HSBC Climate Change

WORLD
RESOURCES
INSTITUTE

WRI

Amanda Sauer

Piet Klop

HSBC

Sumeet Agrawal

OVER HEATING

Financial Risks from Water Constraints on Power Generation in Asia

India, Malaysia, Philippines, Thailand, Vietnam

ISBN: 978-1-56973-742-2

Contents

ABOUT THE PROJECT

This report would not have been possible without the financial support of the International Finance Corporation (IFC) and grant funding from the Government of Japan.

The research project's objective is to guide investors and analysts through assessing the financial impacts of select environmental trends on listed companies in India, Indonesia*, Malaysia, Philippines, Thailand, and Vietnam. Other research reports produced within this series are listed below. More information on the project and copies of the reports are available for download at **http://www.wri.org/project/envest**.

- ***Emerging Risk:*** *Impacts of Key Environmental Trends in Emerging Asia*.
- ***Undisclosed Risk:*** *Corporate Environmental and Social Reporting in Emerging Asia*.
- ***Weeding Risk:*** *The Financial Impacts of Climate Change and Water Scarcity Trends on Asia's Food and Beverage Sector.*
- ***Surveying Risk, Building Opportunity:*** *The Financial Impacts of Energy Insecurity, Water Scarcity and Climate Change on Asia's Commercial Real Estate Sector.*

Weeding Risk, *Over Heating* and *Surveying Risk* include contributions from HSBC's Climate Change Centre of Excellence and HSBC's India Equity Research Division.

**Note: Indonesia is not included in this report because it has no publicly listed power generation companies. It is included in the other reports.*

ACKNOWLEDGMENTS

The authors wish to give special thanks to our World Resources Institute colleagues, Janet Ranganathan, Eliot Metzger, Jeff Rodgers, and Evan Branosky, who generously reviewed drafts of this report. We are also grateful for the thoughtful contributions by the World Business Council for Sustainable Development's working group on power and water, Claudia Kruse from APG Investments, Anthony D'Agostino from the National University of Singapore's Institute of Water Policy, and Daniel Beneat. Special thanks are owed to Euan Marshall and Berit Lindholdt Lauridsen of the IFC for providing ongoing guidance on the scope and direction of this research. We are deeply grateful to HSBC for their valuable contributions, especially from Roshan Padamadan, Sumeet Agrawal, Charanjit Singh, and Pankaj Jain. Also thank you to Jennie Hommel for managing the review process, Allison Sobel for copyediting, and Maggie Powell for providing layout services.

ABOUT THE AUTHORS

Amanda Sauer is a Senior Associate in the Envest project at WRI. **amanda.sauer@wri.org**
Piet Klop is a Senior Fellow in the Envest project at WRI. **piet.klop@wri.org**

COVER PHOTO CREDIT

IStockPhoto.com

April 2010

I. Key Findings for Investors and Analysts

Water-related risks are receiving more attention than in the past, yet the connection to power sector development is not well understood by investors, governments, and companies in South and Southeast Asia. This report presents a framework for investors and analysts to assess the risk of impacts from water-related issues, including growing water scarcity and declining water quality, on thermal and hydroelectric power generation plants. While this analysis focuses on publicly listed power generation companies in India, Malaysia, Philippines, Thailand, and Vietnam, the risks outlined may apply to listed power generation companies operating in other water scarce regions.

CONTEXT

Emerging Asia is projected to have the fastest growth rate of power consumption in the world.

- The drivers behind this power appetite – economic and population growth – are also increasing demands on limited freshwater resources.
- The power sector requires a steady supply of water for cooling and generation to maintain loads and avoid disruptions.

The availability and quality of freshwater is rapidly declining in many parts of South and Southeast Asia due to demographic pressures and climate change.

- India in particular faces critical water shortages in the next decade.
- Malaysia, Thailand, the Philippines, and Vietnam are expected to face localized water pollution and shortages, with climatic patterns shifting towards longer dry seasons with more concentrated rainfall periods.

Investors are taking on more water risk.

