ClimINVEST

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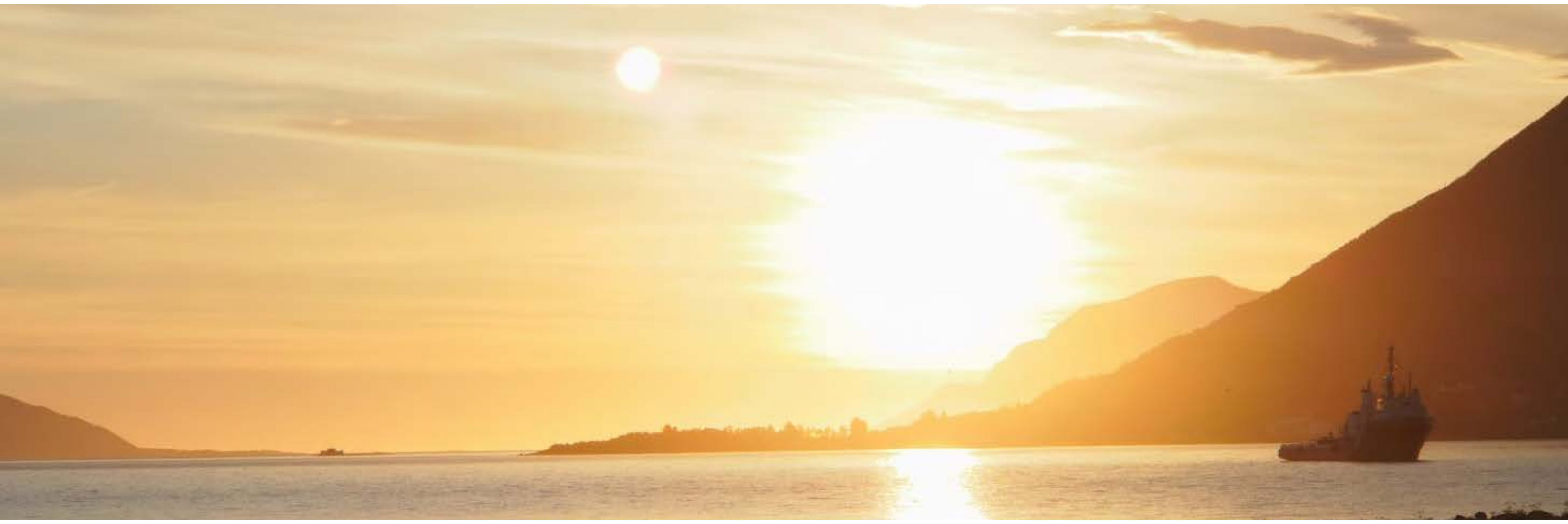
Heat and physical climate risk

This factsheet is intended to help investors understand how increasing temperatures can affect their portfolios, how heat stress is scientifically defined, what to consider when using data on heat stress, and how heat stress can impact different sectors. It also takes a closer look at potential interventions available to manage the impact of heat stress by sector and illustrates the impacts using case study examples from current events.



What is heat?

Heat waves, also referred to as warm spells or extreme heat events, are periods of abnormally hot weather. Heat waves have various and often overlapping definitions. In the climate science community, a heat wave is often defined as a period of at least three days with anomalous high maximum temperature. Besides maximum temperature, other variables, such as night time temperatures (i.e. minimum temperatures) could be relevant when assessing health impacts of heat. Some studies include relative humidity in their definition of heat waves because high humidity may aggravate the impacts of heat waves on the human thermoregulation system.

Extreme heat events refer to the occurrence of temperature values above a threshold value near the upper end of the observed temperature range.

Heat stress refers to heat received in excess to the extent the body can tolerate without suffering physiological impairment.

Key considerations: bottlenecks, challenges, constraints

- **Heat wave and their stress thresholds.** The threshold for heat stress is relative to the region and vulnerability factors. A person living in Northern Europe will experience heat stress at lower temperatures than a person living in Southern Europe. When outdoor temperatures are elevated, a construction worker may experience heat stress while a person in an airconditioned office may not.
- **Cities are warmer than their surrounding areas.** This is due to the different surfaces in urban areas (e.g. concentrated concrete with high heat absorption rates and low tree cover) that affects the storage of heat. This can be measured and is referred to as the urban heat island (UHI) effect. The extent of this effect depends on local climate factors such as wind and cloud cover (which in turn depend on season), on proximity to the sea and other aspects of urban planning, such as green and blue spaces.

