Clim INVEST

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Drought and physical climate risk

This factsheet introduces some key considerations for investors assessing their exposure and vulnerability to droughts, what to consider when using data on drought, and how drought can impact different sectors. It also takes a closer look at potential interventions available to manage the impact of droughts by sector and illustrates the impacts using case study examples from current events.

What is a drought?

A period of abnormally dry weather long enough to cause a serious hydrological imbalance. Drought is a relative term, therefore any discussion in terms of precipitation deficit must refer to the particular precipitation-related activity.

For example, shortage of precipitation during the growing season impinges on crop production or ecosystem function in general (due to soil moisture drought, also termed **agricultural drought**), and during the runoff and percolation season primarily affects water supplies (**hydrological drought**).

Storage changes in soil moisture and groundwater are also affected by increases in actual evapotranspiration in addition to reductions in precipitation.

A period with an abnormal precipitation deficit is defined as a **meteorological drought**.

A **megadrought** is a very lengthy and pervasive drought, lasting much longer than normal, usually a decade or more.

Key considerations: bottlenecks, challenges, constraints

- **Drought does not only mean lack of rain.** Drought can also refer to mismanagement of creeks, rivers, lakes and water aquifers, as well as reduced snowmelt and waterways shifting due to disappearing glaciers. This mismanagement can occur by overdrawing from rivers or aquifers, diverting water from its regular flow, or even paving over creek and riverbeds for urban development. Clearing old growth forests that retain and filter water naturally, or growing water-intensive crops in water stressed regions also contributes to the problem.
- **Drought is regionally specific and closely linked to hydrology.** What is considered a drought in one region may be normal in another.
- **Drought and heat stress do not always occur together.** There can be drought in moderate or even cool weather.
- **Persistent droughts can cause conditions for wildfires.** Dry vegetation will be more likely to catch fire.
- **Climate data on drought is not enough to discuss water stress.** Although drought can be a key driver of water stress, water demand is another key driver that is determined by demographics and economic activity.
- **Projections for drought are uncertain.** Drought is difficult to model accurately because of natural variability and dynamic climate system processes, such as shifting currents. For some regions, like the Mediterranean, the signal for becoming more dry/drought-prone is very certain across all models while for others, such as southeast Asia, it remains quite uncertain.
- **Extended drought causes land to compact and become less able to absorb water, leading to more severe impacts of floods that can occur several days/weeks later.** This can be exacerbated by poor land management practices and irreversible land and soil degradation.

Aletsch Glacier, Switzerland. Heavily affected by climate change. Photo: Didier Baertschiger

The Rhine, the Alps' glacier melt, and the shipping sector

In July 2019, the combined effects of shrinking alpine glaciers (i.e. hydrological drought) and severe (meteorological) drought dropped water levels of the Rhine River to half its usual levels, hitting a 12-year low.

This is expected to get worse as summertime glacial melt from the Alps that feed the Rhine continues to outpace accumulation of snow in winter, reducing the amount of melt feeding the rivers each year. Alpine ice flows shrank by 28 percent between 1973 and 2010, and may be up to 35 percent now, according to Wilfried Hagg, glacier expert at Munich University.

This will increase the river's dependence on rainfall, which may shift with climate change. The Rhine River connects the Rotterdam Port of the North Sea to Switzerland, serving as an 800-mile major commercial artery for industry, shipping, and tourism through the Netherlands, Germany, France and Switzerland. It serves as a key conduit for raw materials and goods, from coal and iron ore to chemicals, fertilizers, food, tourists, and car parts, with large manufacturers such as Daimler AG, Robert Bosch GmbH, Volkswagen AG, and Bayer AG depending on the transportation route.

The drought conditions in July 2019 made the river impassable for most commercial ships for months and preventing barges from loading at full capacity until December.

The result was delayed shipments, a skyrocketing demand for storage along the river (already tight because of Brexit-related stockpiling), and high costs of alternative goods transportation by road and rail (shipping costs around 40% less than rail transport).

