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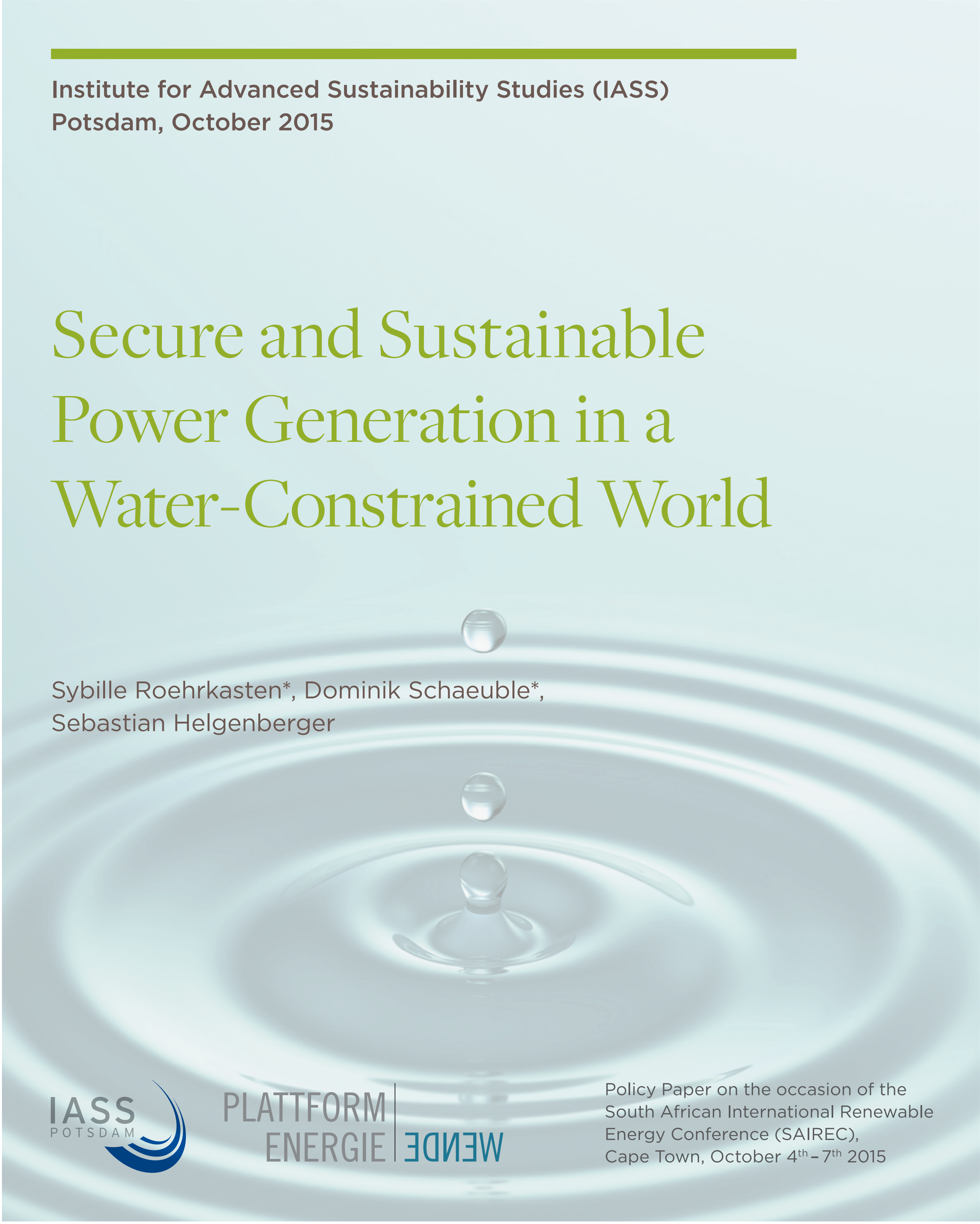
Secure and Sustainable Power Generation in a Water-Constrained World



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PLATTFORM ENERGIE WENDE

Policy Paper on the occasion of the
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Key messages

- **Water constraints are a risk for a secure electricity supply that will intensify in the future.** In many parts of the world, droughts and heatwaves have led to forced reductions in power generation. Not surprisingly, hydropower has been the most affected energy source. However, generation from nuclear and coal power plants has also been curbed due to water constraints. Given the globally rising demand for water resources and climate change, water-related risks for power generation will become more severe in future.

- **Although a global phenomenon, it is the localised reliance and impacts on water resources that makes large hydro and thermoelectric power plants vulnerable to water constraints.** To reduce vulnerability different technological options are available, like a fuel switch to wind power and solar photovoltaic (PV), dry-cooling systems or non-freshwater cooling for thermoelectric power plants.

- **The water demand of wind power and solar PV systems is considerably lower than that of coal and nuclear power plants.** Considering the whole life cycle, wind turbines and solar PV systems consume about 0.1–14% and withdraw about 2–15% of the water typical thermo-electric power plants (coal or nuclear) use to generate 1 MWh of electricity. Compared to other water-saving options for power generation, solar PV and wind are truly sustainable solutions, especially due to their very low greenhouse gas emissions.

- **Policy changes are needed to increase the energy sector's resilience to water constraints.** So far, energy decision-makers tend to mistakenly consider water an abundant resource that they do not need to worry about.

- **Policy recommendation #1: Enhance transparency on water use in the energy sector.** The limited data on actual water requirements in the energy sector in different parts of the world is a fundamental deficiency for informed decision-making. Collaboration between energy companies, governments, international organisations, civil society, academia and the media is crucial to building awareness and a shared knowledge base.

- **Policy recommendation #2: Incorporate water scarcity into energy decision-making.** Charging the energy sector for its water use in a way that better reflects actual water costs and scarcities can be a very effective way to improve water management in the sector. Integrating water scarcity into energy system models for public policy planning is a low-hanging fruit that could make a big difference.

- **The Sustainable Development Goals (SDGs) further reveal the potential for conscious and conserving water management in the energy sector.** Providing access to affordable, reliable, sustainable and modern energy for all (SDG 7) should not undermine the availability and sustainable management of water and sanitation for all (SDG 6). Alliances between the water sector and water-friendly renewable energy sources can pave the way to meeting global water and energy needs, reconciling socio-economic development paths with planetary boundaries.