- The power sector is being liberalized in many countries in the region to attract the investment necessary to meet economic goals, with higher risk-reward propositions for investors.
- Deregulated power markets may offer little or no protection to shareholders in the event of an outage or load loss resulting in lost revenues or increased costs (if stipulated by operating license).
- New thermal and hydro power development places long-term bets on water availability – yet future water supplies are often uncertain and potentially oversubscribed in the most electric power hungry and water scarce regions.

Technology will play a key role in mitigating water risk yet at a price and efficiency tradeoff.

- Advanced cooling systems for thermal power such as dry cooling can reduce or eliminate freshwater dependency yet increase carbon emissions per unit power output through efficiency losses.
- Likewise there are water penalties for carbon dioxide emission reducing technologies such as carbon capture and storage.

- These competing priorities make it difficult for investors and companies to anticipate the impact of future climate change and water policies on investments.

Water risk has been obscured to date by regulatory protections.

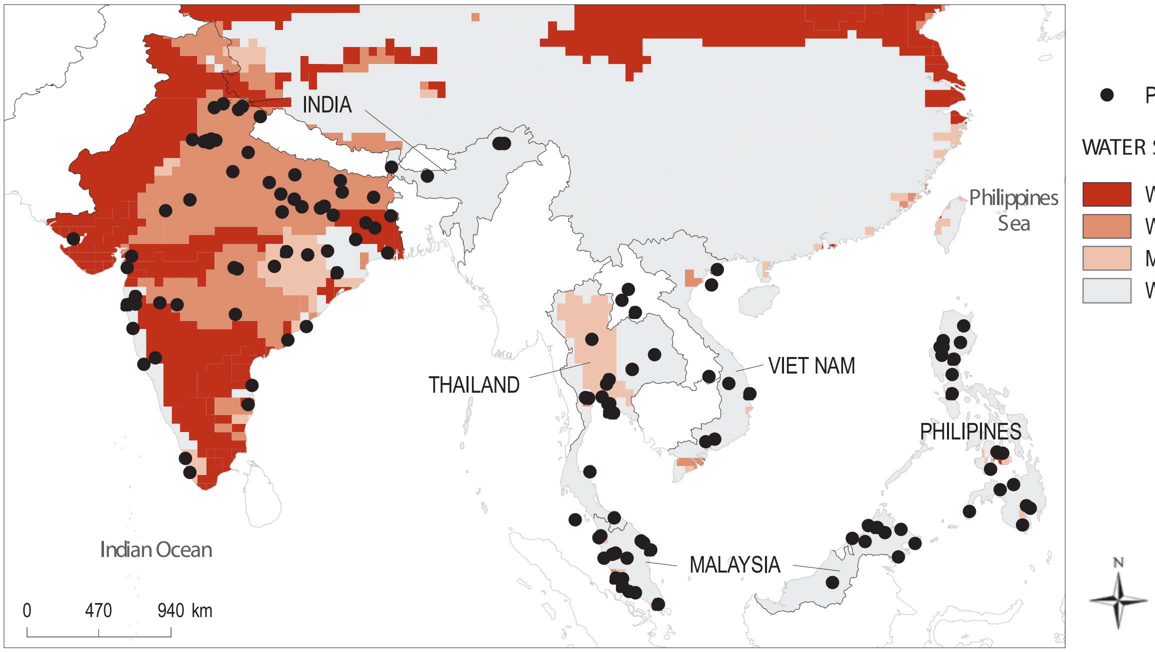
- Examples of water-related load losses or outages have occurred throughout South and Southeast Asia yet the financial impact has been limited due in part to heavy governmental support that minimizes shareholder risks.
- Shareholder protections will become more costly to sustain and may drive regulatory change as freshwater scarcity increases over the longer term.

KEY FINDINGS

74 GW – over half of existing and planned capacity for major power companies – is located in areas that are considered to be water scarce or stressed.

- WRI mapped water scarcity data with plant locations for the largest publicly listed power generation companies in the region, as shown in Figure 1.
- See Appendix A for more information on this analysis.

