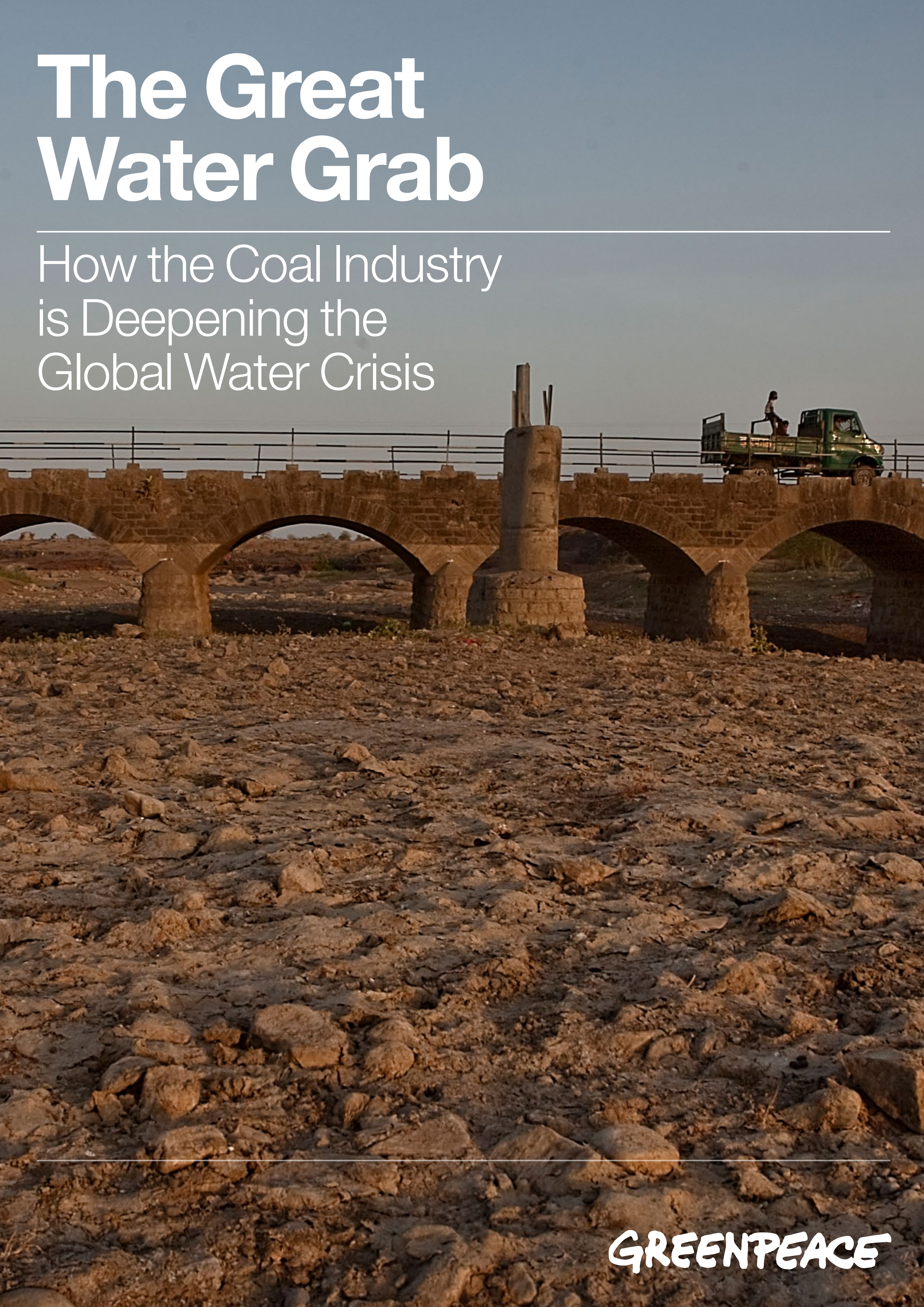
The Great Water Grab

How the Coal Industry is Deepening the Global Water Crisis



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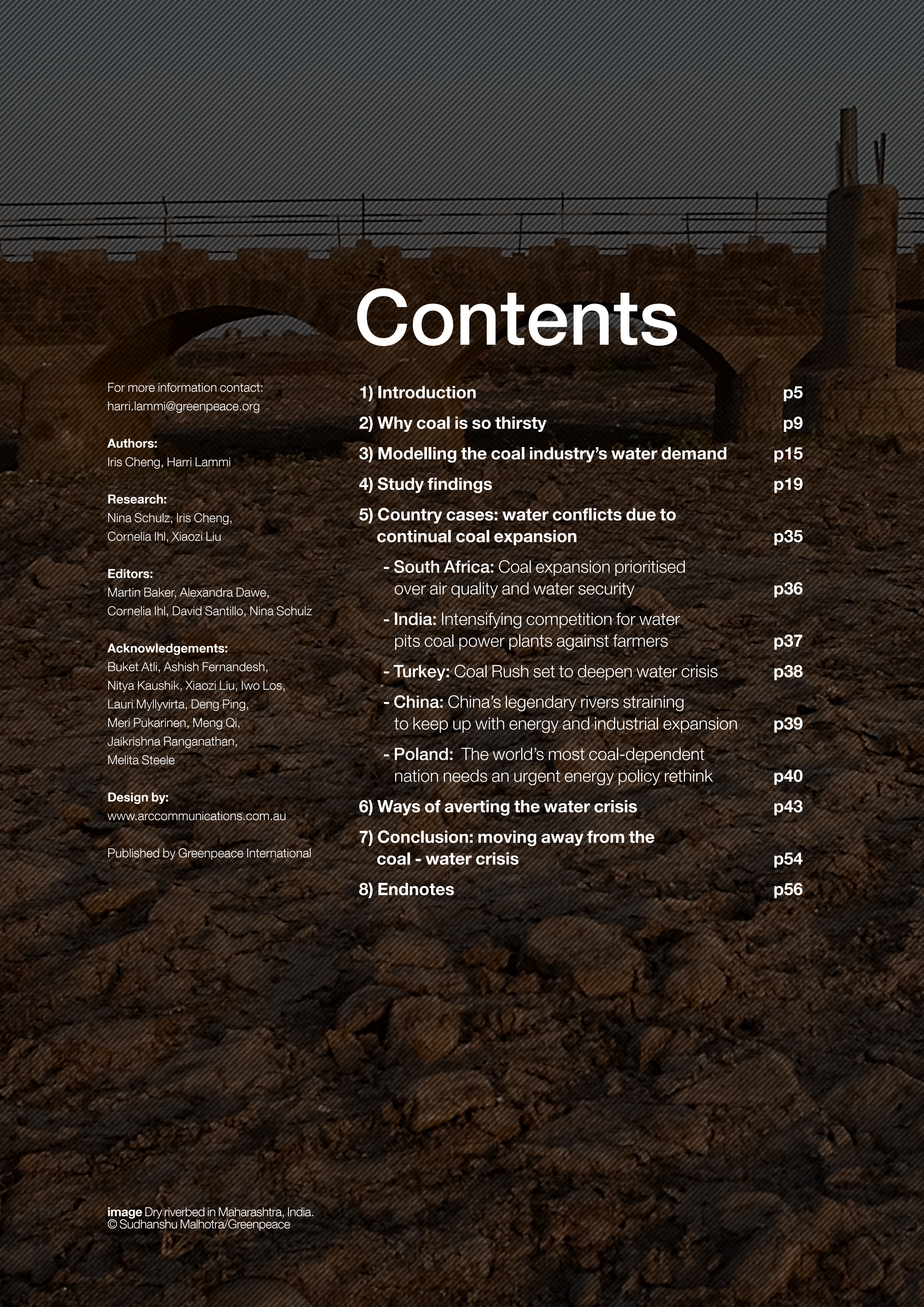

image Dry riverbed in Maharashtra, India.

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image Boy collects water from a community tap near Matimba coal fired power station, Waterberg, South Africa - December 2013.

Introduction 01

Water is essential for all life on earth and plays a central role in human development: from sanitation and health, to food and energy production, to industrial activities and economic development. However, human activities are depleting our planet's water resources at an alarming rate. The World Economic Forum's *Global Risks report 2015* identified water crises as the greatest risk that the world faces over the next 10 years in terms of potential impact, with political, business and civil society leaders agreeing that **"water security is one of the most tangible and fastest-growing social, political and economic challenges faced today."[1]**

Despite this, Greenpeace International has discovered that governments are failing to manage water sustainably, by continuing to allow the coal industry to tap into this precious resource without first conducting thorough evaluations of the consequences. The whole lifecycle of coal-generated electricity has enormous impacts on freshwater systems, from mining and washing to combustion and combustion waste management. **A 500 MW coal-fired power plant, using once through cooling, can withdraw enough water to suck dry an Olympic-sized swimming pool roughly every three minutes.[2]** In many countries, the coal industry creates one of the largest demands on freshwater resources.

Plans for further major increases in coal-fired power plant capacity around the world (almost 1300 GW proposed additional coal-fired capacity as at the end of 2013) could plunge many regions already suffering severe water stress into crisis and serious drought.

There is also the increasing risk of serious conflicts over already depleted water resources between agricultural, industrial and domestic users. This huge demand on water resources coupled with the importance of all these major sectors, could severely impact societies. In some countries the water conflict could force policy makers to make very difficult choices regarding the balance of water availability for food production, power supply or water sources of major cities, as well as for maintaining environmental needs.

This report for the first time evaluates and discloses the severe global impacts that our continuing reliance on coal-fired power is having on the world's fresh water resources.

Ground breaking modelling of coal's water demand

Greenpeace International commissioned the Dutch engineering consultancy Witteveen+Bos to develop a model to calculate the existing and growing fresh water withdrawal and consumption (hereafter referred to as water demand) from coal-fired power plants and coal mining, and to analyse the detailed impact of coal-fired power plant water demand on surface freshwater resources.

It combines data on existing and proposed coal-fired power plants as of the end of 2013, drawing mainly from Platts World Electric Power Plant Database. Field research, academic literature, news articles, industry information and other specific techniques were also used to estimate the missing information; and water factors for different parts of the coal lifecycle drawn from relevant literature in the key countries.

This study covers 1811 GW installed capacity of coal-fired power plants globally, and 1300 GW proposed capacity of coal-fired power plants, as at the end of 2013. This amounts to 8,359 installed coal-fired power plant units and 2,668 proposed units.

The data were used to carry out a thorough plant-by-plant assessment of fresh water use by the coal industry. It also includes an assessment of water demand of the existing coal industry and the additional demand if all 2,668 proposed coal-fired power plant units come online. The World Resources Institute's Aqueduct 2.1 model was used to carry out a geo-spatial analysis to assess the plants' impacts on the water basins in which they are located. The model and the study were reviewed by Ecofys, a leading consultancy in energy systems, markets and policies, at each phase of this 18-month project.

Our calculations show that existing coal-fired power plants alone consume 19 billion m^3 of freshwater per year globally. **This means that annually the world's 8,359 coal-fired power plant units consume enough water to meet the most basic needs of more than 1 billion people.** If we add the water that the coal industry uses to mine hard coal and lignite, this number rises to 22.7 billion m^3 of water per year, enough to meet the most basic water needs of 1.2 billion people.[3]

The numbers also show that coal-fired power plants account for the majority of the water consumed by the coal sector (84%), while water consumption for mining hard coal and lignite account for the remaining 16%.

Our research also discovered that the issue of over-withdrawal of water is already widespread and severe, meaning that, in many areas water is being used much faster than fresh water bodies can replenish naturally. **Around a quarter of both the existing and proposed coal-fired power plant units are located in areas already experiencing over-withdrawal of water.**

Globally, 44% of the existing coal-fired power plants are clustered in regions with high levels of water stress, which means that water usage is above the level generally associated with significant ecosystem impacts.[4] Despite this, a massive coal expansion is planned in these very same locations, with 45% of the proposed plants in areas of high water stress. This increases the risk of a severe water crisis of an unprecedented scale.

Nearly a quarter of these over-withdrawn coal regions are using more than 5 years' worth of renewable freshwater resources every year. This rate means in just two decades the basin would have spent its water budget for the whole century. This is comparable to spending more than your income without knowing how much is available in your bank account.

In many of these areas the impacts of surface water overuse are masked by sourcing water from underground aquifers, which are replenishing slowly or not at all. Although this relieves the immediate water scarcity issue, consuming the water reserve this way will result in an immediate crisis for major water users when aquifers run out. These regions will also have less resilience against extreme events like droughts, which are being made worse by climate change. Some global studies show the alarming speed of reductions in underground aquifers in major countries, which also overlap with the areas we focus on in this report.[5]

Through our mapping of water usage, we have identified coal expansion regions with high water stress, where the most urgent interventions in energy policy are required in order to avoid emerging water crises. These have been organised into worst affected regions, so called '**red-list areas**', where policy makers should make significant water savings possible by stopping licencing of new coal-fired plants, phasing out existing plants, and replacing them with low water intensity energy choices such as solar photovoltaic or wind power. But tackling the red-list areas alone will not have a big enough effect on the coal industry's water demand on a global scale. To achieve major global savings we also considered the potential water savings that could be achieved by the retirement of all coal-fired power plants over 40 years old.

If all of these measures are implemented, a massive 143 billion m^3 of water would be saved in terms of withdrawal, or 11 billion m^3 of water in terms or consumption[6] - **enough to meet the most basic water needs of half a billion people.** When it comes to energy, we have choices, many of which are not water-intensive; energy-water conflicts are avoidable.

To put these substantial findings into context, this report also describes in-depth the coal water cycle and illustrates the reality of coal-water conflicts with five case studies from "coal-water frontline countries" - China, India, South Africa, Turkey and Poland. These case studies illustrate what happens when users are forced to compete for access to available water resources, and demonstrate which water usage trade-offs must be taken to meet the needs for food production, industrial activities, energy, ecosystem maintenance, or for drinking and sanitation.

This pioneering study should be a wake-up call for all resource planners as it clearly illustrates the need for urgent action to integrate water and energy planning. In addition to that, an energy transition could also be sped up by different technology choices. There are huge potential water savings to be gained from transitioning from water-intensive thermal power generation to non-thermal generation such as solar PV and wind power, both of which require little water. **The results should spur new policy discussions and meaningful debates about energy choices, especially in already water stressed regions where energy demand is growing rapidly.**

'This pioneering study should be a wake-up call for all resource planners as it clearly illustrates the need for urgent action to integrate water and energy planning'

image Wind turbines next to Grevenbroich coal plant in the Rhenish lignite mining area, Germany - May 2015.
© Bernd Lauter/Greenpeace

Why coal is so thirsty

02

Coal has significant water impacts at every stage of its life cycle, from mining, washing of coal, to burning at the power plants and the treatment of combustion waste.