1. Water constraints: risk for secure electricity supply

In many parts of the world, water constraints have already compromised electricity supply (see Figure 2 on page 6). Although a global phenomenon, it is the localised reliance and impacts on water resources that makes large hydro and thermoelectric power plants vulnerable to water constraints. In most cases, droughts[1] and heatwaves[2] have forced power plants to reduce power generation. At the same time, heatwaves often result in increased electricity demand, further compromising the ability to balance supply and demand.

Not surprisingly, it is primarily hydropower generation that has been affected by water constraints.[3] During several long-lasting droughts, hydropower generation has decreased significantly due to lack of water (Table 1). In regions with high shares of hydropower, blackouts and restrictions in electricity demand have been experienced during droughts: in 2012, for example, a delayed monsoon reduced hydropower generation in India while raising electricity demand at the same time – i.a. to pump groundwater for irrigation. This resulted in blackouts that lasted two days and affected over 600 million people (International Energy Agency (IEA) 2012). The drought in Brazil is a further extreme example from recent times. In January 2015, more than four million people were affected by electricity rationing and rolling power cuts during the worst drought in Brazilian history. This was mainly due to weak hydropower generation and high demand for air conditioning (The Guardian 2015).

However, nuclear and coal power plants have also been switched off temporarily or have had to be operated at reduced load due to water constraints. Especially in the US, Europe and Australia there are numerous examples of water-related incidents compromising power generation from coal and nuclear (Table 2). These regions have been affected considerably as they have large numbers of coal and nuclear power plants and relatively strict environmental regulation. For example, in Poland, a heatwave resulted in reduced power generation from coal power plants due to cooling water constraints in August 2015. As a consequence, the government enforced restrictions to industrial electricity demand (PSE S.A. 2015). During a heatwave in the summer of 2003, the dominant power utility in France, EdF (Electricité de France), had to temporarily curtail nuclear power generation equivalent to the load of four to five reactors because of high river temperatures (The Guardian 2003, IEA 2012).The resulting electricity imports incurred estimated costs of 300 million euros (IEA 2012). With climate change, the combined impacts of lower river flows and higher river water temperatures may significantly increase the risk of forced reductions in coal and nuclear power generation in Europe and the US (van Vliet, Michelle T. H. et al. 2012, U.S. Department of Energy July 2013). Especially in the US, public authorities are increasingly concerned about the vulnerability of thermoelectric power generation to water constraints (Carney 2010, Webber 2013).

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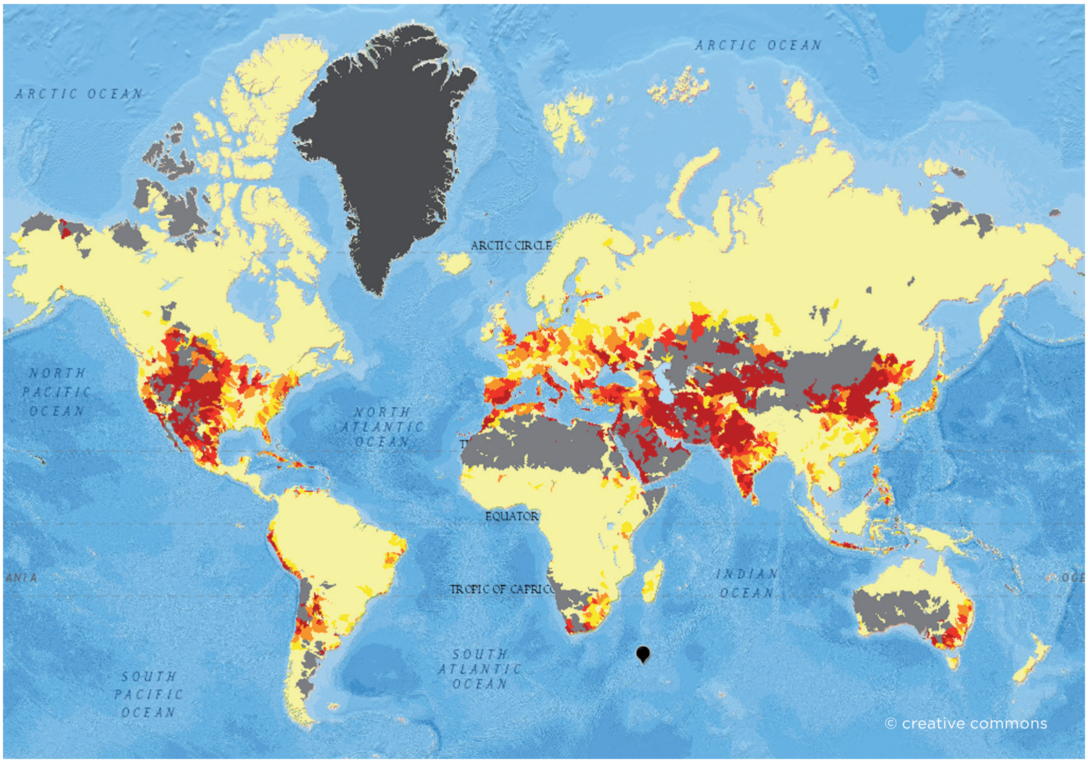
[1] There are a number of scientific definitions for ‘drought’. Here, we use drought to describe an extended period of time with insufficient availability of water (less than needed) often due to a lack of precipitation.

[2] According to the glossary of meteorology of the American Meteorological Society, a heatwave is “a period of abnormally and uncomfortably hot and usually humid weather.” (http://glossary.ametsoc.org/wiki/Heat_wave)

[3] In a detailed analysis the vulnerability of different kinds of hydropower generation (in-stream power plants, pumped-storage power plants, big dams, etc.) should be differentiated. However, this is beyond the scope of this paper.