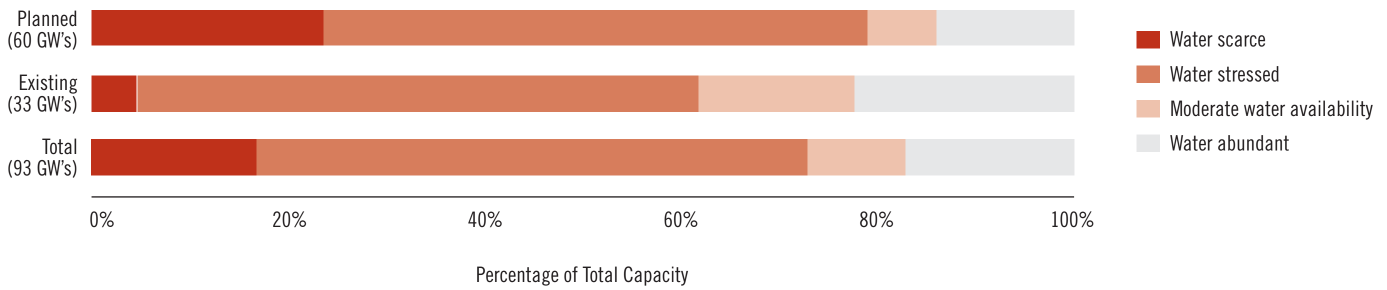
FIGURE 1. **Thermal Power and Hydropower Plant Locations and Water Stress Level**



Note: Water stress indicators (WSIs) represent the ratio of total withdrawals to utilizable water. These indicators do not reflect anticipated demographic or climate changes (such as the timing/quantity of precipitation) and therefore do not represent all facets of water-related risk. See Appendix A for information.

Source: WRI. Data for power plants are from carma.org and 2008 company reports. The water stress indicators are from CGIAR/WRI/University of Kassel 2004.

FIGURE 2. Location of Power Capacity* by Water Stress Level in India



* Includes thermal and hydro plants owned by NTPC, Tata Power, and Reliance Infrastructure (including Reliance Power).

Note: Planned capacity includes all stages of project development reported in corporate financial disclosures but not yet operational in 2009.

Source: WRI. See Appendix A for more information.

In India, 79% of new capacity will be built in areas that are already water scarce or stressed.

- NTPC, Tata Power, and Reliance Infrastructure's (including Reliance Power's) new capacity is increasingly located in water scarce or stressed areas, as shown in Figure 2.
- Water scarcity is expected to intensify in the future as the impacts of climate change and demographic pressures decrease renewable water supplies.

Water risk is determined by a plant's business model, dependency on water, and security of water supplies.

- Table 1 presents a framework that investors and analysts can use to assess exposure to water risks.

TABLE 1. Water Risk Framework for the Power Generation Sector

		Business Model	Water Dependency	Water Security
		Are shareholder returns protected from falling output?	*How much water is required to maintain loads?*	*Is the plant in a water scarce region?* *How are the plant's water supplies secured?*
Risk Level	High	• Merchant	• Open-loop thermal • Run-of-the-river hydro	• Water scarce or stressed area • History of water-related events • High rate of urbanization/industrialization in watershed
	Medium	• Hybrid (Regulated/ Merchant) • Regulated (high utilization rate required)	• Closed-loop thermal • Reservoir hydro • Supercritical coal • Combined cycle gas	• Reservoir with irrigation commitments • Dependence on seasonal precipitation
	Low	• Regulated (no risk from falling output) • Captive • Competitive tariff	• Renewables (excluding biomass and concentrated solar thermal) • Seawater cooling • Wastewater cooling • Air cooling	• Water abundant area • Long-term water contract

Source: WRI.

Potential financial impacts of water-related issues for the power generation sector include:

Lost revenues and increased costs of goods sold (COGS).