Coal already accounts for around 7% of all water withdrawal globally and is set to double in the next 20 years. Huge quantities of pollutants are discharged by mines, coal washeries and coal plants further threatening our scarce water supply.

Renewable energy requires almost no water to generate electricity. Switching from coal to renewable energy is one of the most effective and actionable ways to save water, and ensure clean water supply for people, agriculture and environment.

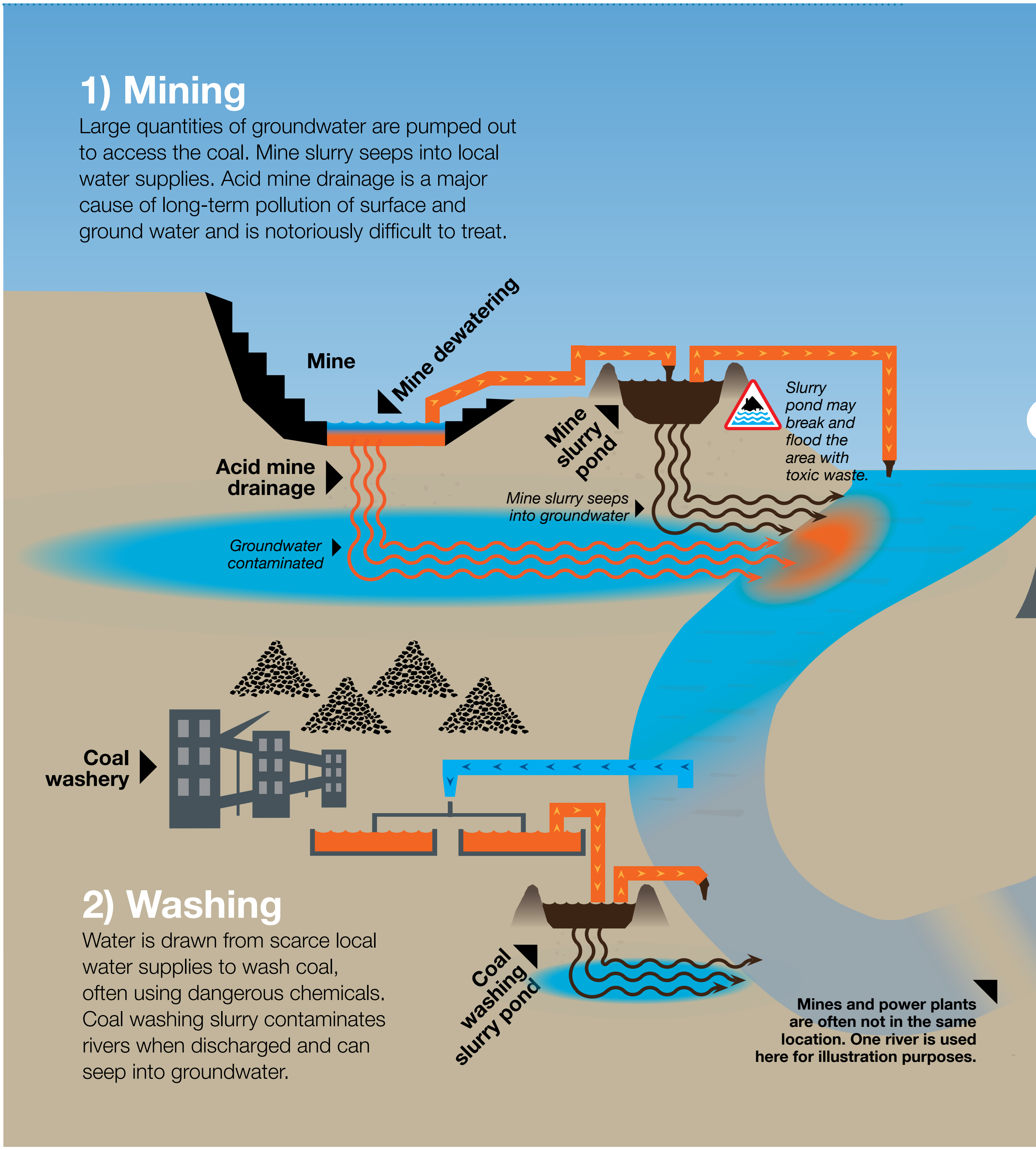
1) Mining activities have tremendous water impacts, beginning with the draining of groundwater to keep the mine dry to enable mining to coal. The depleted groundwater resources may take decades to replenish. Serious water pollution can occur in nearby water bodies through rain and seepage of polluted water. Soil erosion resulting from the removal of vegetation and subsidence from underground mining can radically change the runoff and an area's water retention capacity. In the longer term, acid mine drainage (AMD) can form, even long after a mine is closed, and can lead to serious and persistent water pollution which is notoriously difficult and expensive to manage.

2) Coal washing is carried out to remove stone, sulphur and ash from the coal ore. This process typically uses water from water bodies and creates a slurry of toxic material, which is removed from coal. This has to be treated before being released back into water bodies, and the toxic materials as far as possible isolated from the environment.

3) Cooling the power plants makes up the largest demand for fresh water. The exact amount of water depends on the cooling technology, but **a coal-fired power plant, using once-through water cooling, withdraws enough water to suck dry an Olympic-sized swimming pool roughly every three minutes.** The water needed for coal power cooling is often concentrated in specific regions by clustering of coal-fired power plants and other coal industry activities. This can have a tremendous impact on local water resources, and even result in plants having to be shut down because of a lack of water. Cooling water discharges can also lead to ecosystem changes. Power plants using once through cooling (either freshwater or seawater) produce thermal pollution by discharging warm water into the aquatic ecosystems, causing damage to ecosystems and fisheries sensitive to heat. Some of the heated water is also lost to evaporation in the process of it being returned to its source.

4) Waste in the form of coal ash represents a permanent water pollution risk, due to the toxic and very persistent materials it contains including heavy metals, and the vast volumes of waste produced. Coal burning produces huge quantities of coal ash. Coal ash has to be contained by keeping it wet to prevent dusting and by damming to prevent leakages to water bodies. Coal ash dam breaks and leaks are regular events and can create massive pollution to water bodies, soils and even urban areas.[7]

Figure 1: Water usage at major stages of the coal life cycle

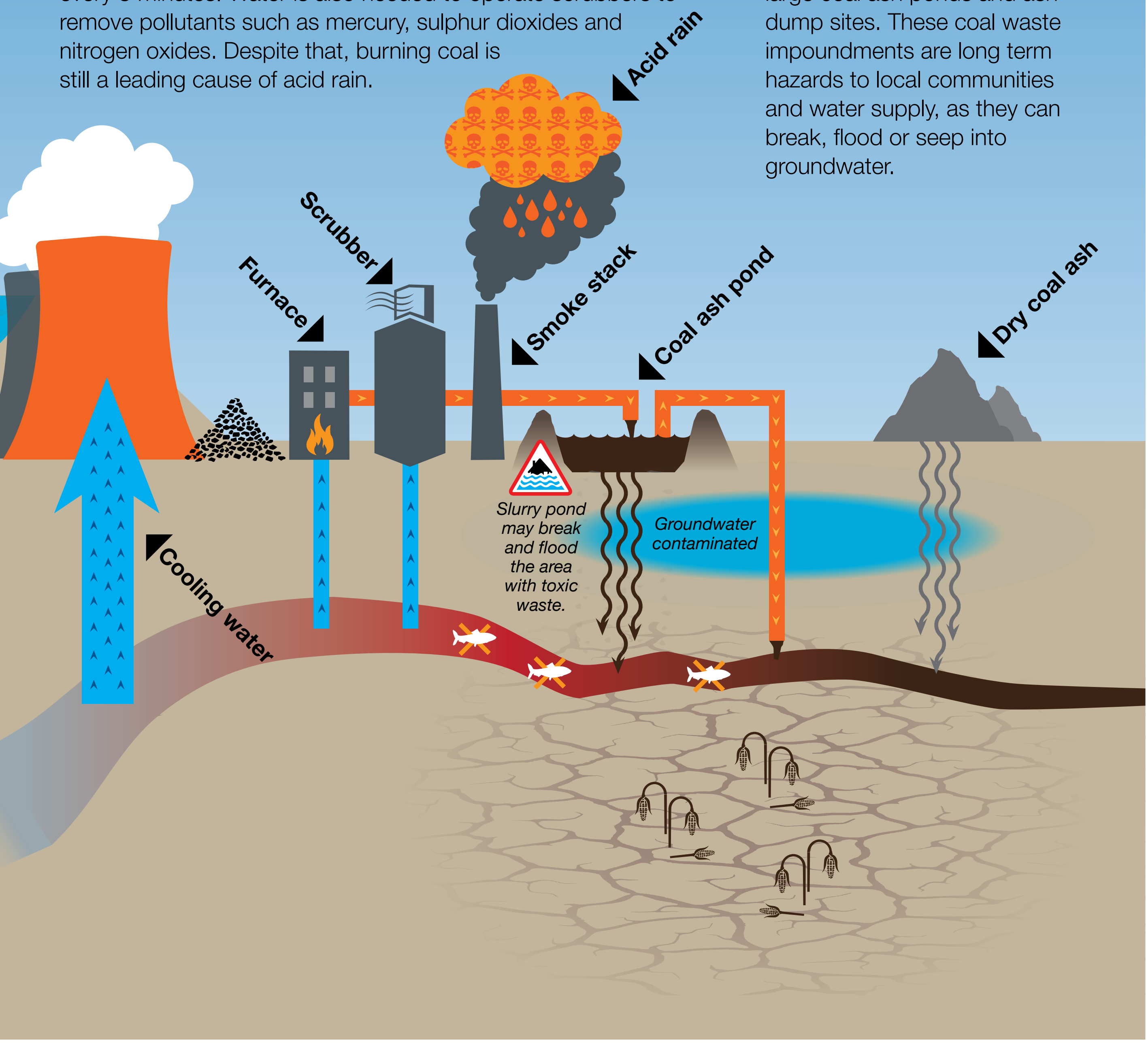


3) Cooling

Water is used for cooling, running the steam turbine and washing out the coal ash. A 500MW coal plant using once through cooling can empty an Olympic sized swimming pool of water every 3 minutes. Water is also needed to operate scrubbers to remove pollutants such as mercury, sulphur dioxides and nitrogen oxides. Despite that, burning coal is still a leading cause of acid rain.

4) Waste

Burning coal produces huge quantities of toxic waste which is stored in large coal ash ponds and ash dump sites. These coal waste impoundments are long term hazards to local communities and water supply, as they can break, flood or seep into groundwater.



Air pollutants from coal power plants can have major impacts on water bodies. Sulphur emissions cause acid rain and acidification of lakes, and heavy metals such as mercury bio-accumulate in the fish. Even when some of these pollutants can be removed from coal by scrubbers, a process which needs fresh water, the pollutants do not vanish. Toxic elements in the coal ash can increase further as a result of the operation of scrubbers designed to reduce air pollution. Pollutants such as mercury and other heavy metals can accumulate instead in the ash, posing a long-term problem of the storage of hazardous waste and the risk of water pollution from leaching and from spills.

Even when withdrawn water is returned to the water system after use, rather than being consumed in the process of cooling, its quality can be quite different from the receiving water bodies as a result of its temporary use. Deterioration in water quality is generally not taken into account when calculating water consumption. Often, even seriously polluted water returned to the waterbody is seen as recirculating water, even if it is not of a suitable quality for other uses. Similarly polluted water can spoil other, larger water bodies, if released back into them, multiplying the effect of water use. Despite this, during preliminary research into the issue, Greenpeace International found no established quantitative framework to assess coal pollution in combination with water demand planning.

The focus of this research was to estimate the withdrawal and consumption of water (hereafter referred to as water demand) by existing and proposed coal-fired power plants on the individual water basins in which they are located. The water demand of coal mining activities was also modelled on a national scale.

BOX 1: Water Definitions used in this report

Water withdrawal is the total amount of water taken from a water system in order to meet the demands for cooling, scrubbing or coal production.

Water consumption is defined as the difference between the total amount of water withdrawn and the amount returned to the same water system, and therefore represents a loss during the cooling process and coal production, due to evaporation or to other processes.

Water demand is a combined term and used for water consumption and water withdrawal.

Available Blue Water is the total amount of fresh surface water available to a catchment before any uses within that catchment are satisfied. This does not refer to or include groundwater.

Baseline Water stress is the ratio of total water withdrawal for all human uses (m^3/year) to the available blue water (m^3/year), used by the World Resource Institute (WRI) in the Aqueduct tool (Gassert, 2014). Water stress is defined in categories ranging from low (<10 %), low and medium (10-20 %), to medium and high (20-40 %), high (40-80%), and extremely high (80-100 %). In this report we have also categorised over-withdrawal (>100 %) separately, with permission from WRI Aqueduct team.

Catchment is defined as a water basin area that gathers rainfall into surface water, and finally into one discharge point. Catchments are hierarchical, with sub-catchments, like river tributaries discharging their water into the main catchment, for example the main river body.