The globally rising demand for water resources and climate change will further aggravate water-related risks. The *World Water Development Report 2015* estimates that worldwide freshwater demand will increase by 55% by 2050. If there is no radical improvement of water resource management, 40% of worldwide water demand will not be met in 2030 (2030 Water Resources Group 2009). By 2050, more than 40% of the global population is expected to live in areas of severe water stress (UNESCO 2014). The *Global Risk Report 2015* of the World Economic Forum ranks water crises – defined as significant declines in the available quality and quantity of fresh water, which result in harmful effects on human health and/or economic activity – as the worldwide risk with the highest potential impact (World Economic Forum 2015). In terms of their likelihood, water crises are among the top 10 risks. The *Global Risk Report* warns that decision-makers will increasingly be forced to make tough allocation choices in the light of competing water demands, which will impact users across the economy. Moreover, climate change is increasing variations of rainfall and the frequency and severity of droughts, rising temperatures are leading to greater evaporation and transpiration by vegetation, and sea-level rise is threatening groundwater in coastal areas (UNESCO 2015).

Figure 1: Worldwide water stress



Baseline Water Stress, current conditions

🟨 Low (<10%)
🟨 Low to medium (10–20%)
🟧 Medium to high (20–40%)
🟥 High (40–80%)
🟥 Extremely high (>80%)
⬛ Arid & low water use
⬛ No data

Definition
Baseline water stress measures the radio of total annual water with drawals to total available annual renewable supply, accounting for upstream consumption use. Higher values indicate more competition among users.

Sources: WRI Aqueduct 2014; FAO AQUASTAT 2008 – 2012; NASA GLDAS-2 2012; Shiklomanow and Rodda 2004; Flörke et al. 2012; Matsutomi et al. 2009

Table 1: Selected examples for water-induced cuts in hydropower generation with significant impacts. (✪ in Figure 2)

Index	Country	Year	Weather/ hydrological condition	Impact	Source
1	**Brazil**	2015	Drought	Electricity rationing and rolling power cuts	The Guardian 2015
2	**USA, California**	2015, 2014	Drought	Hydro generation in 2014 at 50% of its value in 2013	California Energy Commission 2015
3	**India**	2012	Delayed monsoon	Blackouts lasting two days and affecting over 600 million people	IEA 2012
4	**China**	2011	Drought	Strict energy efficiency measures, electricity rationing	IEA 2012
5	**Vietnam, Philippines**	2010	Drought	Reduced generation, electricity shortages	IEA 2012
6	**Ecuador**	2009	Drought	Electricity crises, black-outs across Ecuador	BBC News 2009
7	**Uganda**	2006, 2004	Drought	Reduced generation, Supply stress, Price increases	Fiott 2010
8	**Kenya**	2002, 1999	Drought	Reduced generation by 25%	Fiott 2010

Figure 2: Global map of selected incidents highlighting the vulnerability of power generation to water constraints (See tables 1 and 2 for details)

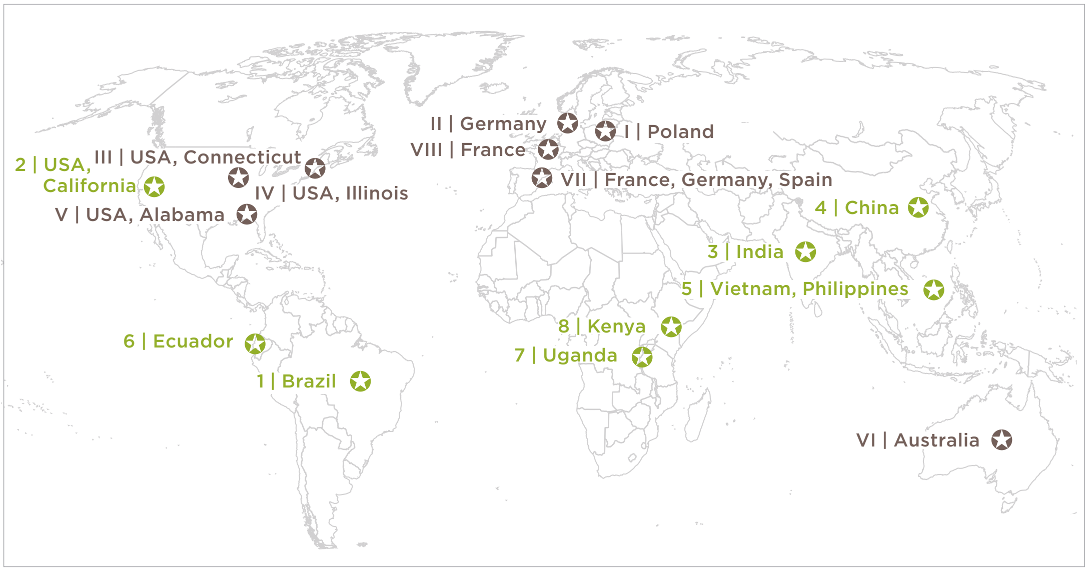


**Table 2: Examples for water-induced cuts in coal and nuclear power generation.
(✪ in Figure 2)**

Index	Country	Year	Fuel	Weather/ hydrological condition	Impact	Source
I	**Poland**	2015	Coal	Heatwave	Restrictions on industrial demand due to reduced coal power generation	PSE S.A. 2015
II	**Germany**	2015	Coal	Heatwave	Reduced generation from two coal power plants	STEAG 2015
III	**USA, Connecticut**	2012	Nuclear	Heatwave	One of two reactors shut down due to high seawater temperatures	Argonne National Laboratory 2012
IV	**USA, Illinois**	2012	Nuclear	Heatwave	Operation beyond cooling pond temperature limits	National Geographic News 2012
V	**USA, Alabama**	2011, 2010, 2007	Nuclear	Heatwave	Reduced generation	Energy and Water in a Warming World Initiative 2011
VI	**Australia**	2009, 2007	Coal	Drought	Reduced generation and electricity price peaks	van Dijk, Albert I. J. M. et al. 2013, Plumb, Davis 2010
VII	**France, Germany, Spain**	2006	Nuclear	Heatwave	Reduced generation due to high river water temperatures	The Guardian 2006
VIII	**France**	2003	Nuclear	Heatwave	Reduced generation equivalent to the load of 4 to 5 reactors; operation beyond temperature limits	The Guardian 2003

2. Why current power generation depends on water

The global water needs of the energy sector are large and will increase in the future. In 2010, an estimated 583 billion cubic metres (15% of total global withdrawals) were attributable to the energy sector (IEA 2012). Water consumption[4] accounted for about 66 billion cubic metres. According to the IEA's New Policies Scenario, global water withdrawals from the energy sector will increase by about 20% and consumption will rise by about 85% by 2035.