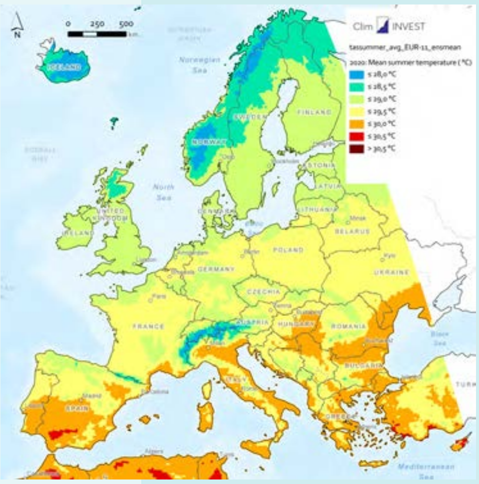
Calculating asset exposure to heat: relevant hazard indicators

Climate scientists use a wide variety of indicators and metrics to define and analyze the effects of heat in different sectors and contexts. Maps of climate hazard indicators are a user-friendly way to visualize and identify the locations that are most exposed to a climate hazard and the changes in frequency and intensity in the future. Combined with asset location data, they can be used to explore specific asset exposure to heat stress.

Below, we showcase five climate hazard indicators that can be used to describe heat wave events in Europe. The maps assume an RCP 8.5 scenario which is expected to result in ~4°C warming in global average temperatures by the end of the century. This scenario was used to illustrate what more extreme climate hazards might look like but should not be used as a predictive tool.

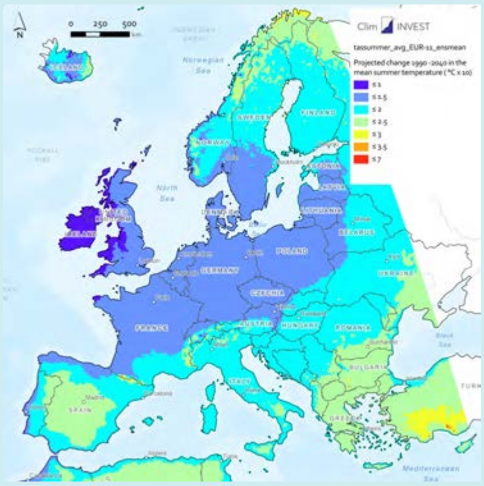
Note that these maps are only part of the climate risk assessment equation; they can demonstrate an asset's exposure to potential heat stress conditions but do not show an asset or portfolio's vulnerability to the hazard (determined by specific ground conditions and asset specification), nor do they definitely describe the probability that an area will be affected by heat stress (as determined by land use, in particular deforestation, water use, urbanization, and agricultural practices, and other factors) nor timing of the event. See our **Calculating climate risks and Climate modeling 101 factsheet** for more information about scenarios and uncertainties.

Climate indicator	Definition
Average temperature in summer	Summer mean temperature, calculated from the daily average of all days in summer months: June, July and August. This can be used either as a baseline for reference or to note long term trends.

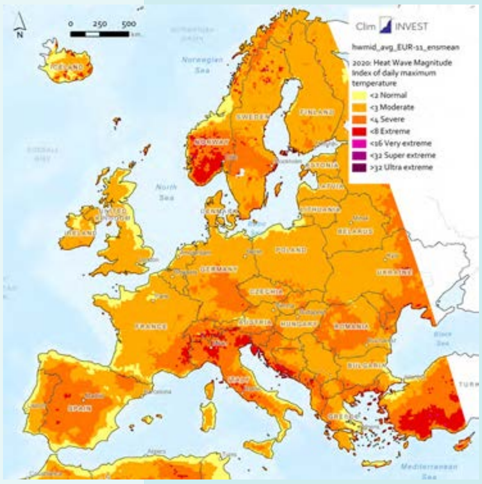


Left: Summer mean temperatures in Europe in 2020. Blue represents less than 28°C and dark red represents mean temperatures that are higher than 30.5°C.

Right: Projected changes in summer mean temperatures in Europe from 1990 to 2040. Indigo represents none to 1°C change and red represents up to 7°C change.