These all had a damaging effect on the German economy. For instance, BASF had to close some of its factories and suffered a burden of 250 million euros on 2018 operating income from low levels of the River Rhine.

Extreme low water at the river Rhine, near Koblenz, Germany, during the 2018-drought. Foto: Onnola / Flickr

Summary:

- **Exposure**: Shrinking alpine glaciers and reduced precipitation levels caused exposure.
- **Vulnerability factors:** Cost efficiency of shipping encouraged heavy dependency on shipping over train or trucking alternatives. Brexit exacerbated scarcity of storage options and drove prices higher.
- **Adaptive interventions:** Invest in shallow water barges, diversify supply chain sources and routes.

Calculating asset exposure to drought: relevant hazard indicators

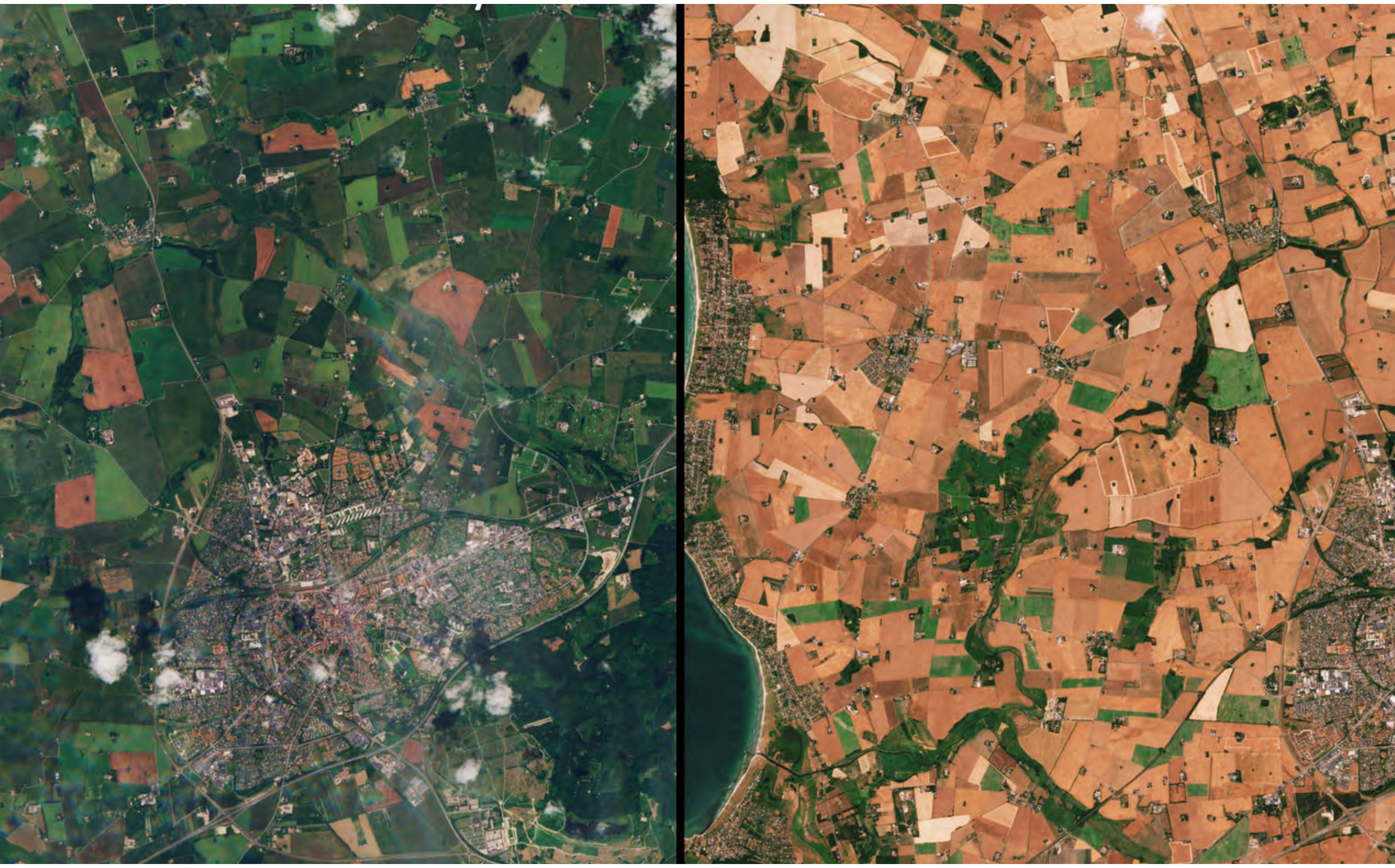
Climate hazard indicators (like the ones below) drawn from climate models, can be used to develop hazard maps. These maps provide a user-friendly way to interact with the hundreds of available indicators used to describe the factors that contribute to drought conditions. They can also be used to understand specific asset exposure to each indicator if asset location data is available to overlay on the map.