Power generation accounts for the bulk of water use in the energy sector and a large share of total water use in industrialised countries. Conventional power generation uses water mainly for two purposes: water is the working medium in hydropower plants and the standard cooling medium in thermal power plants such as coal or nuclear power plants. In the United States, freshwater withdrawals for thermal power generation account for about 40% of total freshwater withdrawals and 4% of total freshwater consumption (U.S. Geological Survey 2014, EPA 2014). In Germany, 64% of freshwater withdrawals are attributed to thermal power generation (University Oldenbourg 2006). In developing and emerging countries, with economic development the amount of water used in the energy sector may increase significantly if conventional forms of power generation (hydro, steam turbines) are established on a large scale.

Physical and regulatory constraints limit the water use of power plants. The volumes of water withdrawn for power plant cooling need to be physically available.[5] Further, power plant water consumption may be limited by water allocation rights. Thermal pollution due to cooling water discharge from power plants may be regulated by temperature thresholds to protect local ecosystems. Limits may also be imposed on the extent of chemical water resource contamination due to power plant discharge (e.g. zinc compounds for cooling water conditioning), again to protect local ecosystems.[6] In the past, water availability and thresholds for water temperature have been the factors that have influenced power supply the most.

The mix of energy sources greatly affects the volumes of water needed for power generation. Looking at the whole life cycle of power generation, in thermal power plants most water demand is attributable to operation, i.e. to cooling during power generation (see Figure 3 on page 9, Meldrum et al. 2013). When we compare different energy sources, we see that nuclear, coal and concentrated solar power plants have the highest requirements for cooling water. Combined-cycle power plants that are fuelled with natural gas need less water due to their higher efficiency. Wind turbines and solar PV systems have very low water needs, which are mainly attributable to production and operation (e.g. cleaning of solar panels especially in dusty regions) (see Figure 4 on page 9, Meldrum et al. 2013). The water use of hydro, geothermal and biomass power generation varies widely, depending on local circumstances like climatic conditions (evaporation, precipitation).

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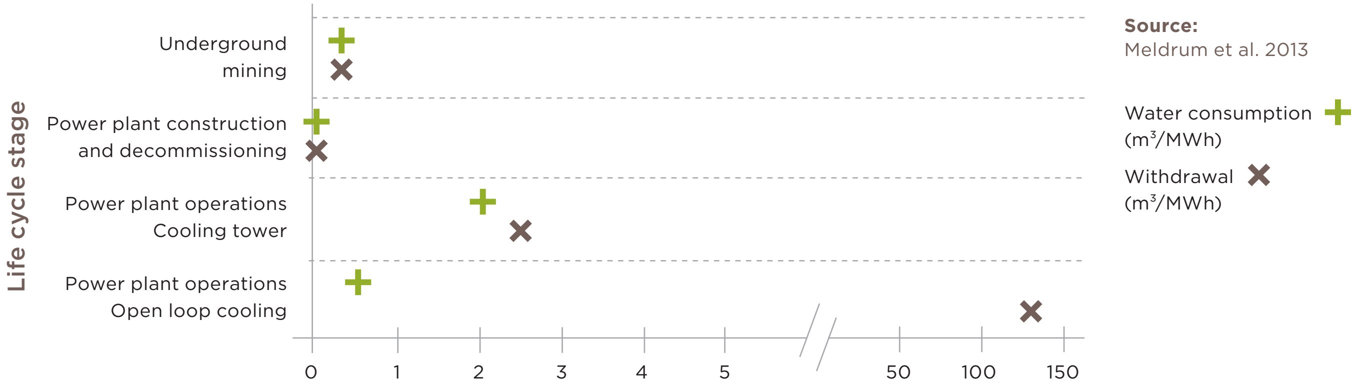
[4] It is important to distinguish between water withdrawal and water consumption. Water withdrawal is the total water volume removed from a water resource even if only temporarily. Water consumption is the water volume removed from a water resource for a very long time, typically by evaporation.

[5] In addition to physical limitations there may be regulatory constraints: e.g. in Germany, withdrawal volumes are regulated via a definition of river minimum flow: withdrawal of water for cooling is only allowed if there is no negative impact on the ecological and chemical condition of the water resource Federal Law 2009.

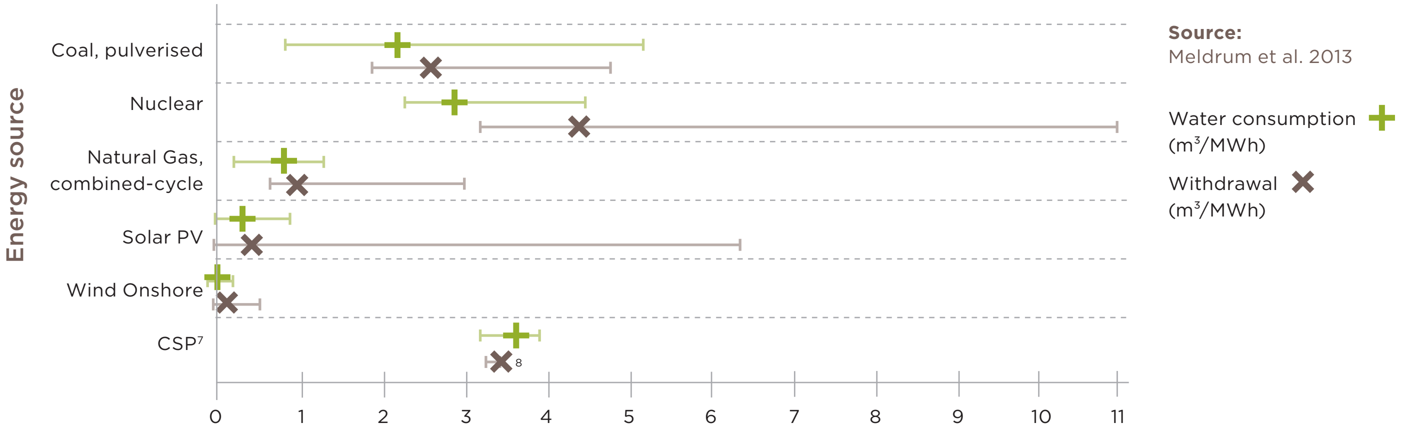
[6] For Germany: Abwasserverordnung (AbwV)

Figure 3: Water consumption and withdrawal at different life cycle stages for pulverised coal power plants.