- Water-related disruptions such as prolonged droughts and heat waves can lead to low reservoir levels and insufficient cooling water, resulting in load losses or outages that often coincide with periods of heavy demand, thereby forfeiting revenues.
- Water shortages can necessitate temporary water and power supply measures that increase production costs and therefore COGS.
- Water shortages are episodic in nature and can occur in any timeframe, although their frequency and severity are projected to increase over time.
- Impacts on shareholder value will vary by business model and power purchase contracts.

Higher capital expenditures (CAPEX).

- As water availability and quality declines, companies may need to invest in water infrastructure projects to secure supplies (such as pipelines, dams/reservoirs, and desalinization facilities), water treatment systems (for plant influents or/and effluents), and/or more advanced cooling systems (such as air, seawater, wastewater reuse, or condensed water cooling).
- The need for such investments will increase in the future, with the impact on the industry determined by regulations and financing terms.

Project execution delays and constraints on growth.

- As water shortages become more acute, policymakers are likely to respond by requiring more stringent water efficiency and usage requirements. This could increase permitting and development periods for new plant projects. As a result, financing may become more difficult and expensive.
- New plants may be restricted in water scarce regions by government decree or by lack of financing if water supply cannot be secured at an attractive rate.
- These risks are currently present in some Indian states where signed MOU's for new power capacity are believed to exceed available water resources.
- Over time these risks will increase in severity and geographic scope.

An HSBC analysis suggests that delays in project execution and loss of output due to water scarcity could be material.

- Analysts found that a delay of three months in project execution due to water permitting issues will result in the internal rate of return (IRR) dropping by a mere 25 basis points (bps), but as the delay period extends, the drop in IRR becomes more serious. A 12-month delay in commercial operation results in the IRR dropping by nearly 150 bps.
- If water shortages reduce power output, each 5% drop in the plant load factor will result in nearly a 75 bp drop in the project IRR.

NEXT STEPS FOR INVESTORS AND ANALYSTS

Investors and analysts should integrate current and future water risks into their evaluation of power generation companies.

This report takes the first steps in this direction by:

- Providing the groundwork for navigating the complex issues of water availability and quality.
- Identifying the potential financial impacts arising from water risks.
- Presenting a framework to understand a plant's exposure to water constraints.
- Providing indicators and questions to inform engagement with companies on these risks.

Additional information/data needed to assess water risk at the company level include:

- Financial information, including IRR models at the plant level
- Plant data, including exposure and vulnerability to water risks (i.e. location, water source, water usage, and cooling technology)
- Water availability data at smallest scale possible
- Rules governing water contracts
- Terms of PPA's regarding disruptions

Investors and analysts may need to engage companies to acquire this information/data. Important questions for investors and analysts to ask power companies include (as summarized from section IV of this report):

- Is the plant located in a water scarce region?
- What factors threaten the plant's water supply? Are these threats growing in significance? Has the risk of climate change been taken into account?
- What is the plant's water usage? What water reducing technologies are in place?
- Can load losses and power outages from water shortages have a financial impact? For example, will such events violate the terms of power purchasing contracts?
- How is the plant's water supply secured? What degree of volatility exists under this arrangement? Which water users are given priority in scarcity situations?

With this information, examples of approaches that can be taken to integrate water risks into the analysis of power companies include:

- *Sensitivity analysis*: For plants dependent on freshwater resources, conduct a plant level sensitivity analysis of IRR impacts of outages and load losses. This will reveal which companies have the highest financial risk tied to disruptions.
- *Scenario analysis*: Develop scenarios around water availability at the river basin level for each plant based on future projections (if available) or key risk factors present at the local level. When combined with the sensitivity analysis above, this provides insight into which plants are most at risk from water constraints and the potential magnitude of financial impact.
- *Management quality analysis*: Assess and rank companies based on the ability of corporate initiatives, including comprehensive water management strategies, and advanced

technologies, such as air cooling, to mitigate water risk. Use this information to appropriately adjust conclusions from the sensitivity and scenarios analyses.

How, or if, the results from these approaches can be integrated into financial models will depend on factors including the analyst's view on the probability of impact and the reliability of the underlying data. However, even if they cannot be integrated into financial models they can be used to inform the general view on management quality. This subjective viewpoint on a company, combined with investor data on companies, can inform the following investment decisions: buy/sell decisions, engagement of various intensities and stock/sector weightings in portfolios.