On the next page, we showcase two climate-related hazard indicators that can be used to describe the frequency or intensity of drought conditions in Europe. The maps assume RCP 8.5 scenario which correlates to around 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. The maps do not depict probability of events nor timing, . See our **Calculating Climate Risks and Climate Modeling 101 factsheet** for more information about scenarios and uncertainties.

Note that these maps are only part of the climate risk assessment equation; they can demonstrate an asset's exposure to potential drought 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 drought (as determined by land use, in particular deforestation, water use, urbanization, and agricultural practices, and other factors).

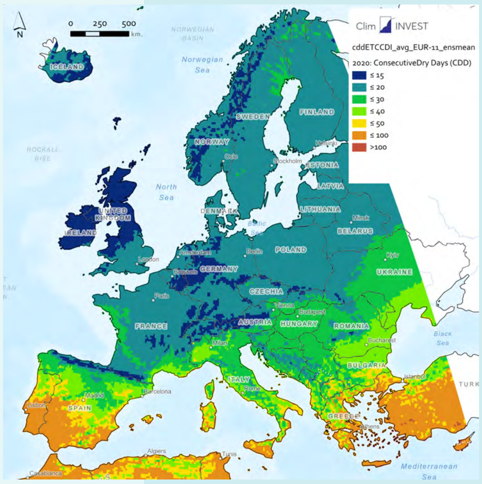
The European Commission has put together a Global Drought Observatory to incorporate data on drought characteristics and their impact, to better understand the relationship between both.

Other useful resources include the World Resource Institute's Aqueduct, which features tools developed by open-source, peer reviewed data to identify and evaluate water risks around the world. The tools include a water risk atlas, country rankings, and maps showing drought and the impact of water risk on agriculture and food security. Explore the tools here: www.wri.org/aqueduct

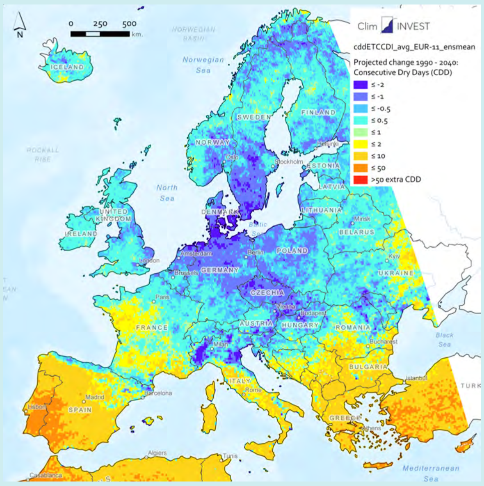


These two images from the Copernicus Sentinel-2 mission show agricultural fields around the town of Slagelse in Zealand, Denmark. The image from July 2017 (left) shows lush green fields, but as the image from July 2018 (right) shows, the heat and lack of rain has taken its toll on the health of the vegetation. Photo: ESA / Flickr