Source:
Meldrum et al. 2013

Figure 4: Water consumption and withdrawal of different energy sources for power plants with cooling tower (except wind and solar PV).



Source:
Meldrum et al. 2013

Cooling technology significantly influences the water demand of thermal power plants. The most common cooling technologies in thermal power plants are once-through cooling and recirculating cooling. In the case of once-through cooling the water from a water resource, e.g. a river, is used to cool the working fluid (separated loop) and discharged back into the resource at a higher temperature. Recirculating cooling entails a closed cooling loop in addition to the closed working medium loop. The cooling water cools the working medium and is itself cooled by air and by its own evaporation in a cooling tower. The evaporated water has to be replaced by water from a water resource, e.g. a river. Power plants with once-through cooling have very high water withdrawal, while their water consumption is relatively low (see Figure 3, Meldrum et al. 2013). Power plants with recirculating cooling systems have much lower withdrawal, but the bulk of the withdrawn water is consumed (see Figure 3, Meldrum et al. 2013). In arid regions with decreased availability of cooling water new cooling technologies like dry cooling (using air as a cooling medium) and hybrid cooling (combining wet and dry cooling) are used in some new power plants.[9]

[7] Power tower with cooling tower Meldrum et al. 2013.

[8] Only one sample

[9] Eskom: Medupi Power Station Project. Available online at http://www.eskom.co.za/Whatweredoing/NewBuild/MedupiPowerStation/Pages/Medupi_Power_Station_Project.aspx, checked on5/6/2015.

3. Wind and solar PV: technological solutions for water-resilient power generation

Solar PV systems and wind turbines need very little water. Over their whole life cycle they consume about 0.1–14% and withdraw about 2–15% of the water typical conventional power plants (coal or nuclear) use to generate 1 MWh of electricity (see Figure 4 on page 9, Meldrum et al. 2013). Apart from their reduced water demand, another huge co-benefit of solar PV and wind is their very low greenhouse gas emissions. Further benefits are well known, not least fuel (fossil, nuclear) import independence, local value creation, improved system resilience and opportunities to improve electricity access for off-grid regions due to the decentralised nature of these technologies. With the strong expansion of the solar PV system and wind power plant markets[10] the costs of these technologies have dropped dramatically. Now renewables are becoming cost-competitive with new conventional power plants even without integrating all external costs.[11] Two major challenges for the deployment of solar PV and wind power systems are their relatively high share of investment costs (compared to operational costs) and their intermittent power generation. However, several countries are showing how these challenges can be handled. Creating a stable political support framework is the key to reducing the risk associated with investment in renewables. Furthermore, the intermittent supply by solar PV and wind power can be handled by making use of a whole range of flexibility options to balance supply and demand.[12] In regions that are already experiencing water stress or will be under stress in the future, investments in solar PV and wind can be a promising option to cover rising electricity demand without increasing stress on climate and on scarce water resources. The same is true of regions where alternatives to hydro generation need to be found due to decreasing water availability (e.g. in Brazil and California).

Dry cooling can greatly reduce the water demand of thermal power plants, but it is expensive and land-consuming. Dry cooling is a proven technological option to make power generation from thermal power plants less water intensive. If dry-cooling systems are used, the water demand of thermal power plants can be reduced to about 2%[13] of the water demand that would otherwise apply with wet-cooling (Meldrum et al. 2013). However, there are significant trade-offs. Firstly, dry cooling is not as efficient as

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[10] The global installed capacity in 2014 was 177 GW of solar PV and 370 GW of wind power (REN21 2015).

[11] The levelised costs of electricity (LCOE) differ from country to country due to different framework conditions, such as capital costs, transactions costs or risk markup. In Germany, one of the leading markets for solar PV and wind power plants, the levelized costs of electricity end of 2013 were 10-14 Ct/kWh for roof-top solar PV, 7.8 – 12 Ct/kWh for utility scale solar PV and 4,5. – 11 Ct/kWh for wind onshore (Kost et al. 2013). This compares to 6.3 – 8.0 Ct/kWh for hard-coal power plants and 7.5 – 9.8 Ct/kWh for combined-cycle gas power plants (Kost et al. 2013).

[12] Important flexibility options are: large-scale and intelligent grids, flexible conventional power generation, demand side management, and all kinds of storage (thermal, material, electricity). In a system with a considerable share of generation from intermittent renewables, the old paradigm of base, medium and peak load is no longer valid. The system will become much more dynamic and flexible, on the generation as well as the demand side.

[13] Consumption or withdrawal of combined-cycle natural gas power plant with dry cooling compared to that of a combined-cycle natural gas power plant with a cooling tower.

wet cooling. This means a higher fuel demand and higher greenhouse gas emissions per MWh generated. Second, dry-cooling systems have higher investment costs than equivalent wet-tower cooling systems (2 to 4 times), since air requires a much larger surface area for heat dissipation than water (World Bank 2013). And thirdly, given their larger cooling towers, dry-cooling systems have much greater land area requirements than wet-cooling systems (IEA 2012).

Freshwater for cooling may be partly replaced by non-freshwater sources, but this is associated with increased costs and reduced efficiency. By using wastewater (municipal wastewater, shale gas discharge, coal mining discharge, etc.) or saline water from the sea or saline aquifers, demand for freshwater can be reduced (Carney 2010). However, wastewater usually needs to be treated before it can be used as cooling water to avoid corrosion in the cooling system, inducing additional costs and reduced overall efficiency of the power plant (World Bank 2013). Similar to freshwater cooling from surface sources, seawater cooling can have adverse impacts on local aquatic ecosystems especially due to thermal pollution. Moreover, seawater cooling is only feasible at or near the coast.

Technological solutions are important but will not suffice. In order to decrease the energy sector's vulnerability to water constraints and lessen its water impacts, policy changes are needed as well.