II. Sector Overview

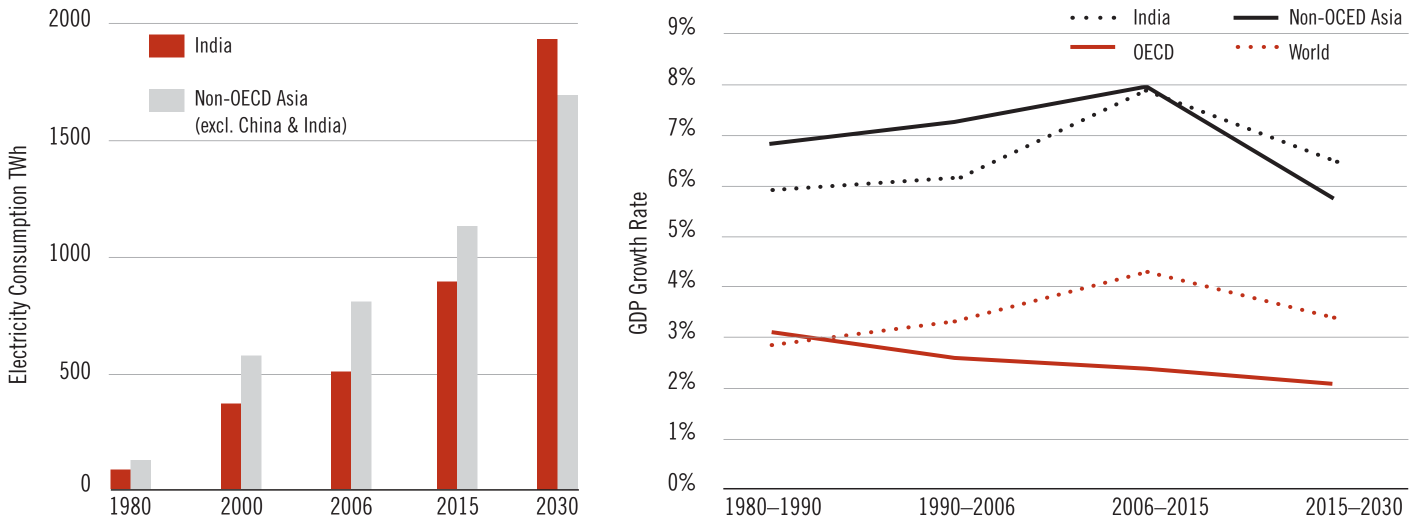
KEY POINT

- The rapid growth of thermal and hydroelectric power plants increases the risk of water-related issues for power generation companies in the region.

The power sector in South and Southeast Asia is expected to experience significant growth over the medium to long-term.

Emerging Asia has the fastest projected growth in electric power generation in the world.[1] Despite the recent global economic downturn, longer-term projections point to sustained growth in electricity demand and higher than average GDP growth rates (Figure 3).[2] Conventional wisdom indicates that in a developing economy the rate of growth of demand for power is about 50% more than the rate of economic growth.[3] Vietnam has exceeded this with the electricity industry growing at 15% versus 7% GDP growth between 2001 – 2008.[4]

FIGURE 3. Electricity Consumption and GDP Growth Rate Projections to 2030

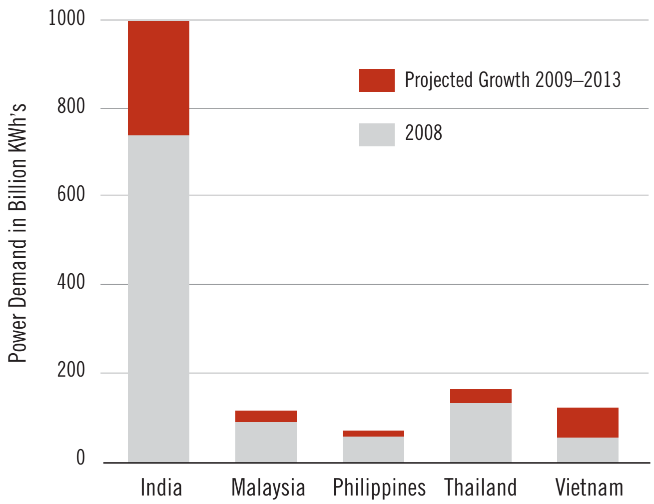


Source: IEA WEO 2009.