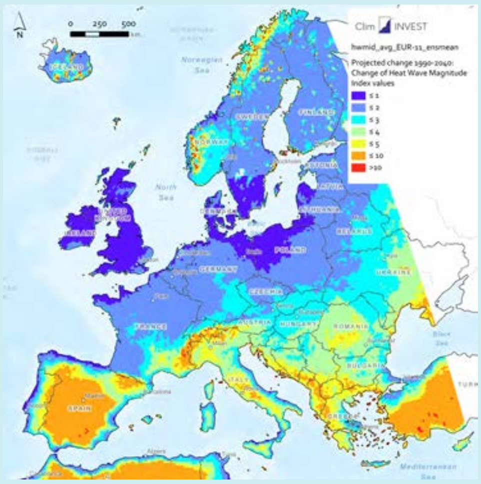


The heat wave magnitude index daily (HWMId)	The heat wave magnitude index daily (HWMId) merges the duration (days) and the intensity (daily maximum temperature) of prolonged extreme temperature events into a single numerical index. *E.g. high magnitude may have implications for human health, impairing worker productivity (especially in agriculture and construction sectors) which may lead to financial losses*

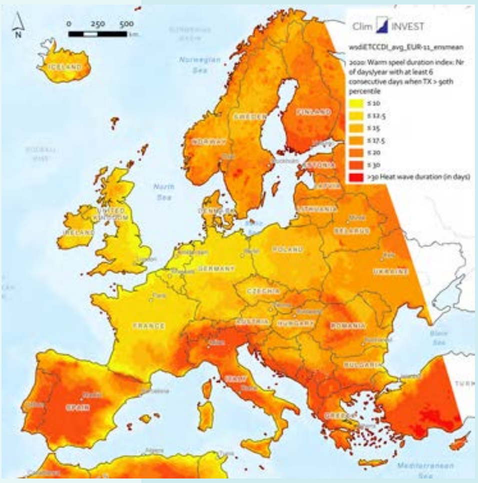


Left: Simulated magnitude of heat waves over Europe in 2020. Yellow represents normal values and dark purple represents ultra-extreme events both in terms of temperature and duration of heat waves.

Right: Projected change in heat magnitude (HWMId) over Europe from 1990 to 2040. Indigo represents no- or small change and red is severe change.

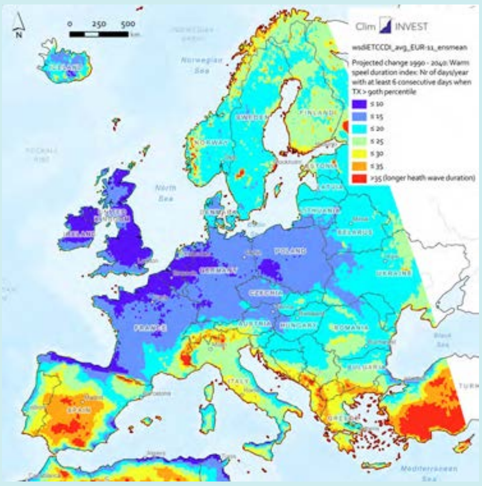


Climate indicator	Definition
The Warm Spell Duration Index (WSDI)	The Warm Spell Duration Index (WSDI) measures the length of heat waves in days. WSDI is the total number of days in a year that are part of heatwave of 6 days or longer, when maximum temperature is higher than in 90% of days in the reference period 1981-2010. *E.g. high WSDI may have negative implications for agriculturally intense areas where long lasting heat waves can impair crop growth and decrease crop yields.*

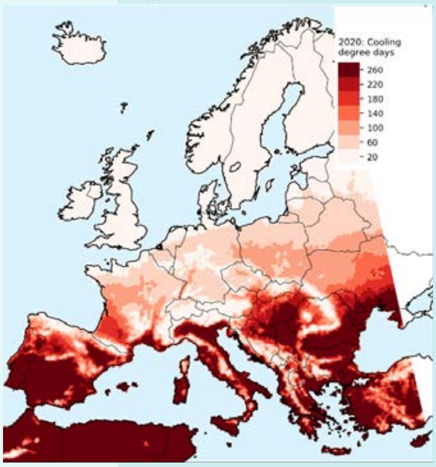


Left: Projected warm spell duration (WSDI) over Europe in 2020 (obtained by using an average of model values in the period 2011-2030). Yellow represents heat waves which last between 6 and 10 days and red represents heat waves longer than 30 days.

Right: Projected change in warm spell duration in Europe, from 1990 to 2040. Indigo represents warm spells less than 10 days long and red represents warm spells longer than 35 days. The 1990 value was obtained as the average value for historical model runs from 1981-2000, whereas the 2040 projection is the average of projections for 2031-2050.