4. Water constraints must be part of energy decision-making

Energy decision-makers tend to mistakenly believe that water is an abundant resource that they do not need to worry about.[14] According to the *World Water Development Report 2015*, only the most water-scarce areas of the world might be an exception to this (UNESCO 2015). Water users – in the energy sector and beyond – often treat water as an abundant resource because its value and scarcity are seldom adequately reflected in the prices that consumers pay for it. In many parts of the world, water consumption is free of charge or the prices are so low that they do not even cover the costs of supply (UNESCO 2014). This even applies to major non-household water consumers. *The CDP Global Water Report 2014* points out that energy corporations lag behind in almost all elements of corporate water disclosure when compared to corporations in other sectors (CDP 2014). Interestingly, in the CDP survey the vast majority of respondents from the energy sector (82%) state that water poses a substantial risk to their business; however, only a small fraction (18%) undertakes comprehensive water risk assessments. It is frequently underlined that the public sector lags behind the private sector when it comes to dealing with water risks, since corporations are more likely to take a preventive approach towards risks that affect their business (see, for example, Westphal, Roehrkasten 2013).

One major reason for the insufficient attention paid to water constraints in the energy sector is a lack of data. In many parts of the world, the availability of data on water is very limited. According to the *World Water Development Report 2015*, monitoring water availability remains a huge challenge, since reliable information on water resources is often missing. Assessments of groundwater resources are particularly poor. If water data is available, it is often not compatible with energy data (IRENA 2015; World Bank 2013). IRENA (2015) emphasises that the lack of water data applies to the energy sector as a whole. However, data gaps become even larger if energy sectors beyond electricity (e.g. oil extraction and refining) and full life cycles are considered.

Power imbalances are another major reason for the energy sector's limited consideration of water. As the energy sector is politically and economically powerful, its water demands tend to prevail over other users and uses. In some countries, energy utilities are classified as strategic water users. This means that if the water supply is not able to satisfy competing water demands, energy utilities are the last to be cut off from that supply. Thus, they enjoy a much higher security of water supply than users that are not classified as strategic. This is the case, for example, with the energy utility Eskom in South Africa, which operates coal-fired power plants and is classified as a strategic water user under the National Water Act (Groenewald 2012; Steele, Schulz 2012). The negative impacts of the energy sector's water use – be it reduced availability of water for other users or water pollution – often do not get the political attention they deserve. This is especially the case if the groups that are negatively affected are underprivileged, such as slum dwellers or small farmers, with little political influence.

In addition, implications for water resources are often overlooked because they fall beyond the institutional responsibilities of energy decision-makers. Energy and water are often managed as separate issues. Decision-makers in the energy sector are generally not in charge of water management and vice versa. While division of labour and specialisation bring many benefits, they can also lead to blind spots, since decision-makers are less likely to consider issues that lie beyond

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[14] See for example UNESCO 2015, UNESCO 2014, World Water Week 2014, IRENA 2015, World Bank 2013, Christopher A. Scott, Mathew Kurian and James L. Wescoat Jr 2015, Scott 2011.

their institutional responsibilities. Energy and water management are also dealt with at different scales: while energy is often managed at national level, water is typically managed at local level or on a watershed basis (IRENA 2015; World Water Week 2014). The higher the policy scale, the more difficult policy integration becomes: integrated water and energy planning is most likely to be found at local level while 'silo thinking' increases at national and international scales. Often, there is little or no incentive to coordinate energy and water policies across sectoral institutions (UNESCO 2014).

The public sector in particular tends to neglect water-related risks in favour of short-term interests. This applies primarily to areas where water constraints are not yet a major risk, but will become one in future (see, for example, UNESCO 2015). Even though investment decisions in the energy sector cover long time spans, they are often driven by short-sighted concerns. Short-sighted decision-making is a particular challenge in the public sector: policymakers focussed on the next election have few incentives to consider water scarcities that will only become relevant in the long run – many years after their terms of office have ended.

Policy options are available that can significantly improve the energy sector's water management. These comprise measures to a) enhance transparency on water use in the energy sector, and b) to incorporate water scarcity into energy planning.

a. Enhance transparency on water use in the energy sector

In order to improve the knowledge base on the energy sector's water use, a number of different actors need to collaborate. Each of them can make an important contribution to increasing the available data on the water intensity of the energy sector and the water pollution it causes. As the water intensity of energy technologies may vary significantly from one location to another (IRENA 2015), context-specific data is required. Collecting such data is particularly pressing in areas that are already affected by water stress or will be so in the foreseeable future (see Figure 1 on page 5).

Energy companies can improve how they assess their operational water requirements, both in ex-ante planning and in the course of implementation. This serves the enlightened self-interest of corporations, as this information is a central precondition for effective risk prevention. These efforts might build on voluntary action. Here, a positive example is the Water for Energy Framework Action Group,[15] led by Electricité de France and supported by the European Innovation Partnership on Water, which helps energy companies to assess their water use and water impacts (World Water Week 2014, World Bank 2014). If necessary, regulatory instruments can be employed. For example, the State of California approved a bill that requires oil companies to report how much and what sources of water they use in their drilling operations (IRENA 2015).

Likewise, energy decision-makers in the public sector can also improve their assessment of water requirements. A comprehensive assessment of the energy sector's water requirements covers the different stages of the policy cycle: planning, implementation and evaluation. It should apply to both domestic energy investments and energy projects in international development cooperation. It is important that the results are easily accessible to the public and also outline the distributional implications of the energy sector's water use.

Policy actors involved in international energy cooperation can further raise global awareness of the energy sector's impacts on water resources and advise decision-makers on how to better assess water requirements and water impacts. The *World Energy Outlook 2012* of the International Energy Agency, which comprised a chapter on water for energy (IEA 2012), made an important contribution to raising international awareness on this issue. In future, the IEA could provide regular updates in its World Energy Outlooks and online databases. The *Nexus Report 2015* of the International Renewable Energy Agency (IRENA) was another step in the right direction (IRENA 2015). It presents a conceptual framework for assessing the water and land requirements of different energy-mix scenarios. In addition to international organisations such as the IEA and IRENA, the United Nation's Sustainable Energy for All Initiative and its High Impact Opportunity: Water-Energy-Food

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[15] See EIP Water, W4EF, http://www.eip-water.eu/W4EF

Nexus[16] is a suitable platform for increasing transparency on the energy sector's water implications.