Watershed is defined by the United States Environmental Protection Agency as "the area of land where all of the water that is under it or drains off of it goes into the same place."[8]

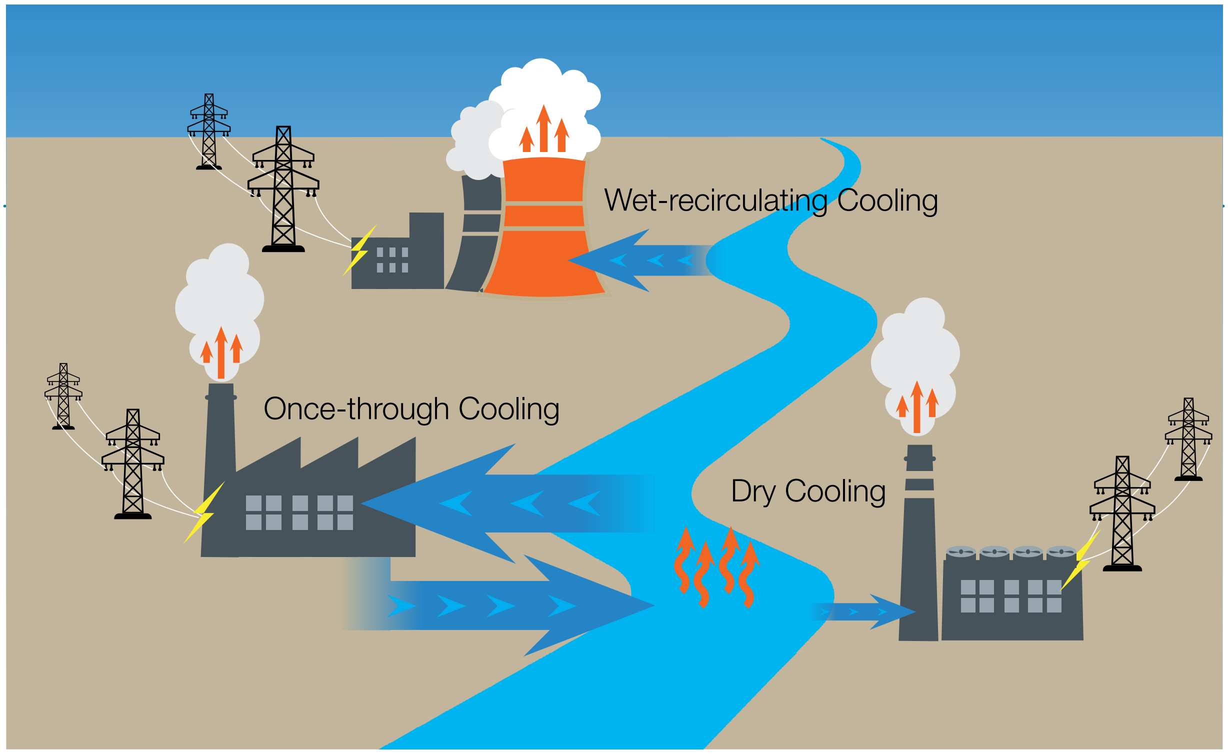


Figure 2: Water usage of the main cooling technologies.

Wet-recirculating or closed-loop systems reuse cooling water in a second cycle rather than immediately discharging it back to the original water source. Most commonly, wet-recirculating systems use cooling towers to expose water to ambient air. Some of the water evaporates the rest is then sent back to the condenser in the power plant. Because wet-recirculating systems only withdraw water to replace any water that is lost through evaporation in the cooling tower, these systems have much lower water withdrawals than once-through systems, but tend to have appreciably higher water consumption. This is the predominant choice of cooling system globally, used in approximately half of the coal fleet. A 500 MW, sub-critical coal-fired plant would withdraw around 10 million m^3 and consumes 8.4 million m^3 of water per year.[9]

Once-through Cooling systems take water from nearby sources (e.g., rivers, lakes, aquifers, or the ocean), circulate it through pipes to absorb heat from the steam in systems called condensers, and discharge the now warmer water to the local source. Some of this heated water is lost in evaporation. This type of cooling system withdraws a lot of water but consumes relatively little. This kind of cooling system is commonly found in coastal plants (using seawater for cooling), older inland plants, or where there is an abundant and reliable supply of freshwater. This cooling type is used in approximately 40% of the coal-fired power plants, half of them using seawater, the other half fresh water. A 500 MW, sub-critical coal-fired power plant would withdraw around 500 million m^3 and consumes 2.9 million m^3 of water per year.[10] A 500 MW plant that uses sea-water for cooling still requires about 1.4 million m^3 of freshwater, for scrubbing air pollutants, steam cycle boiler make up and handling coal ash.[11]

Dry-cooling or air-cooled condensers (ACC) use air instead of water as a medium to remove the heat from the vapour-to-liquid condensation process. The latent heat is dissipated into the atmosphere through the sealed walls of the condenser. This is a relatively new and expensive cooling system developed for thermal power plants operating in arid areas in some countries. Dry-cooling is vulnerable to hot temperatures, which lowers the efficiency dramatically. Power plants with dry-cooling still use significant amount of fresh water for scrubbing of air pollutants, this amounts to 20-25 % of the typical amount water demand of re-circulating wet cooling. A 500MW, supercritical coal-fired power plant would withdraw around 2 million m^3 and consumes 1.7 million m^3 of water per year.[12]

These figures are only illustrative of the scale of water withdrawal and consumption between different cooling types. There is a significant variation from country to country.

image Nearly two decades of coal mining have contributed to river flow disruption. Kuye river, Shaanxi, China - December 2015
© Zhao Hang/Greenpeace

Modelling the coal industry's water demand

03

The central analysis of this study is based on modelling the withdrawal and consumption of water (hereafter referred to as water demand) by existing and proposed coal-fired power plants (at the end of 2013) and mining activities for hard coal and lignite on a global scale.[13] Greenpeace International commissioned Dutch engineering consultancy Witteveen+Bos to develop the model to carry out a global plant-by-plant assessment of fresh water use by the coal industry. Using the modelling results and the World Resources Institute's (WRI) Aqueduct Global Map data 2.1 (2015), Greenpeace International and Witteveen+Bos conducted a geo-spatial analysis to study the impact of the coal water demands on surface freshwater resources.[14]

For this analysis we first mapped all existing and proposed coal-fired power plants globally, then estimated the water demand from those power plants, based on existing life cycle analysis in individual countries. We then modelled the impact of those coal-fired power plants on water availability in the watersheds where they were, or would be, located. At the end of 2013, there was a total of 1811 gigawatts (GW) installed capacity of coal-fired power plants globally, with another 1300 GW being proposed or in construction. We then compiled a list of the most impacted watersheds in need of the most urgent intervention, which we call 'red-lists areas', then estimated the impact of different policy measures on water availability for coal-fired power plants to reduce the depth and scale of the water crises.

Methodology

This study focuses on all countries with coal production and/or coal-fired power plants. We adopted an ambitious local impact analysis approach that draws from Life Cycle Analysis (LCA) literature, including water use in coal production and for use in coal-fired power plants.

The methodology consisted of five steps:

• **Step 1 – data collection and literature review:** This step involved choosing suitable databases, and collecting data on existing and proposed coal-fired power plants and their geo-locations. A detailed literature review of industry practice and national legislations in key coal countries was conducted in order to produce a gap analysis regarding cooling technology and estimated water withdrawal and consumption, and to develop assumptions based on the best available information. Particular attention is paid to research on water use in China and India, as they account for a very significant share of the existing and proposed coal fleet.

• **Step 2 – calculation of the water demand of coal based electricity production in baseline year 2013:** This step involved two parts: the first part was a plant-by-plant calculation of the annual water demand for each operating coal-fired power plant. The second part calculated water used in coal production, based on reported national production volumes of hard coal and lignite mining. The two parts were then combined to arrive at the global water demand of coal based energy production in the baseline year 2013.

• **Step 3 – calculation of the water demand of the proposed coal fleet:** To estimate future demand, a plant-by-plant calculation of the water demand for the proposed coal-fired power plants was made.

• **Step 4 – geo-spatial analysis:** In this study, we used the World Resources Institute's (WRI) Aqueduct tool[15] for water stress assessment, as it provided a detailed global data set on water demand and water availability; open access to the data; as well as a well-developed and easy to use online mapping tool. Using WRI Aqueduct Global Map data 2.1 (2015) as a basis, we aggregated coal water demand for each of the sub-catchments. The extent of the current water stress level was examined, with a focus on basins with coal. The share of water demand from existing coal-fired power plants and additional water demand by the proposed coal fleet were analysed and mapped.

• **Step 5 – findings:** Modelling results and geo-spatial analysis were used in combination to calculate how much water is used in the focus areas of the research listed above.

For each of the life cycle stages included in this study, three estimates are given for water use factors: median, minimum and maximum. Note that Meldrum et al. (2013) state that "the minimum and maximum in the available literature may not represent the true minimum and maximum considering all deployment conditions, technological permutations, etc." Nevertheless, these values give a valuable range for the water use for the purposes of a global study.

BOX 2: Data sources

- **Basic data set:** (a) Plant specific information: PLATTS is the major source of data for this study. The database provides plant specific information such as cooling technologies, boiler type (subcritical, supercritical), installed capacity, and location. Field research, academic literature, news articles, industry information and other specific techniques were also used to estimate the missing information. (b) Water availability at the plant location: based on World Resources Institute (WRI) Aqueduct Global Map Data 2.1. Blue water availability in the near future is assumed to be same as the baseline year. (c) Coal mining data as of end of 2012 was attained from Energy Information Administration, US Government, and China Energy Statistics Yearbook 2013.

- **Plant operational data:** capacity factor (operating hours per year), efficiency factor (water use per kWh (for power plants) or per ton of coal extracted (for mining)) are based on literature review including IEA World Energy Outlook, national energy statistics and academic literature.

BOX 3: What does "over-withdrawal" mean?

Baseline water stress greater than 100% means that humans in the area of the sub-catchment are withdrawing water from it faster than the waterbody is able to regenerate. This means that the sub-catchment is dependent either on inter-basin transfer, use of groundwater or is at risk of running dry. WRI explains it like this: "This means that the sub-catchment is dependent on groundwater, inter-basin transfer or desalination, and is more vulnerable to drought."

Hydrologists generally agree that a withdrawal rate exceeding 40% is considered high water stress and that significant ecological impacts can already happen.[16] In the case of over-withdrawal, when human water demand exceeds total available water, there can be insufficient water left for ecological needs such as sustaining ground vegetation, aquatic ecosystems, flushing out sediments and pollutants in rivers and other key needs to sustain life. Over-withdrawal puts the sub-catchment in a precarious situation:

- Water users have to compete to access available water, trade-offs needs to be made as to whether to use water to meet needs for food production, industrial activities, energy, ecosystem maintenance, or for drinking and sanitation.
- Sub-catchments running a water deficit are dependent on water reserves such as underground aquifers, when often there is no reliable data on the available quantity. The recharge rate of groundwater aquifers is generally much slower than surface water bodies. It may take decades to millennia to return to the original volume stored, depending on the local hydrology. In practice this means this groundwater is effectively exhausted once it's used.[17]
- Overexploitation of groundwater resources can lead to severe land subsidence (thus more prone to flooding) and salinisation of groundwater reserves in coastal areas. In Europe this is a leading cause of salt water intrusion in aquifers.[18]
- A depleting reserve also means the area is more vulnerable to inter-seasonal and inter-annual variation of water availability, both of which can be significantly influenced by climate change, making the sub-catchment less resilient.
- Regions with over-withdrawal of water can also be more exposed to pollution disasters – drought (seasonal or multi-year drought) can reduce the river flow significantly or even cut-off flow. Less water leads to higher concentrations of pollutants, which can seriously impact the aquatic and soil systems.

image Sink-holes in Inner Mongolia, China - June 2012. © Lu Guang/Greenpeace

Study findings 04

Using the methodology outlined in the previous chapter, we carried out a plant-by-plant assessment of fresh water use by the coal industry on a global scale. The study includes an assessment of water demand of the coal industry as of the end of 2013 and the additional water demand if all 2,668 then proposed coal-fired power plant units were to come online.

To do this accurately we used the WRI analysis of the global baseline water stress defined as "total withdrawal by human uses and available blue water resources". The water stress is divided into categories, ranging from low to extremely high and over-withdrawal.

We then geo-located the existing and proposed coal power plants globally and combined this into a map. This study covers 1811 GW installed capacity of coal-fired power plants globally, and 1300 GW proposed capacity of coal-fired power plants as at end of 2013. This amounts to 8,359 installed coal-fired power plant units and 2,668 proposed coal-fired power plant units.

How much freshwater does the global coal industry currently use?

Our calculations show that total freshwater consumption is estimated at 22.7 billion m^3 per year in 2013 as a median value, and water withdrawal is estimated at 281 billion m^3 per year as a median value. Water consumption due to coal mining activities for hard coal and lignite is about 16% of the total coal water consumption.[19] Coal-fired power plants account for the lion's share of water use, 84% of consumption and 90% of withdrawal as Table 1 illustrates.

Putting coal's water use in human terms, the World Health Organization (WHO) says that between 50 to 100 litres of water is needed per person per day for the most basic needs.[20] Taking 50 litres per day as the bare minimum, that's 18,250 litres or 18.3 m^3 per person per year. Coal plants globally consume 19 billion m^3 of water per year. **This means that annually the world's 8,359 installed coal-fired power plant units consume enough water to meet the most basic needs of more than 1 billion people.** If we add the water that the coal industry uses to mine hard coal and lignite, this number rises to 22.7 billion m^3 of water per year, enough to meet the most basic water needs of 1.2 billion people.

Table 1: Global total freshwater use coal-based power production – baseline year (2013)

		Consumption (billion m^3/year)			Withdrawal (billion m^3/year)		
	Power capacity (GW) /Coal production (in million metric tons, Mt)	median	minimum	maximum	median	minimum	maximum
Coal plants	1811.45 GW	19.055	14.622	26.714	255.202	160.231	365.261
Hard coal	6357.43 Mt	3.238	0.981	13.294	3.238	0.981	13.294
Lignite	2037.79 Mt	0.407	0.110	1.074	22.912	17.184	28.640
Total water use (2013)		**22.700**	**15.713**	**41.081**	**281.352**	**178.396**	**407.195**

How much will global water demand increase if all the proposed coal plants come online?

As previously stated, at the end of 2013, there were 8,359 installed coal-fired power plant units and 2,668 proposed coal-fired power plant units. This amounts to 1811 GW installed capacity of coal-fired power plants globally, and 1300 GW proposed capacity of coal-fired power plants as at end of 2013. This would mean roughly 70% growth compared to the existing capacity. If these plants come online, water withdrawal is set to increase by 32 billion m^3/year and consumption by 17 billion m^3/year. Although the amount of water withdrawn by the new plants would be significantly lower than the existing coal power fleet, water consumption would grow by 90%. The results reflect the projected gradual transition to re-circulating wet cooling with cooling towers as the dominant cooling technology, which has a much lower withdrawal rate than once-through cooling systems. However, using cooling towers comes with a high water consumption rate - so the coal plants withdraw less water but consume a much higher proportion of what they withdraw. **This leads to water consumption nearly doubling - from 19 to 36 billion m^3, if all the new coal power plants come online with the expected cooling technology configuration.**

Table 2: Global total water use by coal plants – existing fleet (end 2013) and proposed

		Consumption (billion m^3/year)			Withdrawal (billion m^3/year)		
Global total	Capacity (GW)	median	minimum	maximum	median	minimum	maximum
EXISTING	1811.45	19.055	14.622	26.714	255.202	160.231	365.261
PROPOSED	1294.60	17.200	14.152	21.681	31.695	25.578	37.718
TOTAL		36.256	28.774	48.395	286.897	185.808	402.979

In this study we have chosen to focus on assessing the impacts of additional coal plants that are in various stages of planning and approval or in construction, rather than abstract future projections for coal power capacity. This approach can provide a more accurate and actionable assessment of the coal industry's threat to water resources.