India is by far the largest power consumer and producer in the region, with expected demand in 2013 more than double that of the rest of the countries combined (Figure 4). To meet this demand, power capacity is expected to grow by over 50% in India to 217 GWs (Figure 5).[5]

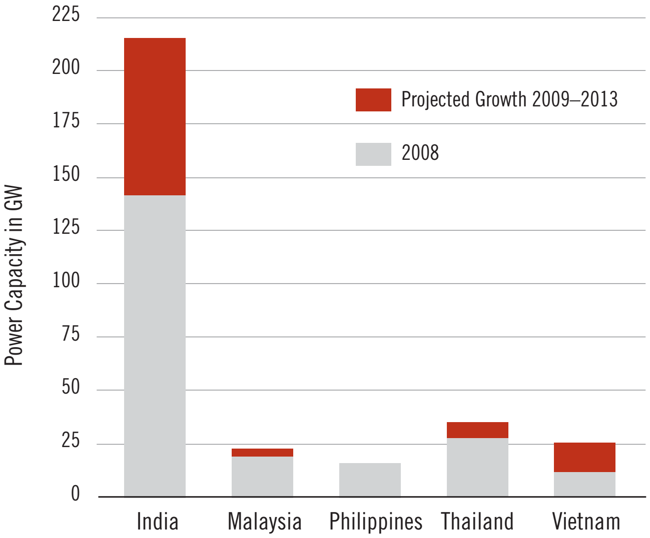
The Indian government has determined that generating capacity needs to grow from the 2006 level of 144 to 778GW by 2032.[6,7] In the nearer-term, the Central Electricity Authority of

FIGURE 4. Power Demand 2008 and Projected New Power Demand 2013 (Billion KWh)



Source: JPMorgan 2009, Electricity of Vietnam (EVN) 2009.

FIGURE 5. Power Capacity 2008 and Projected New Power Capacity 2013 (GW)



Source: JPMorgan 2009, Electricity of Vietnam (EVN) 2009.

the Indian government has instated a goal to reach "power for all" by 2012, requiring an additional 56 GW from 2008 to 2012.[8] Even if this rapid capacity addition is achieved, supply would still not be able to meet demand, with a demand-supply mismatch projected to continue until at least 2017.[9]

Heavy regulation of the sector will continue with governments planning to meet energy goals primarily with thermal and hydroelectric power.

The sector is far from liberalized, with state ownership characterizing the majority of power production in the region. In India, states own 52% of power production, the central government owns 34%, and the private sector owns 14%.[10] The private sector share is expected to rise in the future, with one source estimating 27% of installed capacity will be privately owned by 2017.[11] The Indian government plays a large role in project development, with 90% of new power projects publicly funded.[12] In Vietnam, only 24% of installed capacity in 2006 was private, although this share is expected to increase as it depends more heavily on IPPs (independent power producers) and SPPs (small power producers) to meet energy goals.[13]

The majority of private sector power projects are regulated, with companies entering into long-term power purchase agreements (PPAs) with state entities that encourage investment by reducing risks for shareholders through guaranteed rates of return, cost pass-through mechanisms, and/or tariffs/subsidies. In South and Southeast Asia, such agreements are often paired with a single-buyer model – that is, when the state entity is the sole purchaser of wholesale power. Each country has undergone some degree of power sector reforms in recent years with more planned in the future. To date, electricity spot markets exist only in India and the Philippines. See Table 2 for a comparison of key power sector characteristics.