Non-governmental organisations, academic institutions and journalists around the world can provide additional and independent analysis on the water impacts of energy decisions. While this supports energy decision-makers who are willing to consider water constraints in their decision-making, it can also provide the public pressure necessary to induce behaviour changes in those energy actors who have so far been reluctant to act – for example, in cases where energy sector actors use water at the expense of others. As such, assessing the distributional impacts of the energy sector's water use would help to make transparent who loses from the energy sector's water use.

b. Incorporate water scarcity into energy planning

Necessary behaviour changes will only happen if energy decision-makers recognise that water is not an abundant and (almost) no-cost resource. Introducing price signals and accounting for water use in energy models are important starting points for incorporating water scarcity into energy planning.

Charging the energy sector for its water use in a way that better reflects actual water costs and scarcities can be a very effective way to improve water management in the energy sector and increase incentives for water savings. In many parts of the world, water consumption is either free of charge or the prices are so low that they do not even cover the costs of supply (UNESCO 2014). What might be a well-intended policy leads to adverse effects: while the centrality of freshwater for human survival might be a major rationale for zero or low costs, this pricing signals to consumers that water is something they do not need to worry about. This leads to overuse and aggravates water scarcity. Ultimately, such pricing might even undermine the human right to water. Moreover, the low pricing does not only apply to private households, but also to water users in industry, the energy sector and agriculture – which together account for 90% of global water withdrawals (World Water Week 2014). Thus, most of the benefits of cost savings due to subsidised water prices are enjoyed by these end-use sectors rather than private households. In order to ensure that water pricing does not undermine the human right to water by creating an access barrier for low-income households, price increases would need to apply to non-household water use only or to household water use above a certain threshold.

Integrating water scarcity into the energy models of public policy planning is a low hanging fruit that can have major positive effects. In this context, the launch of the World Bank's Thirsty Energy Initiative[17] in 2014 was an important step (see World Bank 2013,World Bank 2014). It helps countries to identify synergies, to quantify trade-offs between energy development plans and water use, and to pilot cross-sectoral planning. In addition, it designs assessment tools and resource management frameworks that help governments to coordinate decision-making. The Thirsty Energy Initiative currently has projects in South Africa, Morocco and China. In the case of South Africa, it integrates water scarcity into an energy planning tool that previously neglected water as a constraining factor and failed to consider water-related costs.

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[16] See SE4All, High Impact Opportunity: Water-Energy-Food Nexus, http://www.se4all.org/hio/water-energy-food-nexus/

[17] The World Bank: Thirsty Energy Initiative – Securing Energy in a Water-Constrained World, http://www.worldbank.org/en/topic/sustainabledevelopment/brief/water-energy-nexus

5. Widening the perspective: energy and water for global sustainability

Energy and water, now integral parts of the United Nation's Sustainable Development Agenda, need to be considered as mutually dependent. The Sustainable Development Goals (SDGs) have set the course: by 2030, the international community shall ensure the availability and sustainable management of water and sanitation for all (SDG 6) and provide access to affordable, reliable, sustainable and modern energy for all (SDG 7). In the realm of energy, the SDGs are a remarkable step. Until recently, the UN had remained almost silent on energy issues since it could not achieve consensus among its member states (Roehrkasten 2015). Accordingly, the predecessors of the SDGs – the Millennium Development Goals – did not include a goal on energy. Yet water was already part of the Millennium Development Agenda. The UN also established safe and clean drinking water and sanitation as a human right in 2010, recognising that access to safe and clean drinking water is not only a human right in itself, but also integral to the realisation of all human rights (United Nations General Assembly 2010). As freshwater is an indispensable resource on our planet, it is vital that it is wisely managed. However, this is also a very challenging task: while demand for freshwater is increasing rapidly due to a growing world population and rising levels of socio-economic development, there are natural limits to expanding its supply. A sustainable management of water resources has to respect the limits of local water cycles. If these are exceeded, serious consequences can be expected, such as groundwater depletion.

Conscious and conserving water management practices in the energy sector are crucial to pursuing the SDG on energy without undermining the SDG on water. Founded on the vision of sustainable development formulated by the international community in 1992, the catalogue of 17 SDGs comes with the requirement and the opportunity to create synergies among different goals. Integrated water and energy management and the promotion of water-saving energy technologies such as wind and photovoltaics are a good case in point. Expanding energy access at the cost of water scarcity and climate change forgoes these opportunities and perverts the idea of sustainability by reducing the agenda to individually selected goals.

The SDGs are an important window of opportunity for strengthening alliances between the water sector and water-friendly renewable energy sources. The power of the new Sustainable Development Agenda lies in the way it raises awareness of and sets the agenda for sustainability policies and international cooperation around the globe. The goals on energy and water are being given special priority by the international community: when the UN Secretary General asked UN member states for their priorities with regard to the SDGs, water, energy and food were mentioned as the top three (Beisheim 2013). We need to seize this exceptional window of opportunity for reconciling water and energy security.

Bibliography

2030 Water Resources Group (2009) Charting our water future: Economic frameworks to inform decision-making. Washington, United States.

Abwasserverordnung (AbwV) Verordnung über Anforderungen an das Einleiten von Abwasser in Gewässer, Anhang 31 Wasseraufbereitung, Kühlsysteme, Dampferzeugung. In : Bundesgesetzblatt.

Argonne National Laboratory (2012) Impacts of Long-term Drought on Power Systems in the U.S. Southwest, 2012.

BBC News (2009) Dark truth about Latin American energy. In BBC News, 11/20/2009. Available online at http://news.bbc.co.uk/2/hi/americas/8368785.stm.

Beisheim, Marianne (Ed.) (2013) Der "Nexus" Wasser-Energie-Nahrung. Wie mit vernetzen Versorgungsrisiken umgehen? Stiftung Wissenschaft und Politik.

California Energy Commission (2015) Hydroelectric Power in California. Available online at http://www.energy.ca.gov/hydroelectric/, checked on 9/25/2015.

Carney, Barbara (2010) Water Vulnerabilities for Existing Coal-fired Power Plants. Edited by Department of Energy (DOE). National Energy Technology Laboratory (NETL).

CDP (2014) From water risk to value creation. CDP Global Water Report 2014.

Christopher A. Scott, Mathew Kurian and James L. Wescoat Jr (2015) The Water-Energy-Food Nexus: Enhancing Adaptive Capacity to Complex Global Challenges.

Energy and Water in a Warming World Initiative (2011) Freshwater Use by U.S. Power Plants - Electricity's Thirst for a Precious Resource. A Report of the Energy and Water in a Warming World Initiative. Cambridge, MA.