Climate indicator	Definition
Maximum number of consecutive dry days	Maximum number of consecutive days per year when daily precipitation is under 1mm per day. The indicator lists the length of a single longest period and not the number or frequency of such periods. This indicator is used to help identify and describe the length of drought events, chronic or seasonal drought patterns or recurring flashfloods. It does not describe temperature trends nor does it consider precipitation frequency or intensity for the rest of the year, which are important factors to consider when assessing exposure. *E.g. higher precipitation in spring and longer dry spells in summer would have opposite effects on water resources.*

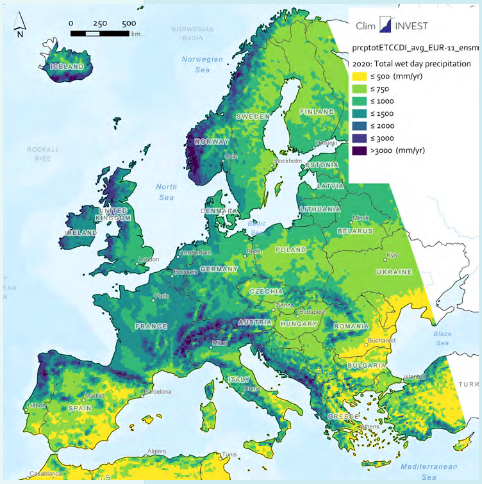


Left: Maximum number of consecutive dry days per year around 2020 (averaged over projected values for the period 2011-2030).Dark blue is fewer than 15 days, red is over 100.

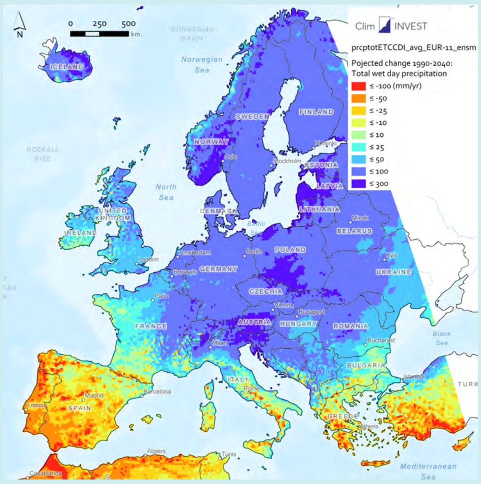


Right: Projected change in maximum number of consecutive dry days per year in Europe from 1990 to 2040 Indigo is two fewer days per year, red is over 50 extra days per year. The visualization demonstrates that regions with ongoing dry periods will see further increases in dry periods in the future. The 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.

Total pre-cipitation (PRCPTOT)	Shows total rainfall – or lack of – per year in mm across Europe. The map does not show in what season the rainy or dry season is concentrated, e.g. light rain every other day or months of drought at a time. This can generally inform land use planning and drought management, but must be put into local context or combined with other indicators such as CDD to be more useful. *E.g. general trends towards drought in southern Spain suggest that investing in water efficiency projects, rainwater catchment, and other green or grey rainwater retention infrastructure would benefit real estate projects.*



Left: total rainfall per year in mm, where yellow is under 500 mm per year and deep purple is over 3000 mm per year around 2020 (averaged over projected values for the period 2011-2030).



Right: Projected change in total precipitation per year in Europe from 1990 to 2040, where red is 100 mm less per year and deep purple is over 300 more mm per year. 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.

Vulnerability: sector sensitivity & adaptive capacity

The sector sensitivity table below outlines potential physical impacts of drought on key economic sectors and resulting financial impacts. Sector sensitivity is part of an asset's vulnerability, but must be combined with adaptive capacity factors to fully understand a sector's vulnerability. Sectors with higher potential physical and financial impacts are considered more sensitive to drought, but are not necessarily more vulnerable.