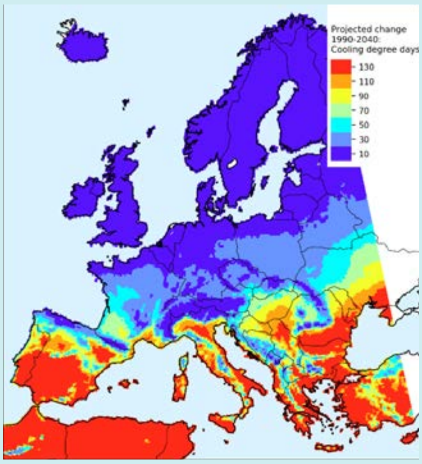


Climate indicator	Definition
The cooling degree days (CDD)	The cooling degree days (CDD) indicator measures how much cooling is needed in buildings, in terms of how much (in °C), and for how long (in days), outside air temperature was higher than a specific "base temperature". The base temperature for Europe is 22°C, as recommended by the EEA. Further details about the methodology can be found here. If temperatures do not exceed the base value, CDD value is 0. CDD is used to calculate energy consumption required to cool buildings.

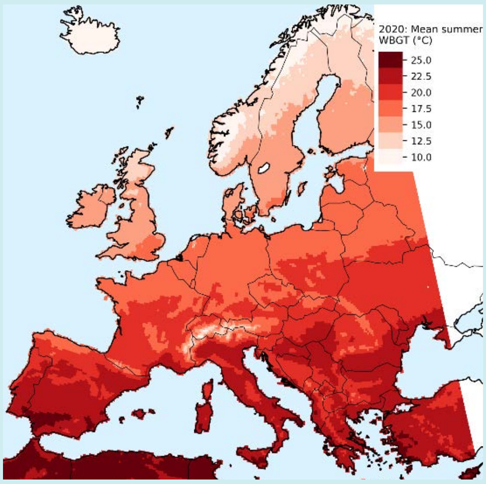


Left: Projected CDD over Europe in 2020 (obtained by using an average of model values in the period 2011-2030). Dark red represents the areas with very high need for cooling in summer months and white represents low- to little need for cooling.

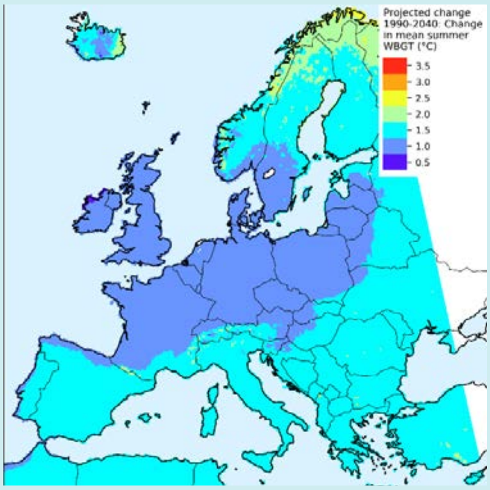
Right: Projected change in CDD over Europe, from 1990 to 2040. Indigo represents areas with insignificant change and red represents strong change. The 1990 value was obtained as the average value for historical model runs from 1981-2000, whereas the 2040 projection is the average of projections for 2031-2050.



Climate indicator	Definition
Wet Bulb Globe Temperature (WBGT)	Wet Bulb Globe Temperature (WBGT) represents the cooling capacity of the human body through perspiration. This indicator calculates the weighted mean of a function of temperature, relative humidity and pressure.



Projcted summer mean WBGT over Europe in 2020 (in °C, note that the scale is different than for normal temperature). The 2020 projection presented here was obtained by using an average of model values for the period 2011-2030. Dark red represents areas with very high heat-related health risks, white represents areas with relatively low risk.



Projected change in summer mean WBGT over Europe, from 1990 to 2040. Indigo represents 0.5°C increase in WBGT and red represents 3.5°C increase in WBGT. The 1990 value was obtained as the average value for historical model runs from 1981-2000, whereas the 2040 projection is the average of projections for 2031-2050

Cooling down in Otto-Maigler-See, Germany, June 2019. Photo: dronepicr

Vulnerability: sector sensitivity & adaptive capacity

The sector sensitivity below outlines potential physical impacts of heat on key economic sectors and resulting financial impacts that can be expected. Sectors with higher physical and financial impacts are considered more sensitive to heat stress, but are not necessarily more vulnerable. Factors that contribute to an asset's vulnerability to heat include the following:

- **Construction materials and design.** Buildings without adequate insulation are more susceptible to overheat. Materials used for infrastructure in the transportation and energy sectors may not be stress tested at high enough temperatures. For example, the railway tracks in the UK failed under the 2018 heat waves. They were stress-tested at 27°C.
- **The age of the asset.** Older infrastructure may have been built to lower standards without taking heat stress considerations into account. For example, leakproof water pipes can help reduce water lost during distribution in water stressed areas.
- **The connectivity of the asset.** Assets in the energy, real estate and transportation sectors are highly interconnected. For example, a physical impact at a power station or along a major transmission line can affect an entire power network. The number of people or value of assets in a network could be a useful indicator to inform project prioritization.
- **Dependency on the asset.** This is particularly relevant for infrastructure such as train lines and roads. Areas with alternative routes available are less vulnerable, whereas areas with fewer transportation options can see significant setbacks in the case of heat stress. The amount of money flowing through a road or trainline could be a useful indicator to inform project prioritization.
- **Time horizons of the asset.** Different sectors have different time horizons: agriculture operates on a seasonal basis, whereas construction and energy work on 20-40-year time horizons. The impacts of climate hazards may therefore have differing levels of relevance or immediacy for each sector.

Heat stress may cost global GDP USD $2,400 billion by 2030

According to a 2019 report by the International Labor Organization (ILO), heat stress is projected to reduce total working hours worldwide by 2.2 per cent and global GDP by US$2,400 billion in 2030. Physical labor in high temperatures imposes significant strain on the human cardiovascular system even in young and healthy adults.

In Europe, worker productivity was reduced with 4% on average, in 2015 due to hot outdoor conditions. Financial losses during summer months were estimated at $60-90 per worker in agriculture sector and at $40-70 in the construction sector. Details of the scientific approach for calculation of financial losses due to decrease in worker productivity can be found here.

Sector sensitivity

Impacts: Physical / Financial

Sector	Impact	Description
Real estate	Physical	Direct. Worker productivity or capacity to work goes down in construction Indirect. Increased energy consumption
	Financial	Revenue. Lost revenue from delays in construction, higher worker turnover, inability to work during temperature peaks. Asset value may decrease in highly exposed areas. Operation costs. Additional cost of increasing energy bills due to increasing need for cooling. Financing costs may increase as revenue goes down and risk exposure goes up.
Transportation	Physical	Direct. Melting asphalt on roads or runways, buckling train tracks. Indirect. Increased need for new infrastructure.
	Financial	Revenue. Lost revenue from delays or reduced operation. Premature impairment or devaluation of existing transportation infrastructure. Operational cost. Additional cost of new infrastructure and materials that are more resilient to heat.
Agriculture and fisheries	Physical	Direct. Reduced crop productivity and quality due to improper temperatures and longer range and lifetime of harmful pests / bacteria Migrating fisheries Indirect. Reduced worker productivity and increased risk for work-related accidents in hot conditions.
	Financial	Revenue. Lost revenue from damaged or reduced crops. Increased operation costs for pest management. Financing costs may increase with risk exposure. Asset value may decrease for a farm in a heat wave-prone area with consistently reduced production levels. Operation costs. Higher transportation costs for fisherman Revenue. Lost revenue from reduced capacity to perform physical work in hot conditions and work bans during the daily heat peaks
Energy	Physical	Direct. Reduced inflow from melting snow and higher rates of evaporation of water in hydro power reservoirs. Increasing temperatures reduce the efficiency of solar panels. Expanding and sagging surface power lines.
	Financial	Revenue. Lost revenue due to low production capacity and high demand. Revenue. Lost revenue due to low electricity production. Operationcosts. Increased operational costs to maintain felled power lines due to wind, fallen trees, passing traffic.
Health	Physical	Direct. Increased incidence of cardio-vascular and respiratory diseases. Increased spread of vector-borne diseases.
	Financial	Operation costs. Increased costs for the health system due to higher numbers of patients.

Heat waves drive up energy prices in Norway

Rising summer temperatures around the world have driven up demand for indoor air cooling, particularly in urban areas. Like most regions in Europe, temperatures in Scandinavia have increased by about 0.3 degrees every decade since 1960 (source: EEA, 2019). 2018 was one of the hottest years on record. The highest anomalies were registered in northern Scandinavia and Ireland, with heat waves more than five degrees warmer than the average hottest three days of the year in 1981-2018 (WWA, 2018).

97% of Norwegian electricity is generated with hydropower. Every spring, hydropower reservoirs fill with water from melting snow, generating a surplus of energy and decreasing the prices. The winter months (January, February, March) in 2018 saw a lot of snow, which started to melt in April filling the reservoirs. Due to the fast accumulation of water in the dams, the energy producers were forced to release the surplus causing the energy prices to drop. In May 2018 however, temperatures changed abruptly from winter cold to hot, sunny days, causing the remaining snow to simply evaporate instead of melting. Because of this, reservoir levels remained low while electricity prices increased sharply, destabilizing the energy market.