EPA (2014) The Impact of Traditional and Alternative Energy Production on Water Resources: Assessment and Adaptation Studies. USA. Available online at http://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100MJXC.pdf.

Federal Law (2009) Gesetz zur Ordnung des Wasserhaushalts (Wasserhaushaltsgesetz – WHG), revised 2015.

Fiott, Daniel; Kantu, Patrice; Iwinjak, Florian (2010) Energy security. In Climate Change and Security, ed. Fiott, D., Institute for European Studies.

Groenewald, Yolandi (2012) Coal's hidden water cost to South Africa. Greenpeace Africa.

International Energy Agency (IEA) (2012) World Energy Outlook 2012.

International Renewable Energy Agency (IRENA) (2015) Renewable energy in the water, energy

Kost, Christoph; Mayer, Johannes N.; Thomsen, Jessica; Hartmann, Niklas; Senkpiel, Charlotte; Philipps, Simon; Nold, Sebastian; Lude, Simon; Schlegl, Thomas (2013) Stromgestehungskosten Erneuerbare Energien. Fraunhofer ISE.

Meldrum, J.; Nettles-Anderson, S.; Heath, G.; Macknick, J. (2013) Life cycle water use for electricity generation. A review and harmonization of literature estimates. In *Environ. Res. Lett.* 8 (1), p. 15031. DOI: 10.1088/1748-9326/8/1/015031.

National Geographic News (2012) Record Heat, Drought Pose Problems for U.S. Electric Power. In *National Geographic News*, 8/17/2012. Available online at http://news.nationalgeographic.com/news/energy/2012/08/120817-record-heat-drought-pose-problems-for-electric-power-grid/, checked on 5/20/2015.

Plumb, Michael; Davis, Kathryn (2010) Developments in Utilities Prices. Reserve Bank of Australia.

PSE S.A. (2015) Information on the situation in the Polish power system. Available online at http://www.pse.pl/index.php?dzid=32&did=2516.

REN21 (2015) Renewables 2015 – Global Status Report. Paris.

Roehrkasten, Sybille (2015) Global Governance on Renewable Energy. Wiesbaden: Springer VS Research

Scott, Christopher et al (2011) Policy and institutional dimensions of the water–energy nexus. In *Energy Policy*.

STEAG (2015) Transparency Data STEAG GmbH. Available online at http://transparenz.steag.com/t-s-home.html.

Steele, Melita; Schulz, Nina (2012) Water hungry coal. Burning South Africa's water to produce electricity. Greenpeace Africa.

The Guardian (2003) Heatwave hits French power production. In *The Guardian*, 8/12/2003. Available online at http://www.theguardian.com/world/2003/aug/12/france.nuclear, checked on 5/5/2015.

The Guardian (2006) Heatwave shuts down nuclear power plants. In *The Guardian*, 7/30/2006. Available online at http://www.theguardian.com/environment/2006/jul/30/energy.weather, checked on 5/20/2015.

The Guardian (2015) Brazil's worst drought in history prompts protests and blackouts. In *The Guardian*, 2015. Available online at http://www.theguardian.com/world/2015/jan/23/brazil-worst-drought-history.

United Nations General Assembly (2010) Resolution adopted by the General Assembly on 28 July 2010. A/RES/64/292. Available online at http://www.un.org/es/comun/docs/?symbol=A/RES/64/292&lang=E.

U.S. Department of Energy (July 2013) U.S. Energy Sector Vulnerabilities to Climate Change and Extreme Weather. U.S. Department of Energy.

U.S. Geological Survey (2014) Estimated Use of Water in the United States in 2010.

UNESCO (2014) Water and Energy. The United Nations World Water Development Report 2014.

UNESCO (2015) Water for a Sustainable World. The United Nations World Water Development Report 2015.

University Oldenbourg (2006) Hydrology. Water use in Germany by sectors. Available online at http://www.hydrologie.uni-oldenburg.de/ein-bit/12044.html.

van Dijk, Albert I. J. M.; Beck, Hylke E.; Crosbie, Russell S.; de Jeu, Richard A. M.; Liu, Yi Y.; Podger, Geoff M. et al. (2013) The Millennium Drought in southeast Australia (2001–2009). Natural and human causes and implications for water resources, ecosystems, economy, and society. In *Water Resour. Res.* 49 (2), pp. 104018–1057. DOI: 10.1002/wrcr.20123.

van Vliet, Michelle T. H.; Yearsley, John R.; Ludwig, Fulco; Vögele, Stefan; Lettenmaier, Dennis P.; Kabat, Pavel (2012) Vulnerability of US and European electricity supply to climate change. In *Nature Climate change* 2 (9), pp. 676–681. DOI: 10.1038/NCLIMATE1546.

Webber, Michael (2013) Effect of Drought on the Energy Sector. Testimony before the committee on energy and natural resources Unites States Senat.

Westphal, Kirsten; Roehrkasten, Sybille (2013) Energieversorgung: Vom Umgang mit internationalen und vernetzten Versorgungsrisiken. In: Beisheim, Marianne (Ed.): Der "Nexus" Wasser-Energie-Nahrung. Wie mit vernetzen Versorgungsrisiken umgehen? Stiftung Wissenschaft und Politik.

World Bank (2013) Thirsty Energy (Water Papers).

World Bank (2014) Thirsty Energy Update.

World Economic Forum (2015) Global risks 2015. Geneva.

World Water Week (2014) 2014 Overarching Conclusions.

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- The Water-Energy Nexus
- From Coal to Renewables
- Transformative Energy Governance

Launched in March 2012, our platform takes up the suggestions of the Ethics Commission for a Safe Energy Supply, which was co-chaired by IASS Executive Director Klaus Töpfer on behalf of Chancellor Angela Merkel. In addition to carrying out original research on different aspects of the Energiewende and a global energy transition, the team organises thematic working groups and workshops, and bilateral talks with experts from Germany and its partner countries.

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Founded in 2009, the IASS is an international, interdisciplinary hybrid between a research institute and a think tank, located in Potsdam, Germany. The publicly funded institute promotes research and dialogue between science, politics and society on developing pathways to global sustainability. The IASS focuses on topics such as sustainability governance and economics, new technologies for energy production and resource utilization, and Earth System challenges like climate change, air pollution, and soil management.

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