Factors that contribute to an asset's vulnerability to drought include the following:

- **Construction materials and design.** Older infrastructure may have been built to lower standards without taking drought considerations into account. For example, leakproof water pipes can help reduce water lost during distribution in water stressed areas.
- **Land use around the asset.** Drought can lead to soil subsidence which can cause foundations to shift and crack.
- **The age of the asset.** Aging infrastructure may begin to break down over time, particularly if maintenance is lacking. It may also not have been designed with the impacts now expected from climate change.
- **The connectivity of the asset.** Assets in the energy, water, 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. A water treatment plant with reduced capacity may have health implications for an entire community. The number of people or assets in a network could be a useful indicator to inform project prioritization.
- **Dependency on the asset.** Some assets are used more heavily than others – ports or train stations in New York City or Amsterdam have a heavier daily flow of traffic and financial capital than the same assets in Tanzania. This is particularly relevant for inland shipping infrastructure such as ports. The amount of money flowing through a port 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.

Note that financial impacts can have positive or negative effects on revenue, operation costs, the value of an asset or financing costs.

Sector sensitivity

Sectors — Impacts: Physical / Financial

Real estate

Physical

Prolonged drought dries out soil, which then compacts and can shift foundations of buildings.

Potential interruptions to water services in severely water stressed areas.

Financial

Operation costs. Cost of repair to foundations / structures can be severe over time. May necessitate investments in water efficiency technology. Cost of insurance (wildfire) may go up with exposure.

Asset value may decrease in highly exposed areas.

Financing costs may increase with risk exposure.

Transportation

Physical

Inland shipping and ports may be affected by lower water levels, e.g. Panama Canal and the Rhine – reduced load factors which increases number of vessels required to ship load.

Financial

Revenue. Lost revenue from delays or reduced operation.

Operation costs. Cost of smaller boats, dredging to deepen a lock or docking station, or alternative land-based routes financing.

Asset value. Ports, locks or deep-water barges may loose value in rivers that are consistently too low to use.

Agriculture

Physical

Reduced crop yields from dried soil.

Increased reliance on irrigation which drives up energy costs.

Financial

Revenue. Lost revenue from reduced or damaged crops.

Operation costs. Investments in drip irrigation infrastructure and other water management systems increase. Premiums for crop insurance likely increase.
Asset value may decrease for a farm in a drought-prone area with consistently reduced production levels.

Financing costs may increase as revenue goes down and risk exposure goes up.

Energy

Physical

Potential reduced inflow and increased evaporation of water can reduce capacity of hydropower plants.

Introduces risk of wildfires around power plants and transmission lines.

Thermoelectric and nuclear power plants need water to cool systems – reduced availability from drought and evaporation affects operation.

Soil subsidence can damage oil/gas pipelines.

Financial

Revenue. Potential lost revenue in the case of reduced capacity of hydropower plants or wildfires. Preventative blackouts can reduce revenues.

Operation costs. Purchasing alternate fuel stocks for peak load when baseload hydro capacity is low can introduce significant costs. Liability insurance and increased maintenance increases costs. Switching cooling systems for thermoelectric and nuclear power plants and repairing damage from damaged pipes can also represent high costs.

Asset value. PG&E example is instructive.

Financing costs may increase with risk exposure.

Water

Physical

Reduced river flow or glacial melt and increased evaporation from lakes and reservoirs may reduce supply of potable water and require road and ship tanker deliveries.

Reduced water availability will affect normal operation of wastewater treatment plants.

Soil subsidence can damage distribution pipes.

Financial

Operation costs. Delivering potable water by road and ship tanker, and repairing damaged or leaking pipes increases costs. Cost of insurance may increase.

Financing costs may increase with risk exposure.

PG&E bankruptcy and California wildfires

California has seen conditions for wildfires (i.e. drought and high winds) increase since 2007, resulting in 14 of the 20 most devastating wildfires in state history. A state-commissioned report projects that under current emission trends, the average burn area in California will increase 77 percent by the end of the century. California's power producer, PG&E Corp, went bankrupt following lawsuits that held it liable for the deadly 2017 and 2018 wildfires. According to a 700-page report by the California Public Utilities Commission released November 2019, the power producer did not properly inspect and correct hazardous conditions on the Caribou-Palermo transmission line before a faulty wire sparked a wildfire that killed over 80 people in the Northern California town of Paradise. The utility filed for bankruptcy in January 2019, citing potential civil liabilities of more than $30 billion from wildfires linked to its gear. Company shareholders have watched the market value of the company plunge to $2.5 billion from $12.4 billion six months before..