However, the list of known proposed coal plants is by no means a complete list of future demand - new coal plants are still being proposed. Adding these high-priority, highly water-intensive users in the very water stressed regions would further deepen the water deficit, which is already threatening the future of these regions.

Almost half of the global coal industry is already situated in seriously water stressed regions

The results showed that 44% of existing coal-fired power plants and 45% of the proposed coal-fired power plants are or would be located in areas with high to extremely high levels of water stress, and in many cases fall into the sub-category of over withdrawal. These stress levels are often associated with severe ecosystem impacts.

Roughly a quarter of existing and proposed plants are in areas that are already suffering from over-withdrawal of water due to high demand for water from various end users. Table 3 details the distribution of existing and proposed coal-fired power plants in locations with different water stress categories in percentages:

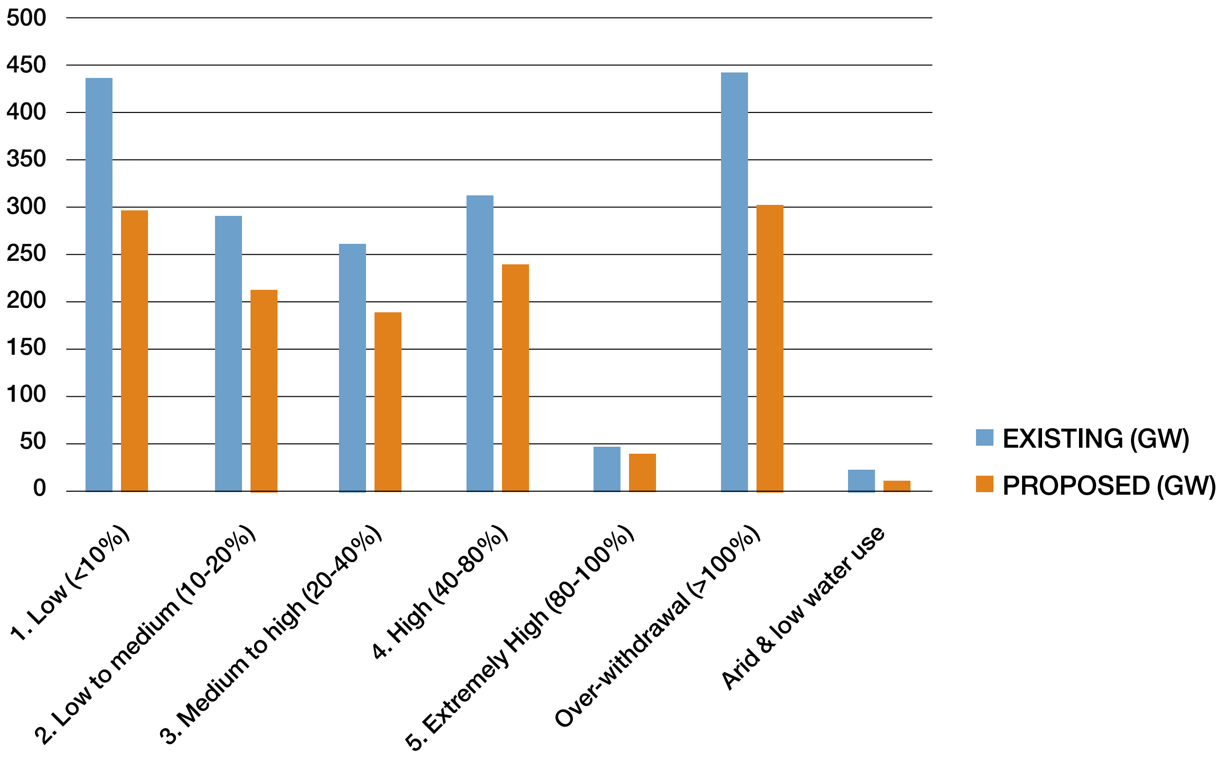
Table 3: Existing and proposed coal-fired power plants are located in areas with varying levels of water stress

Baseline Water Stress categories for sub-catchment	EXISTING (GW)	%	PROPOSED (GW)	%
1. Low (<10%)	436	24%	295	23%
2. Low to medium (10-20%)	287	16%	214	17%
3. Medium to high (20-40%)	261	14%	189	15%
4. High (40-80%)	312	17%	240	19%
5. Extremely high (80-100%)	50	3%	41	3%
Over-withdrawal (>100%)	438	24%	295	23%
Arid & low water use	27	2%	22	2%
No data	0.204	0%	0	0%
Grand Total	**1811**		**1295**	

A withdrawal rate over 40% is already considered high water stress, often associated with significant ecological impacts. Extremely high level means over 80% of water is withdrawn for human uses. Over-withdrawal is a subset of 'extremely high' stress, indicating greater than 100% water stress, meaning that human water demand exceeds total available water.

Figure 3 summarises the detailed distribution of existing and proposed coal-fired power plants in different water stress categories in terms of capacities. In this regard, 800 GW of existing and 576 GW of proposed coal-fired power plants are or would be located in areas with high to extremely high levels of water stress, in many cases over-withdrawal, associated with severe ecosystem impacts. 438 GW of existing and 295 GW of proposed coal-fired power plants are in areas that are already suffering from over-withdrawal, a quarter of these areas are using water at least five times faster than it is naturally replenishing.

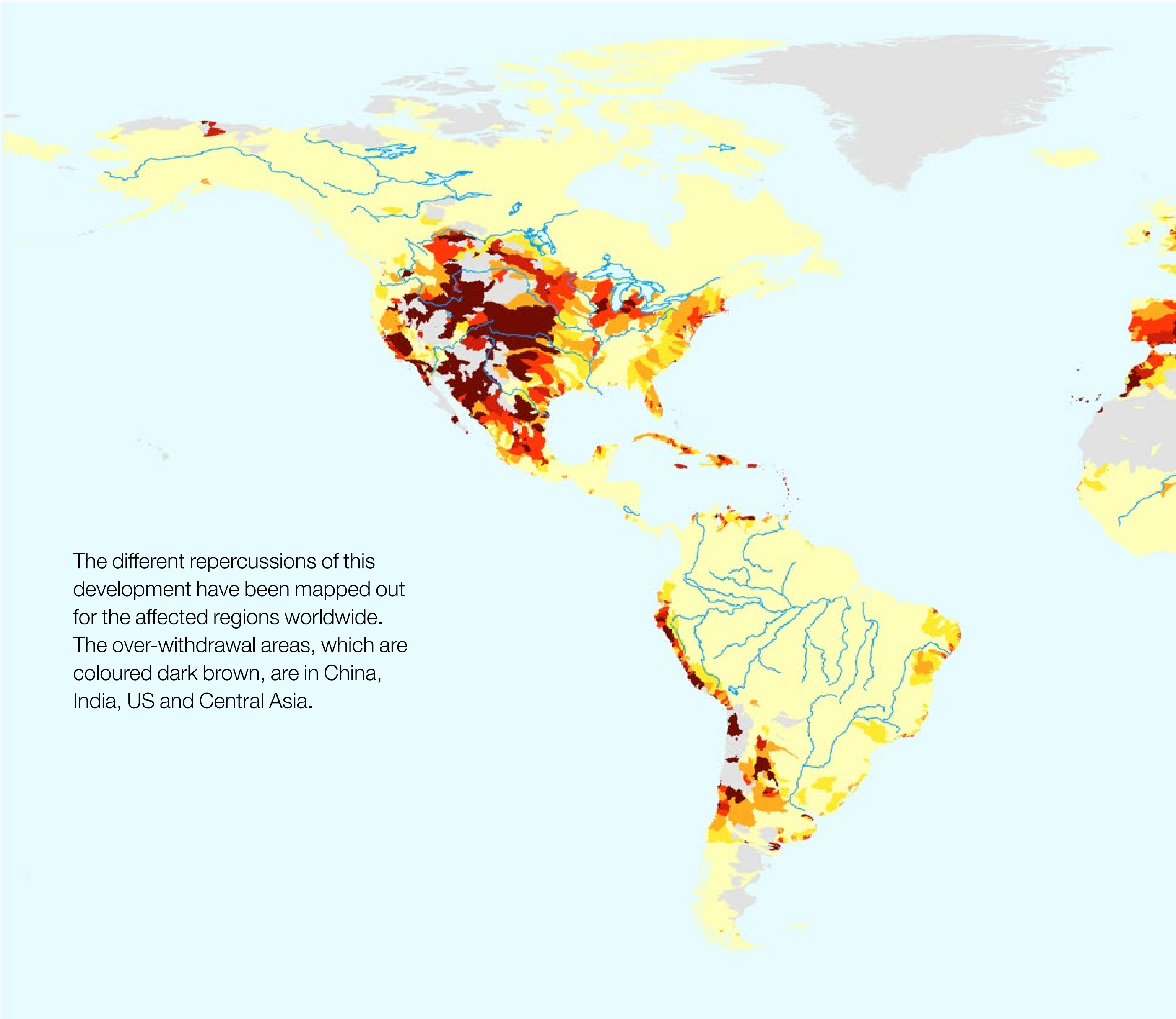
Figure 3: Distribution of existing and proposed coal-fired power plant capacities across different water stress categories



'Roughly a quarter of existing and proposed coal-fired power plants are in areas that are already suffering from over-withdrawal of water'

image: Dried out farmland in Inner Mongolia, China - June 2013. © Qiu Bo/Greenpeace

Global Water Stress



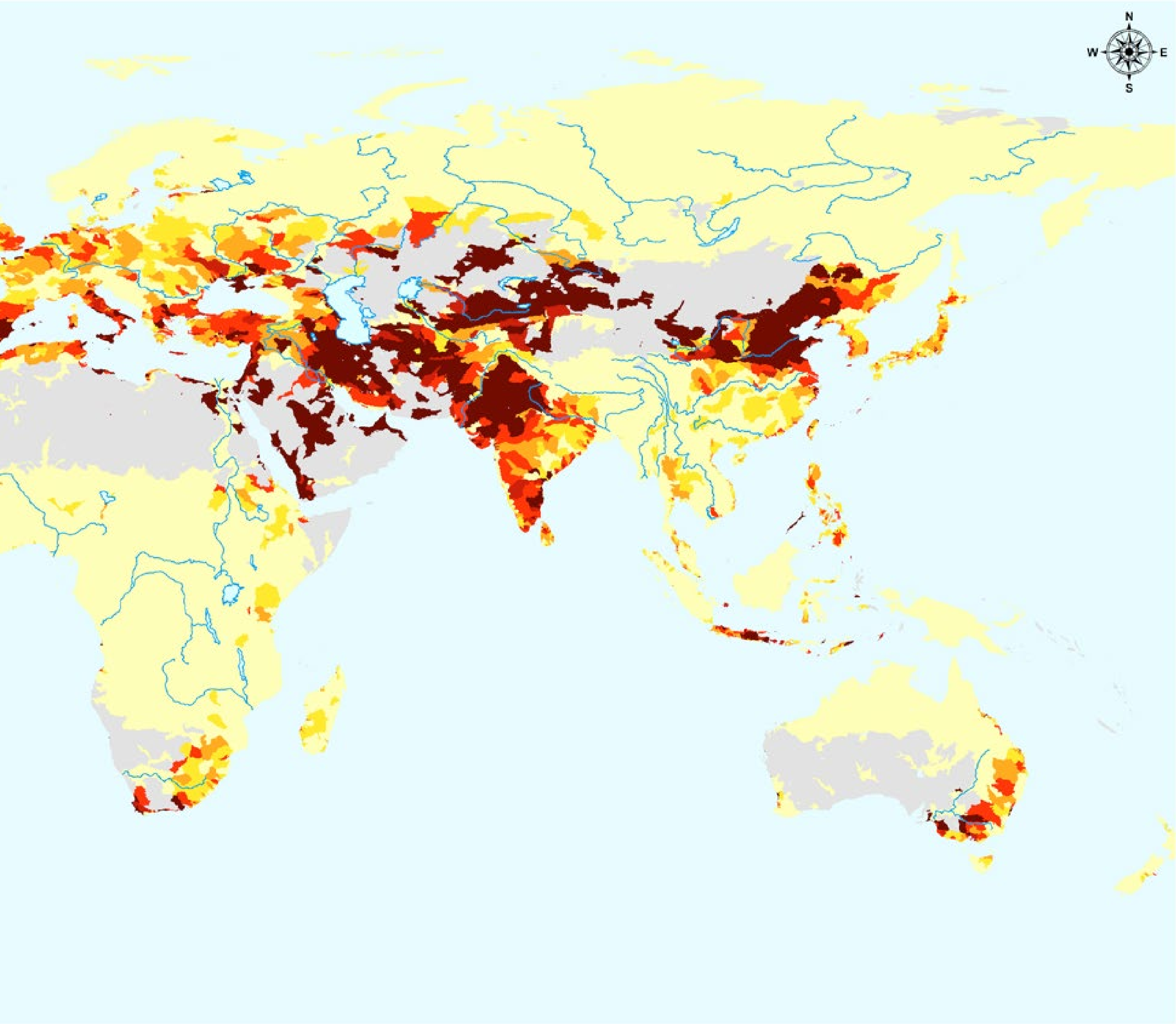
The different repercussions of this development have been mapped out for the affected regions worldwide. The over-withdrawal areas, which are coloured dark brown, are in China, India, US and Central Asia.