Soaring temperatures in Norway had a twofold financial impact on the price of energy: 1) supply of energy was constricted because of dwindling hydropower reservoirs and 2) demand for energy increased as more homes and offices were cooled. The 2018 Norwegian electricity production dropped to 145.7 TWh, 3TWh less than 2017 production while electricity consumption reached an all-time high of 135.4 TWh. These imbalances inflated the 2018 energy prices by 35% compared to 2017 (NVE, 2019).

Norway isn't the only country facing increasing energy prices. Extreme weather conditions in 2018 have also increased energy prices in the UK and EU in general. The EU has seen an average household electricity price increase of 3.5% per 100kWh (Eurostat, 2019). Impacts of such events are often not restricted to one sector but affect entire supply chains. The real estate sector may face higher electricity prices and increased energy consumption due to use of air conditioning on hot days. Indicators such as HDD and CDD (described above) help to assess the energy demand of buildings. Implementing energy efficiency measures in different industry sectors and real estate may reduce energy costs and avoid shortages in supply.

SUMMARY:

- **Exposure**:
  Sublimation of snow increased exposure.
- **Vulnerability factors:**
  Hydropower production relies on availability of water which, in turn is highly susceptible to changes in weather and climate.
- **Adaptive interventions:**
  Invest in early warning systems and improvements in the use of sub-seasonal to seasonal (S2S) forecasts in energy models.

97% of Norwegian electricity is generated with hydropower. Dam in the catchment area for Bjølvo power station in Ålvik, Norway. Photo: Statkraft

Adaptive capacity

Asset or portfolio vulnerability is sector specific and determined by such elements as land use, construction materials, and water management systems. There are hard measures (e.g. investments in infrastructure) and soft measures (e.g. policy or pricing signals) that can be taken to reduce an asset's vulnerability to extreme heat.
The interventions described below are examples of steps decision makers can consider to reduce their vulnerability to heat stress, by sector

Sectors	Measure	Adaptive capacity interventions: Soft measures / Hard measures
Real estate	Soft	Set policy, regulation, and tax incentives for energy efficiency in buildings.
	Hard	Invest in green or grey infrastructure that contribute to cooling such as insulation, green or white roofs, passive cooling strategies such as shaded areas or elevated roofs which allow cooling through natural passage of air, or air conditioning among others.
Transportation	Soft	Provide tax incentives or other financial incentives for investment in climate resilience projects and increase industry standards and regulations for areas with high risk of heat waves.
	Hard	Invest in materials with higher resistance to heat for roads and railways, according to high emission scenarios.
Agriculture	Soft	Invest in liability insurance, emergency response plans, higher standards for equipment maintenance.
	Hard	Invest in early warning systems and improve the use of sub-seasonal to seasonal (S2S) forecasts in energy models - more information on S2S is available here; reinforce power line networks, if possible, run powerlines underground to avoid tampering and damage or increase height of poles supporting power lines, install conductors with hotter operating limits, use low-sag conductors; use light-colored materials for construction of solar panels to reduce heat absorption; install solar panels a few cm above roofs to allow convective air flows to cool the panels.
Energy	Soft	Invest in irrigation systems for areas surrounding power infrastructure, alternative water storage facilities. Set up weather cameras to spot wildfires, put powerlines underground. For new thermoelectric power plants, build closed loop systems (grey water) for water cooling instead of open loop (fresh water) to reduce water use. Build interregional electricity transmission, microgrids and diverse/decentralized sources for baseload power. Increase efficiency of thermoelectric plants to reduce demand for water. Switch to seawater cooling for plants close to the coast. Enhance reservoirs capacity.
	Hard	Liability insurance and emergency response teams for wildfires, set higher standards for equipment maintenance, enhance and enforce engineering design standards to address climate risks. Review demand side management to reduce water consumption and enhance water re-use. Incorporate drought forecasting and reservoir management into management strategies for hydropower.
Health	Soft	Provide vulnerable sector workers with early warning systems and develop corporate policies to protect workers during extreme conditions, adjust working schedules in sectors that involve outdoor labor in hot months (i.e. construction and agriculture).
	Hard	Invest in improvements in cooling systems – green and grey infrastructure – in buildings and shaded areas for outdoor workers.

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