and State Grid Jibei Electric Power Co.

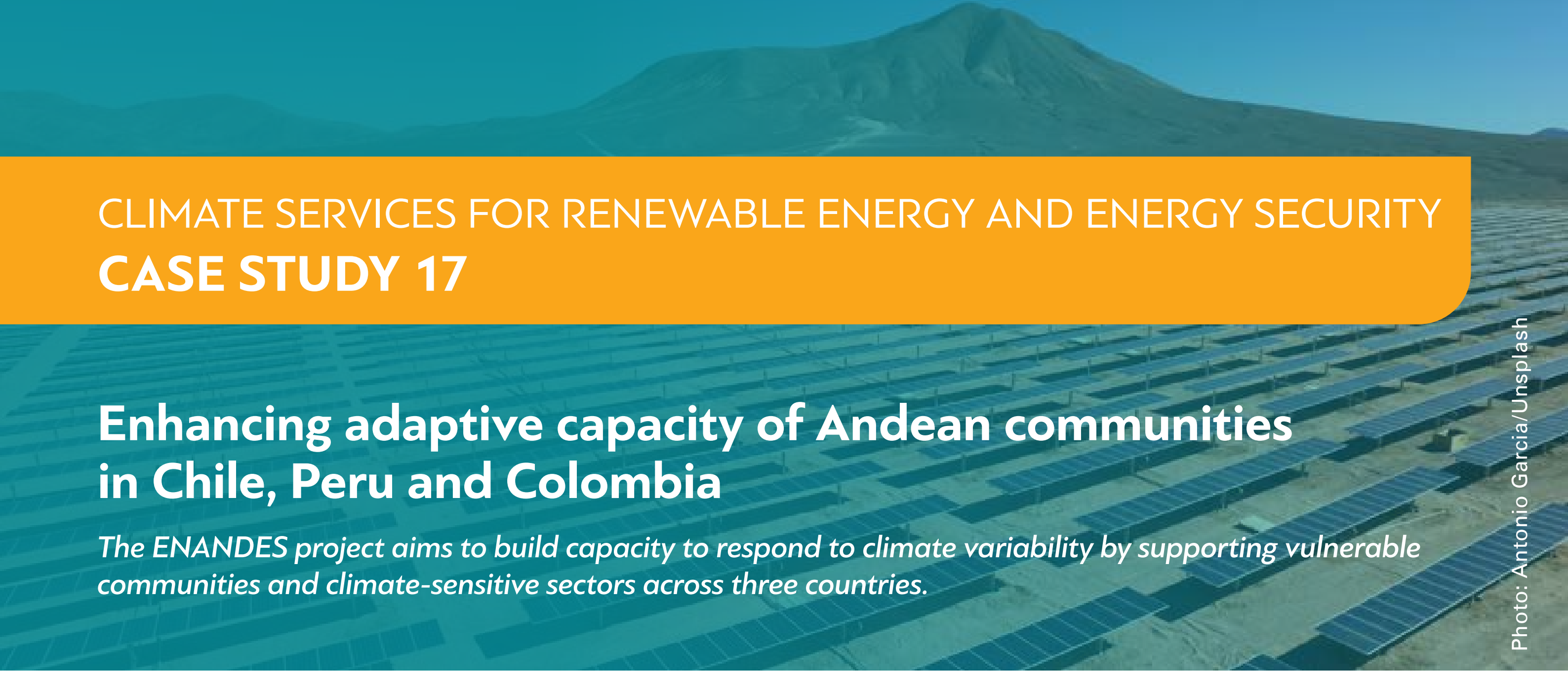


Photo: Antonio Garcia/Unsplash

CLIMATE SERVICES FOR RENEWABLE ENERGY AND ENERGY SECURITY

CASE STUDY 17

Enhancing adaptive capacity of Andean communities in Chile, Peru and Colombia

The ENANDES project aims to build capacity to respond to climate variability by supporting vulnerable communities and climate-sensitive sectors across three countries.

CHALLENGE

The impacts of climate variability and change, growing economies and increasing urbanization in Chile, Peru and Colombia is posing systemic risks to agriculture, water and energy security. Agricultural production is an important source of employment for vulnerable rural populations. The availability of water is fundamental for agricultural production of the region, from subsistence farming in the Andean highlands of Peru and Colombia to export-oriented production in central Chile. Most importantly, hydroelectric power is key for all three countries. Mountain glaciers, steep alpine valleys and long rivers offer ideal conditions for developing hydroelectricity. Nevertheless, climate change and variability (including both rainfall deficits and excesses) are having serious implications for power generation capacity, management of peak supply and demand, and dam safety.

APPROACH

The approach of the Enhancing Adaptive Capacity of Andean Communities through Climate Services (ENANDES) project, a US$ 7.4 million project financed by the Adaptation Fund, is to implement and assess demonstration adaptation activities in various sites throughout the three countries where climate-sensitive activities (agriculture, hydropower generation, water supply) and vulnerable communities and groups (farmers, indigenous population, women and elderly people) are located. The integrative approach proposed by ENANDES contrasts with the siloed approach to water, energy and food that is typical of many national policies, plans and strategies that set out the vision of governments over a 10–30 year horizon.

Effective use of climate information and knowledge to support adaptation not only requires relevant and actionable information about climate trends and fluctuations and their likely sectoral impacts, but also a corresponding understanding of the local contexts that determine whether adaptation practices to manage risks and mitigate climate impacts on agriculture, water and energy are culturally appropriate and economically, environmentally and socially viable. Consequently, the ENANDES project is exploring multiple adaptation activities in three demonstration sites to gain first-hand experience about how to successfully combine actionable and relevant climate services with regional and local adaptation, coping and ex-ante preparedness practices created through the engagement of people and institutions with local authority and responsibility.

As part of the demonstration activities in Chile, the project is exploring how operations could be improved by access to weather and climate information on scales from days to seasons. In Colombia, the feasibility of PV installations for rural areas that do not have access to the country's interconnected electricity grid is being explored in the demonstration sites, to provide cost-effective electricity through small PV installations (capable of supplying power to small hamlets of 8–12 households). In Peru, the focus is on providing climate services that inform the management of water supply to metropolitan Lima, with a population of almost 9 million people, and enhanced management of flooding and landslide risks from the Rímac River, which descends from an elevation of 5 500 meters to the Pacific Ocean at Callao, Lima.

RESULT

The project is expected to deliver socioeconomic benefits to 11.5 million direct and indirect beneficiaries. The participating countries will get gender-sensitive weather, hydrological and climate services, six early warning systems and seasonal forecasts downscaled for demonstration adaptation areas. The project will also increase the number of academia/research institutions collaborating with NMHSs on forecasting systems by 33%.

In Peru, the focus is on providing climate services that inform the management of water supply to metropolitan Lima, with almost 9 million people.

PARTNERS

Dirección Meteorológica de Chile (DMC), Servicio Nacional de Meteorología e Hidrología del Perú (SENAMHI) and the WMO Regional Climate Centre for Western South America (International Research Centre on El Niño (CIIFEN)).

Photo: Valentina Barreto

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