Legend

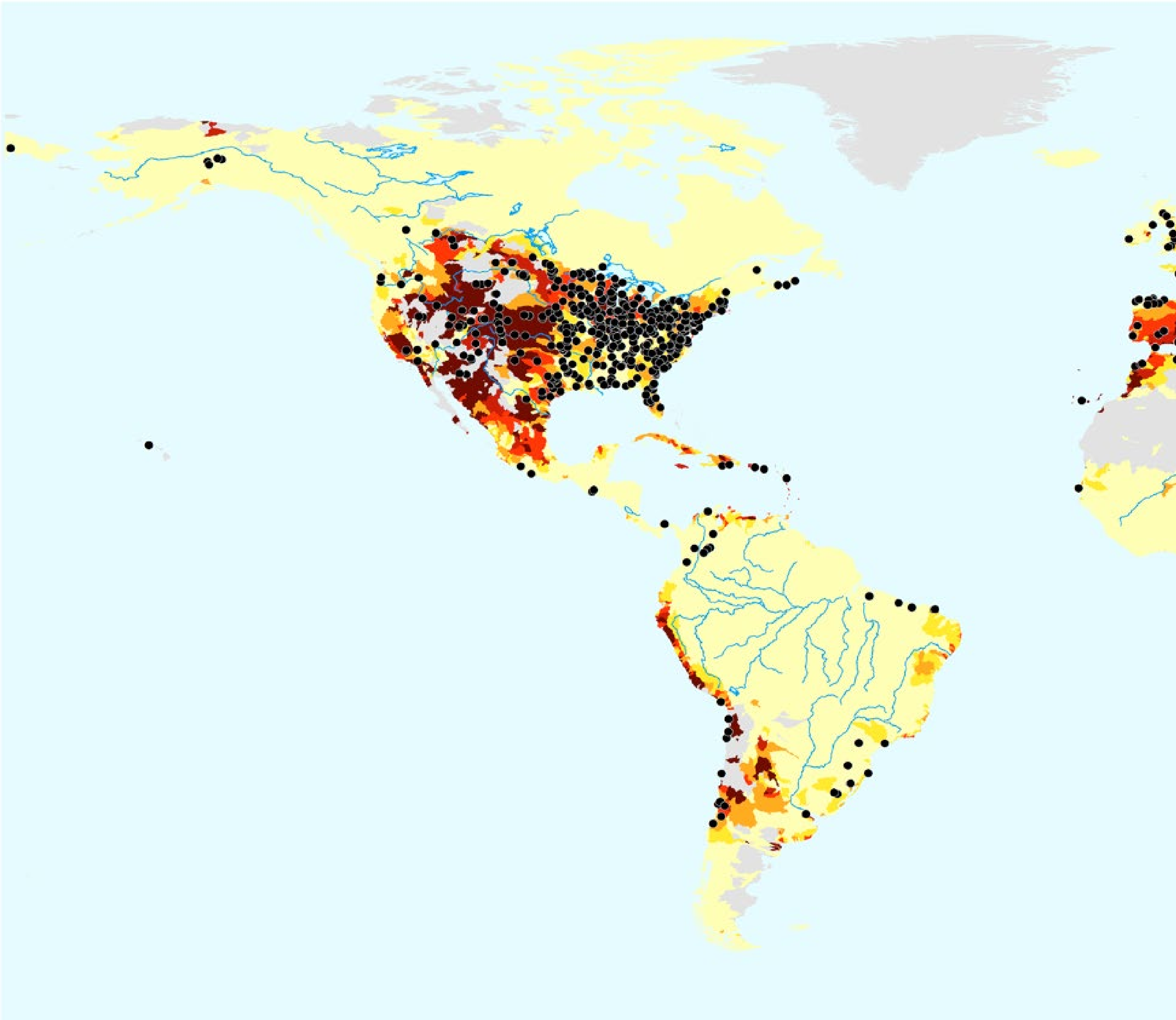
Baseline Water Categories

- 1) Low (<10%)
- 2) Low to medium (10-20%)
- 3) Medium to high (20-40%)
- 4) High (20-80%)
- 5) Extremely high (80-100%)
- 6) Over-withdrawal (>100%)
- Arid & low water use
- Rivers
- Lakes

Figure 4: Map of baseline water stress with over-withdrawal areas listed (red denotes high or extremely high water stress, dark brown areas over-withdrawal).



Global Water Stress



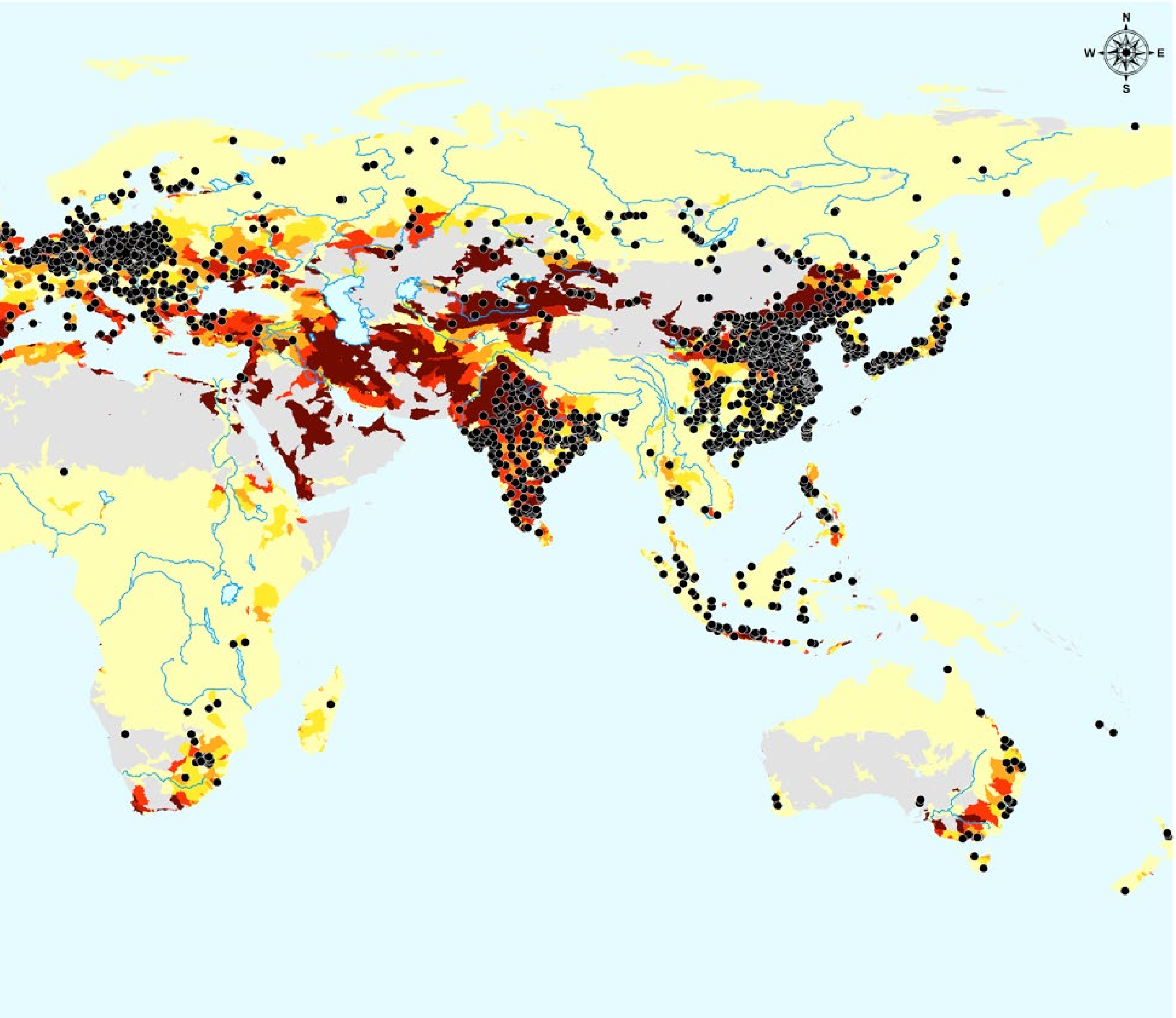
Legend

Baseline Water Categories

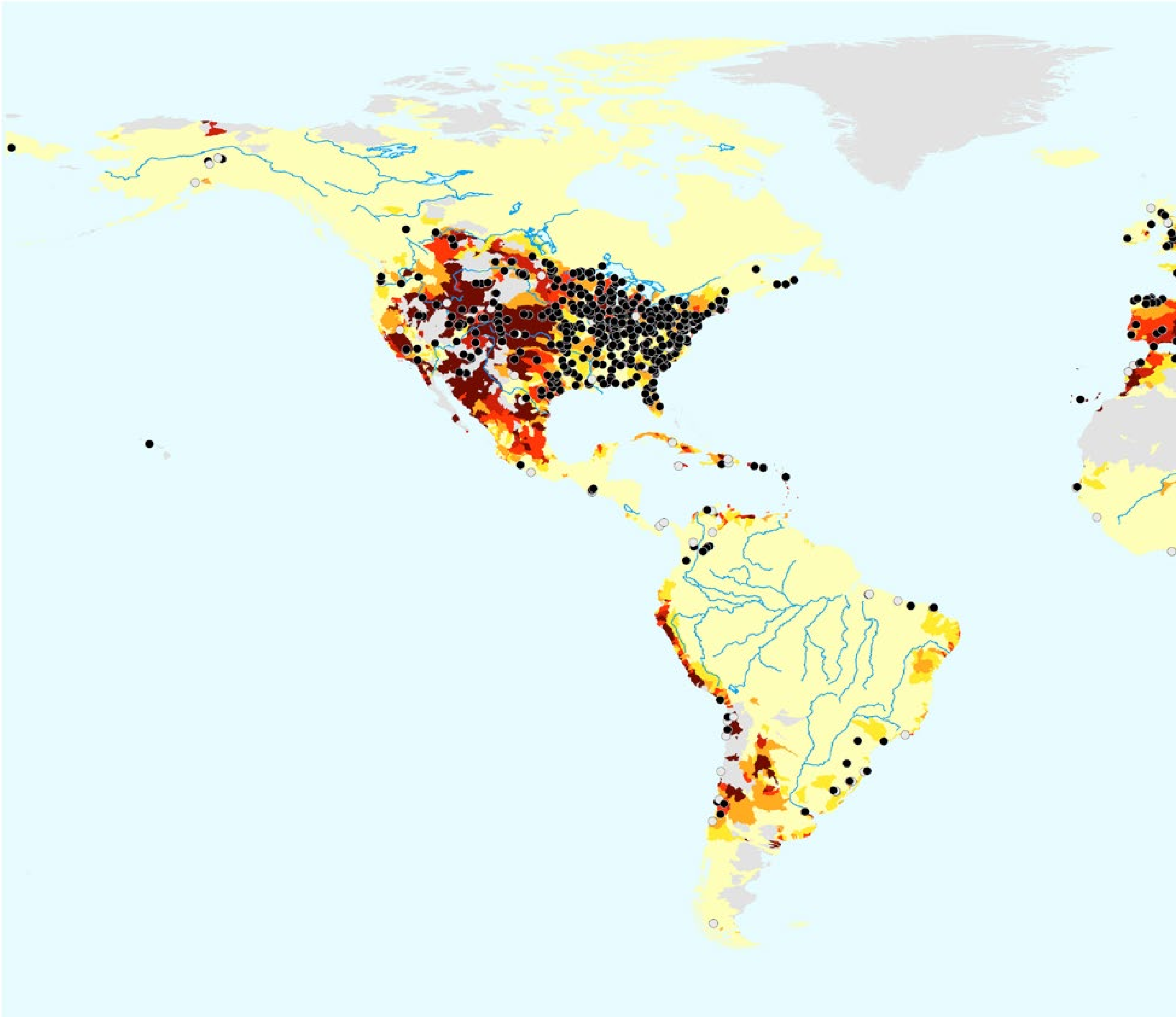
1) Low (<10%)
2) Low to medium (10-20%)
3) Medium to high (20-40%)
4) High (20-80%)
5) Extremely high (80-100%)
6) Over-withdrawal (>100%)
Arid & low water use

Rivers
Lakes
Current Coal Power Plant

Figure 5: Map of baseline water stress with existing coal power plants overlaid.



Global Water Stress



Legend

Baseline Water Categories

- 1) Low (<10%)
- 2) Low to medium (10-20%)
- 3) Medium to high (20-40%)
- 4) High (20-80%)
- 5) Extremely high (80-100%)
- 6) Over-withdrawal (>100%)
- Arid & low water use
- Rivers
- Lakes
- Current Coal Power Plant
- Proposed Coal Power Plant

Figure 6: Map of baseline water stress with existing and proposed coal power plants overlaid.

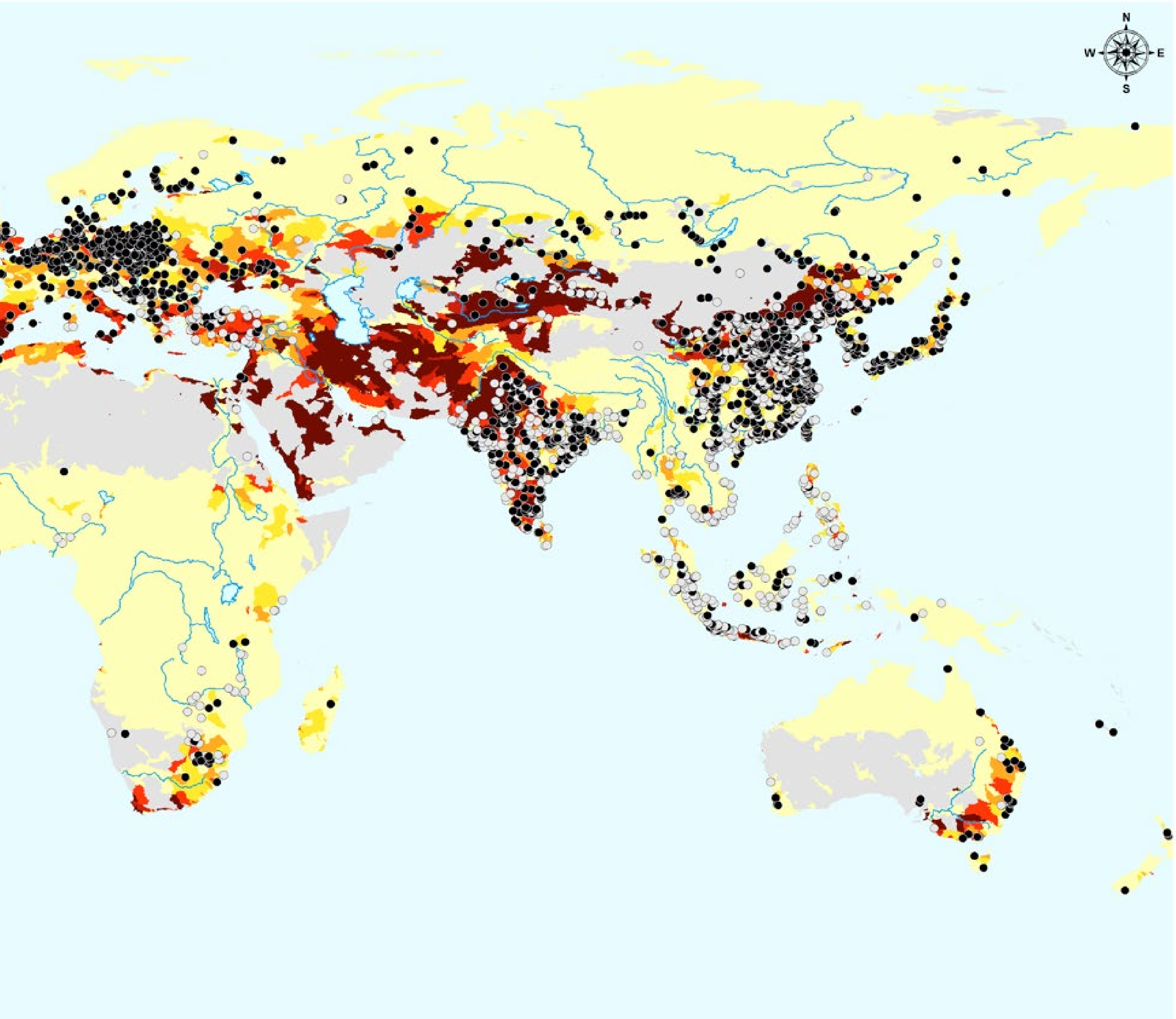


image Dried out farmland near coal-fired power plant in Maharashtra, India - March 2012. © Vivek M./Greenpeace

Widespread and serious over-withdrawal of water, particularly in coal regions

One of the most important findings in the study is that the over-withdrawal of freshwater is already widespread and serious in those areas where the majority of world's coal power plants are located. This means that, **in many regions, surface water is taken from water basins faster than it is naturally replenishing, exceeding more than 100% of the annual water replenishment.**

Regions with over-withdrawal of water which have coal-fired power plants are showing withdrawal rates high above 100%. A quarter of these basins exceed 500% withdrawal rate and one in 10 exceed 1000%. This means that these regions are running dry very fast as water is being consumed many times faster than it is being replenished. **A baseline water stress of 1000% means humans in the region are extracting 10 years' worth of the region's incoming water annually.**

The actual impact on the water body varies based on the situation. Some of this water is being consumed permanently, some of it is returned into waterbodies, but not necessarily to the same areas from where it was extracted, some of it is polluted and rendered unusable for other users. Also, the water shortage experienced is affected significantly by ground water use and inter-basin flows, which are masking the imbalance between demand and supply of water, risking acute water crises if and when these sources of water are depleted.