In an effort to manage risks, PG&E has been turning off power across large parts of its service area during high winds because fallen power lines are a major cause of wildfires. In November 2019, power was cut off preemptively to nearly 3 million people for as many as five days. The blackouts have potentially serious implications for local businesses, low-income families that cannot afford generators or batteries, and older or sick residents who rely on electric medical devices. PG&E expects to use blackouts as a management mechanism for up to a decade until maintenance on all lines and equipment is brought up to standard. To manage the impact of these blackouts, PG&E is installing back up energy systems like microgrids, underground power lines and weather cameras.

Meanwhile, stakeholders – including wildfire victims, PG&E employees, city governments and shareholders – are working out how to cover PG&E's civil liabilities and structure the company for the future. California is exploring the idea of establishing a new state fund that would be used to keep fire liabilities from overwhelming utility companies. The fund will help compensate victims for losses from fires started by the utilities' equipment, beyond the utilities' insurance coverage. Utilities would be required to invest $5 billion on safety improvements to participate in the fund, and executive compensation would be tied to safety performance. Current plans would put $21 billion in the fund. It is a start but may not be enough to cover future costs of damage if the region continues to see wildfires like those of the past two years.

SUMMARY:

- **Exposure:**
  Extended stretches of consecutive dry days and high winds created favorable conditions for wildfires. PG&E's infrastructure network is broadly dispersed across the area affected by drought and high winds, so it was highly exposed.

- **Vulnerability factors:**
  Faulty inspections and equipment.

- **Adaptive interventions:**
  Turning power off preventatively during high winds, investing in microgrids, underground powerlines and weather cameras. Developing more robust insurance schemes, emergency response teams, and early warning systems.

Firefighters from Stockton, California fighting a wildfire. Photo: Daria Devyatkina

Adaptive capacity

Adaptive capacity is 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 or sustained drought, explored below.

Sectors	Adaptive capacity interventions: Soft measures / Hard measures	
Real estate	Soft measures	Flexible water pipes to prevent breakage, irrigation systems around properties, reinforcement of infrastructure and building envelop in clay areas. Explore nature-based solutions such as reforestation, reservoirs, or water gardens that help retain rainwater during dry periods.
	Hard measures	Set a minimum distance between buildings and trees in clay areas, provide incentives for investment in water efficiency, develop sustainable wildfire insurance schemes. Promote water management system maintenance and reward low water use with tax credits. Invest in firefighting equipment and soft infrastructure
Transportation	Soft measures	Invest in smaller boats or shallow water barges, dredge riverbeds and docking stations, secure truck and train routes for goods, increasing stock where it's needed, invest in locks and dams to manage water flow.
	Hard measures	Early warning systems to plan alternative transportation routes and backup sources for raw materials, diversified supply chains.
Agriculture	Soft measures	Install drip irrigation, rainwater catchment systems, grey water, and water harvesting systems. Expand reservoirs. Shift crops to drought resistant varieties, shift to agricultural practices that increase soil water retention (agroforestry, increased organic matter rate, regenerative agricultural practices, cover crops, organic fertilizers, minimum tillage). Shift to controlled agriculture (e.g. greenhouses, vertical farming, hydroponics and aquaponics). Use of multifunctional field margins.
	Hard measures	Early warning systems to adjust crop selection, promote crops with lower water footprints, maintain water-meters and explore water credit systems for big agriculture.
Energy	Soft measures	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, micrograds 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 measures	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.

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Clim INVEST

Tailored climate risk information for financial decision makers

ClimINVEST brings climate scientists and investors together to provide transparency on methodologies for physical climate risk assessment, and develop guidance tools that inform investors' risk management processes. Learn more at www.cicero.oslo.no/en/climinvest

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