It is worth noting that many "low water stress" regions in WRI's Aqueduct model are not necessarily areas in which water is plentiful and which would therefore be at low risk of depletion in the future, but simply areas where water demand is low, underpopulated, or not industrialised, i.e. the water that is available is simply not being used yet. The same is obviously true with the "Arid & Low water use" category. In some of these areas, if demand for water increases markedly with urban, agricultural or industrial development, water stress could increase rapidly.

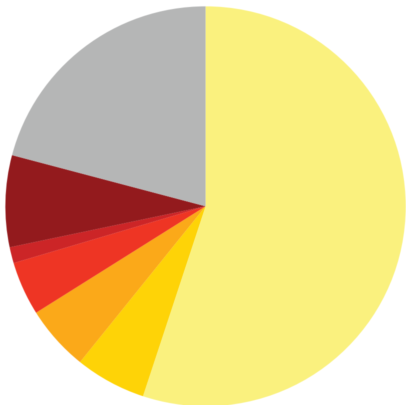
Overall, this study has found that the coal industry accounted for roughly 6.8% of total global water withdrawal, at the end of 2013. However, if we look more closely at only the catchments where coal-fired power plants are already located, coal's share of water withdrawal is much higher, at 11.2%. If proposed plants also come online, this share will increase to 12.6%.

BOX 4: Catchments explained

In this report we talk about catchments defined as a water basin area that gathers all rainfall into surface water, and finally into one discharge point. Catchments are hierarchical, with sub-catchments, like river tributaries discharging their water into the main catchment, for example the main river body. Sub-catchments are the main geological area used in this report for analysing water stress in a water basin area and the impact of coal on that particular water basin.

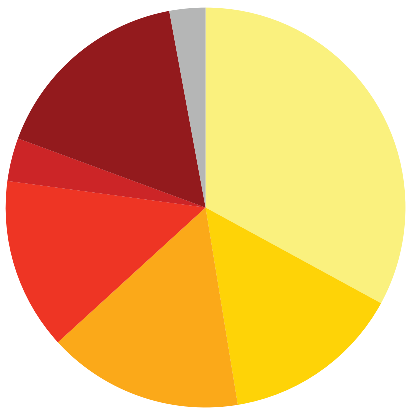
Figure 7 shows the distribution of sub-catchments, in the different water stress categories: the first shows the global distribution of water stress, and the second shows the distribution of water stress of the areas with coal-fired power plants. The basins with existing or proposed coal-fired power plants have a much higher share of "high water stress" to "over-withdrawal" compared to all sub-catchments globally. This is understandable as coal-fired power plants are often placed in populous regions near energy intensive industrial activities and therefore in areas of high existing water demand.

Distribution of Baseline Water Stress (BWS) categories (global)



BWS categories	Number of Basins
1. Low (<10%)	8245
2. Low to medium (10-20%)	857
3. Medium to high (20-40%)	791
4. High (40-80%)	651
5. Extremely high (80-100%)	194
Over-withdrawal (>100%)	1109
Arid & low water use	3127
No data	1(*not included in the chart)
Grand Total	**14975**

Distribution of Baseline Water Stress (BWS) categories in areas with coal plants



BWS categories	Number of Basins
1. Low (<10%)	396
2. Low to medium (10-20%)	174
3. Medium to high (20-40%)	190
4. High (40-80%)	167
5. Extremely high (80-100%)	42
Over-withdrawal (>100%)	198
Arid & low water use	35
No data	1(*not included in the chart)
Grand Total	**1203**

Figure 7: Existing and proposed coal power plants situated in areas with higher than average water stress.

Where are the existing coal plant clusters in over-withdrawal areas?

The picture regarding the existing coal fleet is alarming. A quarter of existing coal plants (690 coal plants with a total capacity of 453 GW) spread across 21 countries are located in over-withdrawal areas, where baseline water stress exceeds 100%. We call these the red-list areas. The top countries with existing plants in red-list areas are China, India, US and Kazakhstan, listed in order of absolute capacity. Our mapping found that 45% of China's existing coal plant fleet (358 GW) and 24% of the Indian fleet (36 GW) are in red-listed areas. Third is US with 6.8 % (22 GW) of coal power plants located in such areas.[21]

Additional information about the coal power plants in red-list regions is available on the Greenpeace website: www.greenpeace.org/thegreatwatergrab

Where are the proposed coal plant clusters in over-withdrawal areas?

A quarter of the proposed coal plants (283 plants with a total capacity of 318 GW), across 20 countries, are due to be located in red-list areas, with over-withdrawal and baseline water stress exceeding 100%. The top five countries with proposed additional capacity in red-list areas are China (237 GW), India (52 GW), Turkey (7 GW), Indonesia (5 GW) and Kazakhstan (3 GW). 48% of the proposed Chinese coal fleet is in red-list areas, in India and Turkey this figure is 13% and in Indonesia 12 %.[22]

Additional information about the coal power plants in red-list regions is available on the Greenpeace website: www.greenpeace.org/thegreatwatergrab

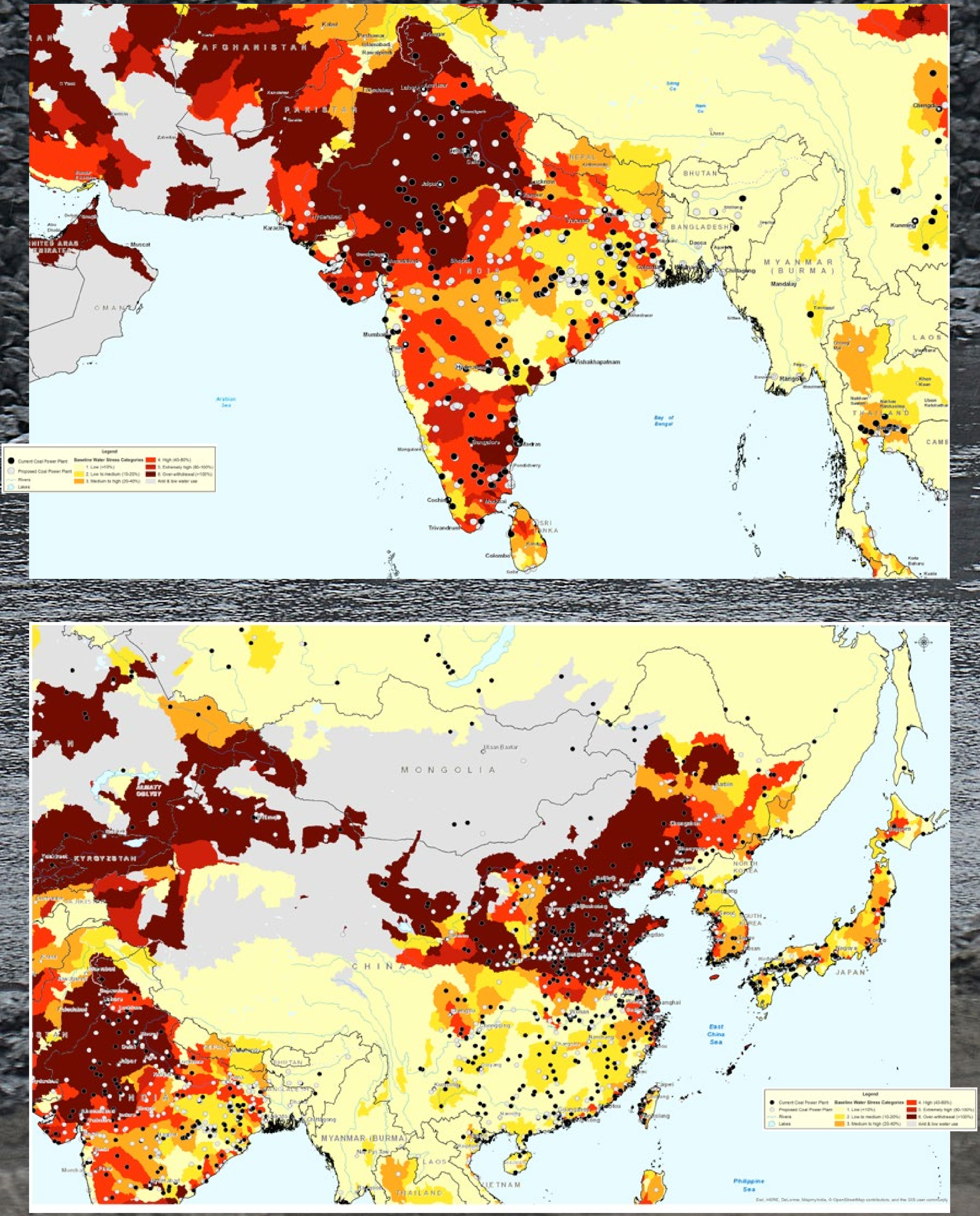
This study provides strong evidence that we are already facing a precarious and highly unsustainable water future, with about half of the global coal fleet in high water stress regions, and a quarter of the fleet in regions running in water deficit. The proposed coal power expansion would increase water consumption by 90%, further exacerbating this highly unsustainable water future. In the next section, we will look at what is happening on the ground in countries on the frontline of coal expansion.

‘We are already facing a precarious and highly unsustainable water future, with about half of the global coal fleet in high water stress regions, and a quarter of the fleet in regions running in water deficit’

image Water outflow pipe from Konin and Patnow coal plants, Poland - December 2008
© Nick Cobbing/Greenpeace

© Mujaheed Safodien/Greenpeace

Figure 8: Baseline water stress overlaid with existing and proposed coal power plants in India and China.



Country cases: Water conflicts due to continual coal expansion

05

The water shortages outlined in this report bring with them major social and environmental impacts, ranging from security of food or energy production, to ecosystem impacts. Water conflicts are unfolding at an unprecedented scale in different parts of the world. We provide here snapshots of five cases of real life water conflict documentation, based on our work in different countries. In these cases, water conflict is already affecting food production and the livelihoods of farmers and herders, impacting human health, endangering ecosystems, and risking whole river basins running dry and a shut down of coal power production.

image Farmer collects water far from his house as groundwater levels in the Kuye River basin are dropping due to coal mining, Yulin, Shaanxi, China - December 2015.
© Zhao Hang/Greenpeace

Case study #1: South Africa

Coal expansion prioritised over air quality and water security

In 2015 South Africa began to face its worst drought in a century, which the World Bank estimates has pushed 50,000 people below the poverty line.[23] It is the 30th driest country in the world,[24] and the National Water Resource Strategy stresses that: "In many parts of the country we have either reached or are fast approaching the point at which all of our financially viable freshwater resources are fully utilised."[25]

Worryingly, 85% of South Africa's current electricity generation comes from coal-fired power stations run by the state owned company Eskom, and major coal expansion is still underway. These new coal investments are planned in already water-scarce areas, including the Waterberg district in northern Limpopo Province - site of a UNESCO Biosphere Reserve.[26]

Expanding coal is courting additional disaster in the form of human health impacts and a decline in water quality and availability. In one second, Eskom uses the same amount of water as one person would use in a year, based on access to the minimum 25 litres of water per day.[27] This water is being consumed for coal, while there are still nearly one million households in Africa without access to the 25 litres of water per person per day.[28],[29] Water scarcity is so severe that Eskom is using it as a reason to avoid installing air pollution technology, arguing it cannot comply with the country's new air quality law, because of scarce water resources.[30] In 2015, the Department of Environmental Affairs granted Eskom a five year postponement from complying with the country's Minimum Emission Standards.

The question of Eskom's compliance with air quality legislation is an important one, since it involves taking the necessary measures to protect people's lives from the side effects of pollution: it is estimated that Eskom's non-compliance with the Minimum Emission standards, will contribute up to 20,000 premature deaths over the remaining lifespan of the coal plants, according to research carried out and published by Greenpeace in 2014.[31]

By continuing its heavy reliance on coal power Eskom is pushing South Africa to choose between air pollution and water scarcity.

image Worker at coal washing plant, Witbank, South Africa
© Mujaheed Safodien/Greenpeace

Case study #2: India

Intensifying competition for water pits coal power plants against farmers

India is a seriously water-stressed nation and is faced with the prospect of becoming the planet's most populous country by 2050, with an estimated population of 1.6 billion,[32] while only having 4% of the world's water resources.[33] This water stress is already having an alarming impact on farmers in Maharashtra state where there is a serious clash between the use of water resources for agriculture and energy. Not only farmers have been impacted, but several power plants have had to shut down because of a lack of water.[34]

Specific cases of such water stress have been analysed in the Vidarbha region of Maharashtra state. Greenpeace India's study on water availability from the Wardha and Wainganga rivers in Vidarbha, found that operating the government's planned power plants would consume a massive 40% of the future irrigable water from the Wardha and 16% from the Wainganga river.[35]

As of December 2010, 71 thermal power plants, with a collective electrical capacity of nearly 55 GW, were in various stages of approval in Vidarbha.[36] This would mean a total water allocation of 2,049 million m^3 of water per year, which would otherwise be used to irrigate approximately 409,800 hectares of farmland.[37] Allocation of water to thermal power plants is leading to conflict with farmers, and stalled power plant projects.

The situation for farmers in Maharashtra state has already been critical for years, due to a combination of social, financial and environmental pressures, contributing to comparatively high rates of suicide (e.g. about 60,000 farmers are reported to have committed suicide in the state since 1995).[38] According to Vidarbha Jan Andolan Samiti (VJAS), a farmer's rights group based in Nagpur, there were 942 farmer suicides in the Vidarbha region alone during 2013.[39] Official statistics for the whole state of Maharashtra lists 3146 farmer suicides for the same year.[40] Ever-increasing competition for water would further exacerbate the agrarian crisis in Maharashtra, especially during the drought years, placing additional stresses on farmers and their families.[41]

Despite this alarming water shortage leading to power plants being shut down and new units delayed,[42] India has still become increasingly dependent on coal, as laid-out in its Twelfth Five Year Plan. As of December 2015, there are 75 GW of thermal power projects under construction according to India's Central Electricity Authority.[43]

Crucially, a comprehensive assessment even of the current overall water availability in key river basins still seems to be lacking, making projections of future water availability extremely difficult and uncertain. In particular, decisions about future water allocations in India continue to be hampered by a lack of sufficiently accurate and up-to-date data on the water consumption levels of existing coal-fired power plants.

image Greenpeace and farmer protest at Upper Wardha Dam, Amravati, Maharashtra, India - May 2012. © Sudhanshu Malhotra/ Greenpeace

Case study #3: Turkey

Coal Rush set to deepen Turkey's Water Crisis

Turkey's rapid economic growth has gone hand in hand with a growth in energy demand that outstrips any other country in Europe. Turkey's longer-term energy strategy of using up all domestic lignite potential by 2023[44] has led to a boom in coal-fired power plants, which would result in a total of 80 plants around Turkey. This policy is however adding stress to already drought-prone regions.

Many expanding power plant projects like those in Soma, Manisa province and Can in Çanakkale are situated in high water stressed areas. The rapid expansion in these dry regions threatens to increase water demand from coal power plants, creating competition with other water users. Some of the proposed plants in the vicinity of the coast would use sea water for cooling, creating a risk of thermal pollution from released cooling water. A few of the power plants are using dry-cooling technology. Both sea-cooling and dry-cooling still requires significant amounts of fresh water for scrubbing air pollutants, thus raising water demand in the region.

One of the proposed new plants is in the town of Karapinar, located in extremely water stressed area in the Konya Closed Basin (KCB). Known as "the breadbasket of Turkey" it is one of the 200 most ecologically significant areas in the world.[45] The groundwater in KCB is the region's only source of drinking water, which has already been declining by almost one metre per year[46] due to a long-lasting drought and over exploitation of water in the basin for agriculture.[47]

The planned coal-fired power plant will do nothing but exacerbate this and cause a conflict in water usage for irrigation and drinking.[48] What makes this situation even more critical for Turkey is that the loss of agricultural zones such as the one in KCB also means the loss of the gene pools of drought resistant crops.[49]

Communities in the water stressed Karapinar region have already recently suffered one desertification crisis, which extended to the point where its entire population was on the verge of migration in the 1960s.[50] With the discovery of lignite reserves in 2011 the region is on the brink of another tragedy.

There is neither a river nor a lake left in the region that is suitable for dam construction; the only water resource available for the planned coal plant will be the groundwater.[51] Water needed for cooling of the planned coal plant would further significantly deplete the region's groundwater resources.

image Cooling pond near Afsin-Elbistan A and B coal plants, Kahramanmaras, South East Turkey - March 2014. © Umut Vedat/Greenpeace.

Case study #4: China

China's legendary rivers straining to keep up with energy and industrial expansion

China is facing a resource dilemma - wherever it has coal, there is often limited water. Nevertheless, this is not stopping it from exploiting its coal resources. China is concentrating its coal industry into 14 mega coal bases, which focus on coal production and coal chemical products. Nine coal power bases focus on producing energy which is transmitted to eastern industrial provinces.[52] All of these industries are extremely water-intensive and a high source of water pollution.

In China's current plan three big bases are situated in the upper and middle reaches of the Yellow River (Ordos, Shaanbei, Ningdong). The area is known for its water scarcity, which is creating difficulties in providing enough water for the coal industry, farming, cities and natural ecosystems in the region. Groundwater extraction is partly masking this problem, but groundwater levels have been dropping. One of the large rivers under threat due to this massive coal expansion is the Kuye River, a class I tributary of China's iconic Yellow River, with 878,000 residents living in the river basin.[53]

Rich coal resources have boosted the development of coal-based industries in the Kuye River basin. Kuye River basin is located in the Shaanbei Coal Energy and Chemical Base, which transmits coal-based electricity to serve China's prosperous eastern provinces. Energy and chemical industry parks have been sprouting up from the upstream to lower reaches of the Kuye River up to Shenmu county. In 2011 Shenmu had the largest power hub in western China, with 6 GW capacity.[54]

Upstream of the Kuye River basin, in the provinces of Shaanxi and Inner Mongolia, is China's largest coalfield, Shenfu-Dongsheng, which has expanded rapidly in the last couple of decades. During 1997-2006, coal production in the Kuye River basin averaged around 55 million tons per year,[55] rising to 173 million tons in 2011.[56] During this time water shortages became evident.[57] Since the 1990s, the river has been experiencing a rapid decline of run-off and increasingly prolonged dry periods.[58] The Kuye River has been suffering from severe flow disruption since 2000.[59]

An environmental impact assessment of the integrated plan for the Kuye River basin paints a worrying picture.[60] There is a large discrepancy between the amount of water that can be provided and the amount of water that is demanded under current industrial planning. By 2030 the water deficit is projected to increase to a demand of 416 million m^3, including a significant proportion related to coal, with a projected water supply of only 202 million m^3.[61]

As the water crisis in the Kuye River basin escalates, industrial needs must be reconsidered to avoid environmental disaster. Existing solutions suggested by the integrated planning of the Kuye River basin mainly rely on large-scale, long-distance water-transfer projects that either bring water from the mainstream Yellow River or divert water from the country's south to the dry north.

In China's energy plan for 2014-2020,[62] a coal consumption cap of 4.2 billion tons has been proposed for 2020. In reality coal production and coal consumption in China have decreased since 2014, which is a good sign. In February 2016 China's State Council announced that no new coal mines would be approved before the end of 2019[63] in order to reduce overcapacity in the coal industry. However, considering the large scale of China's existing coal mine bases, the control of coal capacity is not easy. In addition, coal power plant licensing has been accelerating, especially since the approval authority was handed down to provincial governments. Many of these proposed plants are in the driest areas of the country.[64] Coal-fired power plants in China already consume 7.4 billion m^3 annually.

Also, the water-intensive coal chemical industry is still growing. For rivers in dry areas, already suffering from serious reduction of flow and seasonal drought, this growth might be the last straw leading to ecosystem collapse. The competition for water with other big water users, like agriculture, could also become more critical. A more ambitious coal consumption cap would be needed to avoid a deepening water crisis in the driest coal bases of China.

Case study #5: Poland

The world's most coal-dependent nation needs an urgent energy policy rethink

Poland relies on coal for about 85% of its power.[65] The coal fleet is aging and mainly dates back to the Soviet era, meaning it needs to be retrofitted to meet the European Union's norms on industrial pollution in the next years if the plants are to continue operating. Its emissions are incompatible with Europe's self-imposed CO_2 emission reduction goals.[66] However, Poland's hard coal mining sector is teetering on the edge of bankruptcy and the state-owned as well as private mining and energy companies see lignite as the future source of energy. Adding to coal's vices, 45,000 people a year are estimated to die due to air pollution, with the majority attributable to coal.[67]

Poland's coal industry is enormous compared to its water resources. The coal industry (both coal power plants and mining) is responsible for 70% of the total water withdrawal in the country. This is the highest percentage of withdrawal in the world, compared for example to 18% in Germany and 13% in the EU.[68] This is mostly due to the high amount of old power plants in Poland, which use once through cooling.

According to Platts database and additional Greenpeace research an estimated 38% of the Polish national coal capacity is over 40 years old. Retrofitting the old plants to comply with European industrial pollution standards adds to the water risks of the plants. This is due to scrubbing air pollution with wet methods, adding to water consumption, as well as creating additional waste water. Retiring these old plants that are inefficient and replacing them with low water-intensive renewables (such as wind farms and photovoltaic plants), can achieve a huge 45% water saving and stop the coal industry's water use from increasing even further.

All of Poland's coal-fired power plants take water from big rivers or from artificial lakes built near small rivers. The hard coal-fired power plants, which are far away from fuel deposits are usually located on the banks of the country's two main rivers – Wisla (Polaniec and Kozienice PPs) and Odra (Opole and Dolna Odra coal plants). The coal plants in the main Polish hard coal region of Upper Silesia (Jaworzno, Rybnik, Laziska, Lagisza and Siersza coal plants) and all lignite-fired facilities (always sited near coal mines in Belchatow, Turow, Patnow, Adamow coal plants) use local, smaller rivers for their water.

Generally, the rivers or artificial lakes serve as sources of industrial water and recipients of waste waters, from both the chemical and the cooling processes. Numerous hard coal-fired CHPs, present in the majority of large Polish cities, use water from the same rivers as local communities for their domestic purposes.

Around one third of Polish electricity is produced by power plants burning lignite.[69] This is extracted from opencast lignite mines; lowering the level of ground waters to keep the pit mine dry. Coal mines in Poland withdraw 764 million m^3 of water per year, roughly one tenth of the total amount used by the coal industry in Poland.[70] This water is then widely used in the countryside by farmers and in households. The transfer of groundwater from pit mines to rivers is a significant pollution factor, especially from heavy metals.

Poland's hot dry summer in 2015 provided a stark reminder of the impact the nation's continuing huge reliance on coal-fired power could have. For the first time since the communist era the grid operator introduced limitations to big power users to keep the grid from collapsing as Polish rivers could not manage to cool the massive coal plant fleet, while power consumption soared due to people seeking relief from the heat with air conditioning.[71] This underlines the serious vulnerability of Polish people and industry to this water-thirsty form of energy.

image Water pipes near Patnow coal-fired power plant, Konin, Poland - November 2008. © Steve Morgan/Greenpeace

image Wind turbine near Konin coal mines, Poland - November 2008.
© Nick Cobbing/Greenpeace

Averting the water crisis

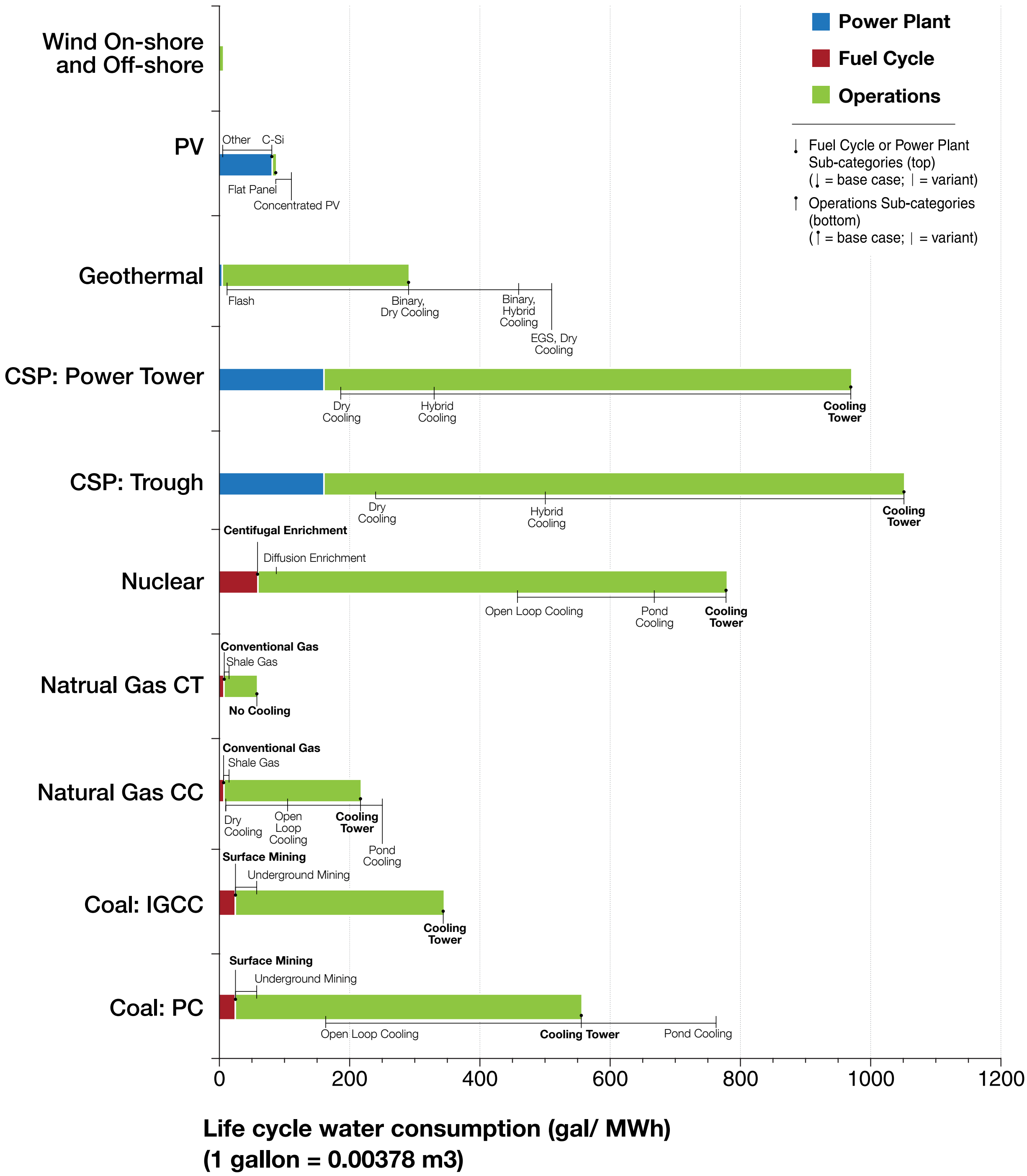
06

Although the previous sections paint a very serious picture, there are still policy and energy choices to be made that could substantially reduce the impact of energy production on water scarcity. It is hard to believe that the option of switching from coal to far less water-intensive renewable energy resources has, until recently, been largely overlooked in energy and water policy discussions.

Most of the research into water use by the power sector ends with discussions around cooling water use efficiency, and do not even list the option of evolving power generation beyond water-intensive thermal generation. As a result, there are far fewer estimates available regarding the huge potential water savings to be gained from transitioning from water-intensive thermal power generation to non-thermal generation such as solar PV and wind power, both of which require little water.

Research from the European Wind Energy Association (EWEA) estimates that wind energy avoided the use of 387 million m^3 of water in 2012 - equivalent to the average annual household water use of almost 7 million European citizens[72] (EWEA, 2014).[73] In the US, electricity from wind energy in 2013 is estimated to have avoided the consumption of more than 132 million m^3 of water, (AWEA, 2013).[74] The National Renewable Energy Laboratories in the US also found that a scenario with 20% wind energy in the energy mix in 2030 could reduce cumulative water use in the electricity sector by nearly 8% (NREL, 2008).[75] The International Renewable Energy Agency (IRENA) published a special report "Renewable Energy in the Water, Energy and Food Nexus" with the first comprehensive renewable energy scenario "REmap" for the key regions. This study found that increasing renewables penetration leads to a substantial reduction in water consumption and withdrawal in the power sector. Water withdrawals in 2030 could decline by nearly half for the UK, by more than a quarter for the US, Germany and Australia, and over 10% in India.[76]

Figure 9: Estimated lifecycle water consumption factors for selected electricity generation technologies (Source: Meldrum et al, 2013)



Dry-cooling coal power plants - not a silver bullet

To address the water scarcity problem some countries, like China, South Africa, US and Australia, have been using dry-cooling systems.[77] Dry-cooling systems in new inland coal plants have been seen to have the greatest water saving potential. However, experiences of dry-cooling reveal major challenges. For instance, using dry-cooling reduces the sent-out efficiency (the ratio of fuel consumed to energy sent out from a power station) of power plants by around 5-7%, and simultaneously increases carbon dioxide emissions and other air pollutants of coal-fired power plants by up to 6%.[78]

Also, dry-cooled coal-fired power plants still use a significant amount of fresh water for scrubbing air pollutants from smokestack exhaust air. This typically amounts to 20-25% of the water consumption of a typical re-circulating wet cooling system.[79] This means that dry-cooled power plants can still have a very significant water demand, especially in water stressed areas.

The operation of dry-cooling plants is also very sensitive to ambient temperature conditions and efficiency losses accumulate rapidly in hot weather. This has created a situation where dry-cooled plants cannot effectively be operated in hot temperatures. China has been exploring the use of hybrid cooling, which in addition to dry-cooling system has a wet cooling system to be used in hot temperatures. However, the double cooling system of hybrid cooling substantially multiplies the capital investments needed. Hybrid cooling systems also typically consume around 50–80% of the water that a standard wet-cooling system would require, reducing their water saving potential.[80] All of this demonstrates that dry-cooling is by no means a silver bullet solution for reducing water demand from coal-fired power plants.

Rather than be distracted by these technological quick fixes, there are other much more important and effective policy changes that governments can implement that will result in major water savings. The risk of water crises cannot be avoided without tackling the fundamental reasons behind them - including coals' intense water use compared to other energy sources.

Red-list: the areas in need of urgent intervention due to water stress

Simply put, this report has shown that a high percentage of existing and new coal power plants are located in areas with high water stress and often with over-withdrawal of water. There are no technological solutions that exist to eliminate water demand by coal power; this significantly increases the risk of serious water crises and water conflict between major users. Water conflict exacerbated by coal is yet another reason to reconsider the role of coal in global energy production, in addition to the health impacts of air pollution, and impacts of climate change. To avoid serious consequences in the water/energy nexus, governments need to face the fundamental reasons behind this issue, and stop licensing and constructing new coal power plants in high water stress areas.

As already outlined in Chapter 4, using geo-spatial analysis, this study has identified the red-listed areas, which, based on our data, indicate the need for most urgent intervention to address water stress by stopping licensing of new plants. But even scrapping plans for new power plants is not enough to avert the water crisis. Existing coal-fired power plants need to be phased out in these red-listed regions and coal plant clusters as well. In these areas there are often drastic levels of over-withdrawal of water, also impacted by coal power plants. These regions are prominent especially in China, India, US, Turkey and Kazakhstan.

To measure the possibilities in water savings in the red-list areas, we carried out two analyses, the first to calculate the water saved for the phase out of the already functioning coal power plants and the second for the proposed plants. These showed significant water savings:

1. **The potential saved water use with the phase-out of coal-fired power plants in the over-withdrawn watersheds would be 4.88 billion m^3 per year of water consumption and 41.3 billion m^3 per year of water withdrawal.**
2. **The potential avoided water demand if proposed plants in those areas are never implemented would be 3.184 billion m^3 per year of water consumption and 9.53 billion m^3 per year of water withdrawal.**

Table 4: Top 5 countries that stand to gain the most water saving benefits from phasing out existing coal power plants in red-listed areas. (sorted by consumption):

Country	Capacity (GW)	Water saving consumption median (billion m³/year)	Water saving withdrawal median (billion m³/year)
CHINA	358.494	3.427	29.124
INDIA	36.342	1.080	5.638
US	22.001	0.227	1.648
KAZAKHSTAN	6.911	0.036	2.711
CANADA	1.689	0.023	0.635
GLOBAL TOTAL	**453.206**	**4.884**	**41.343**

Table 5: Top 5 countries that stand to gain the most from avoided water use if proposed power plants in their red-listed areas are not implemented: (sort by consumption):

Country	Capacity (GW)	Water saving consumption median (billion m³/year)	Water saving withdrawal median (billion m³/year)
CHINA	237.393	1.834	6.543
INDIA	52.528	1.156	1.307
TURKEY	7.870	0.098	0.119
US	1.851	0.020	0.025
KAZAKHSTAN	3.240	0.020	1.363
GLOBAL TOTAL	**318.343**	**3.184**	**9.533**

'To avoid serious consequences in the water/energy nexus, governments need to face the fundamental reasons behind this issue, and stop licensing and constructing new coal power plants in high water stress areas.'

image Dafeng Power Station is China's largest solar photovoltaic-wind hybrid power station - April 2011.

Retirement at 40 – the water benefit of retiring old plants

Taking action in the countries mentioned above could achieve significant water savings in the most water stressed regions, but is not sufficient to turn around the global coal sector´s water use. In addition to red-list areas, we examined the potential water savings of a 'low hanging fruit' - retiring coal-fired power plants, which have repaid their investments and are ripe for retirement.

To assess the impacts of phase out of operating coal-fired power plants, we assessed the potential water savings if those more than 40 years old (as of 2015), that use freshwater for cooling, were retired.[81]

Table 6: Water savings of retiring plants over 40 years old - as share of national total – top 5 countries. (sorted by withdrawal savings in million m³/year)

Country	Withdrawal (plants >40 y.o.) Million m³/year	Withdrawal (national total) Million m³/year	Water savings %	Capacity share (>40 y.o.)
US	56805	76262	74%	45%
RUSSIA	10284	18007	57%	53%
UKRAINE	6554	6721	98%	92%
POLAND	3535	7797	45%	38%
KAZAKHSTAN	2156	4613	47%	43%
GLOBAL TOTAL	95332	255202	37%	16%

Table 7: Water benefits of retiring old plants in high water stress areas (baseline water stress >40%) – top 5 countries (sorted by withdrawal savings in million m³/year)

Country	Consumption savings Million m³/year	Withdrawal savings Million m³/year	National total withdrawal Million m³/year	Water savings %	Capacity share %
US	252.42	9400.88	76262.38	12%	8.1%
UKRAINE	48.92	2620.26	6720.54	39%	37%
CHINA	21.9	1371.9	78641.1	2%	0.2%
RUSSIA	28.13	1250.16	18006.67	7%	10%
KAZAKHSTAN	7.99	758.68	4613.17	16%	13%
GLOBAL TOTAL	**675.24**	**19159.62**	**255202.14**	**8%**	**3.5%**

Our calculations found that retiring older, less water efficient, plants (16% of global capacity) can yield a huge 37% water saving in withdrawal globally, and 14% water savings in consumption.

Out of the plants that are over 40 years old, 63 GW are situated in high water stress areas, where baseline water stress is over 40% or in arid regions. The countries that stand to gain the most water benefits by retiring these plants are US, Ukraine, China and Russia; each stand to save over 1 billion m³ in water withdrawal per year, and the US in particular will save over 9 billion m³ in water withdrawal and 250 million m³ in consumption.

If we change the retirement criteria for power plants which will hit 40 years of operation in 2020, the water savings are even more staggering - 51% of savings in withdrawal and 24% of savings in consumption can be achieved. This means retiring almost a quarter of global capacity (433GW).

Total potential water savings

Table 8: Total potential water savings

Global total	Capacity (GW)	Consumption median (billion m³/year)	Withdrawal median (billion m³/year)
Existing capacity	1811.46	19.055	255.202
Proposed capacity	1294.60	17.200	31.695
TOTAL (existing + proposed)		**36.256**	**286.897**

Total water savings	Capacity (GW)	Share	Consumption median (billion m³/year)	Share	Withdrawal median (billion m³/year)	Share
Phase out existing plants in over-withdrawn regions	453.21	25% of existing fleet	4.884	13%	41.343	14%
Stopping proposed plants in over-withdrawn regions	318.34	25% of proposed fleet	3.184	9%	9.533	3%
Retiring plants >40 years old	281.29	16% of existing fleet	2.706	7%	95.332	33%
Total water savings	**1052.83**		**10.632**	**30%**	**142.632**	**53%**

In this section we have highlighted the regions and coal plant clusters requiring the most urgent intervention to avoid the current global water crisis from worsening. Phasing out the highest water impact coal plants listed above would achieve 143 billion m^3/year of water savings in terms of withdrawal, and 11 billion m^3 savings in water consumption, in the regions where water competition is most intense.[82] 11 billion m^3 of water savings from water consumption alone would amount to the basic annual water needs of half a billion people.[83]

This would require replacing 722 GW of existing coal plants and 318 GW of proposed plants with renewable energy, which requires little or no water. **Taken together, retiring the old coal plants and phasing out the plants in over-withdrawn regions can make a substantial contribution in the battle to avert the water crises.**

The implementation of these phase-outs should be achieved by systematic replacement of the power capacity with renewable energy technologies and efficiency measures, which have far lower or almost no water needs. Although this task is challenging, there are already precedents of energy transitions of this magnitude: Between 2007 and 2009, China shut down and replaced 54 GW of small inefficient coal plants, equivalent to 7% of the national total capacity.[84] Under the Energiewende in Germany, the share of renewable electricity rose from 6% to nearly 25% in only 10 years.[85] The increase of wind and solar PV is already scaling up to meet this challenge.[86]

BOX 5: Urgent policy demands following on from this research:

1) **Immediate stop to the licensing of any new and currently proposed coal-fired power plants in the red-list areas with over-withdrawal of water.**
2) **Plan for phase out of coal-fired power plants in the red-list areas as soon as possible.**
3) **Retiring of old coal power plants at 40.**

BOX 6: Key measures to support the creation of policies on coal and water usage:

- **Transparency around water regulation,** without publicly available and up to date data it is not possible for policymakers to have proper oversight over water allocation , and thus create the right water saving policies.
- **Integrated water and energy planning,** combining the analysis of existing water resources, their future development, changes in water demand from major users as well as the water necessary for the energy choices.
- **Setting strict targets on the use of water on a local level,** by limiting the intake, consumption and levels of pollution (anti-scaling and fouling agents, salt build up when using cooling towers).
- **Setting strict limits for thermal heat discharge into receiving water bodies** in case of once through cooling, strict seasonal limits (i.e. depending on water availability and ambient temperature of water and atmosphere).

‘When it comes to energy, we do have choices, many of which are not water-intensive. Persisting with water-intensive coal, there can only be trade-offs with other essential human and ecological needs.’

image Wind turbines near Neurath coal plant and lignite mines, Germany – May 2015.

Conclusion: moving away from the coal-water crisis 07

Maintaining and further developing an energy system that continues to be heavily reliant on coal poses an additional and unacceptable danger to global water security, in addition to threatening climate stability, and human health. The findings of this report clearly demonstrate that mining and burning coal pose a significant threat to water security in many parts of the world. The link between energy and water has far too long been ignored in planning. It is now becoming critical that energy and water policy makers finally begin speaking the same language in order to avert even more severe water crises. It is our hope that this report will focus policy makers' attention to the growing knock-on effects that energy choices are having on the global water crisis.

There are plans to build some 2,668 new coal-fired power plant units around the world over the next decade. These plants could plunge many regions already suffering severe water stress into serious drought, as well as increasing the risk of conflicts over already depleted water resources between agricultural, industrial and domestic users.

As this report clearly demonstrates, coal-fired power plants are highly water-intensive. Each new plant will lock-in high water use for decades to come, adding tangible water stress to the region in which it is located. Because energy production is often equated with industrial activities and hence GDP growth, coal plants are often given priority access to water resources. However, as illustrated in chapter 5 the consequences on the water catchments are not sufficiently considered, leading to conflicts between the use of water for energy, for other industries and agriculture.

In a bid to raise awareness of the most critically over-withdrawn regions, we have identified water basins that will benefit most from transitioning away from coal. Considering that we already have the technology to generate electricity using little or no water (such as solar PV and wind), it is surprising that coal is still considered an option, and especially in these highly water stressed regions.

These less water-intensive energy choices have so far been a somewhat overlooked option in the energy and water policy discussions. Most of the research into water use by the power sector ends with discussions around cooling water use efficiency, and does not even list the option of evolving the power generation beyond water-intensive thermal generation.

We hope that this study will spur new policy discussion in low-water use energy development. It has identified regions where urgent interventions are required. The first step to turn around the water over-use is transparency. Our observation in many countries is that the regulation and reporting of water use is extremely poor. A meaningful debate about energy choices needs to be tabled, especially in water stressed regions that are growing rapidly in energy demand. **The fact is that when it comes to energy, we do have choices, many of which are not water-intensive. Persisting with water-intensive coal, there can only be trade-offs with other essential human and ecological needs. Governments and energy and water policy makers must take decisive action to phase out coal power to avoid these looming energy-water conflicts.**

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