TABLE 2. Comparison of Power Sector Characteristics, 2008

	% Market Privately Owned	Installed Capacity[1]	New Planned Capacity 2009 – 2013[2]	Current Fuel Mix[3]	Factors Driving Future Fuel Trends	Wholesale Power Markets?	Dominant Business Model
India	14%	144 GW	74 GW	53% coal 25% gas 10% hydro	Domestic coal reserves limited. Emphasis on large capacity thermal projects (4,000+ MWs).	Yes	Regulated PPAs
Malaysia	50%	21 GW	2.8 GW	64% gas 29% coal 7% hydro	Constraints on domestic gas resources. 30GW hydro potential.	No	Single-buyer (TNB)
Philippines	43%*	16 GW	0.3 GW	26% coal 21% hydro 18% gas 12% geo-thermal	Domestic fossil resources limited. Over 1 GW new geothermal and 7 GW hydro potential.	Yes	Long term PPAs
Thailand	37%	29 GW	7 GW	73% gas 19% coal 6% hydro	Natural gas will remain dominant with 60% market share.	No	Single-buyer (EGAT)
Vietnam	24%[4]	12 GW	13 GW	53% coal 25% gas 10% hydro	Hydro to account for 39% of production with 12 GW untapped resources.	No	Single-buyer (EVN)

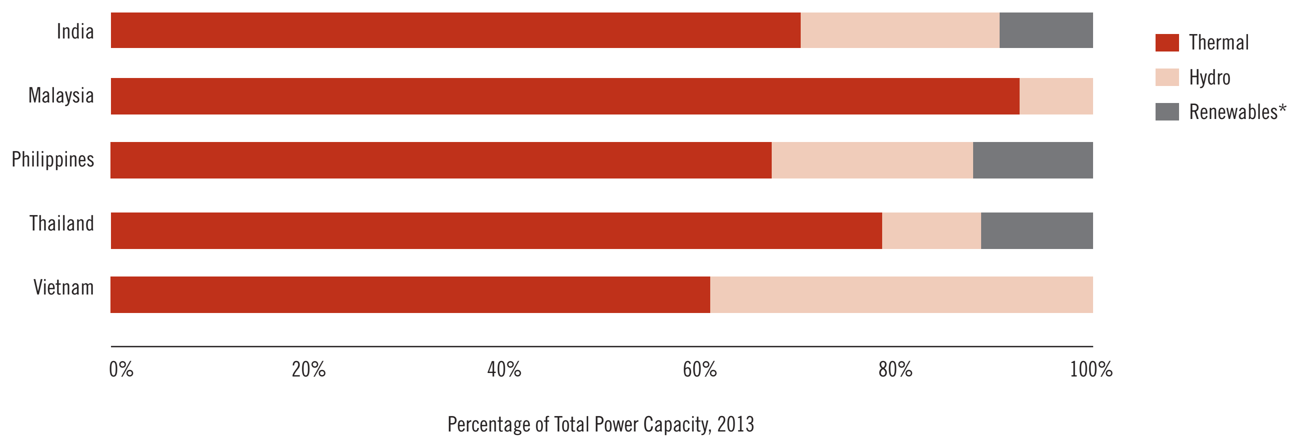
* Percent of state assets privatized as of May 2008.

Sources:

1. World Bank 2008 and EIA 2006.
2. JPMorgan estimates (Lee and Li, 2009) except Vietnam, which was calculated based on data from EIA. 2008 and estimates from JPMorgan "Company Visit Note: VSH" June 8, 2009.
3. World Bank 2008 and EIA 2006.
4. 2006. Source: EVN website. http://www.evn.com.vn/

While many of the governments have goals to increase the development of renewable sources of energy; coal, natural gas, and hydroelectric plants are expected to provide the majority of electricity supply. See Figure 6.

FIGURE 6. Projected Power Mix in 2013



* Not including biomass, which is included under thermal.

Source: WRI. Based on JPMorgan 2009, Nomura International Ltd 2009, World Bank 2008, ADB 2009.

The dependency of thermal and hydroelectric power plants on water for cooling and generation creates water-related risks for the sector.

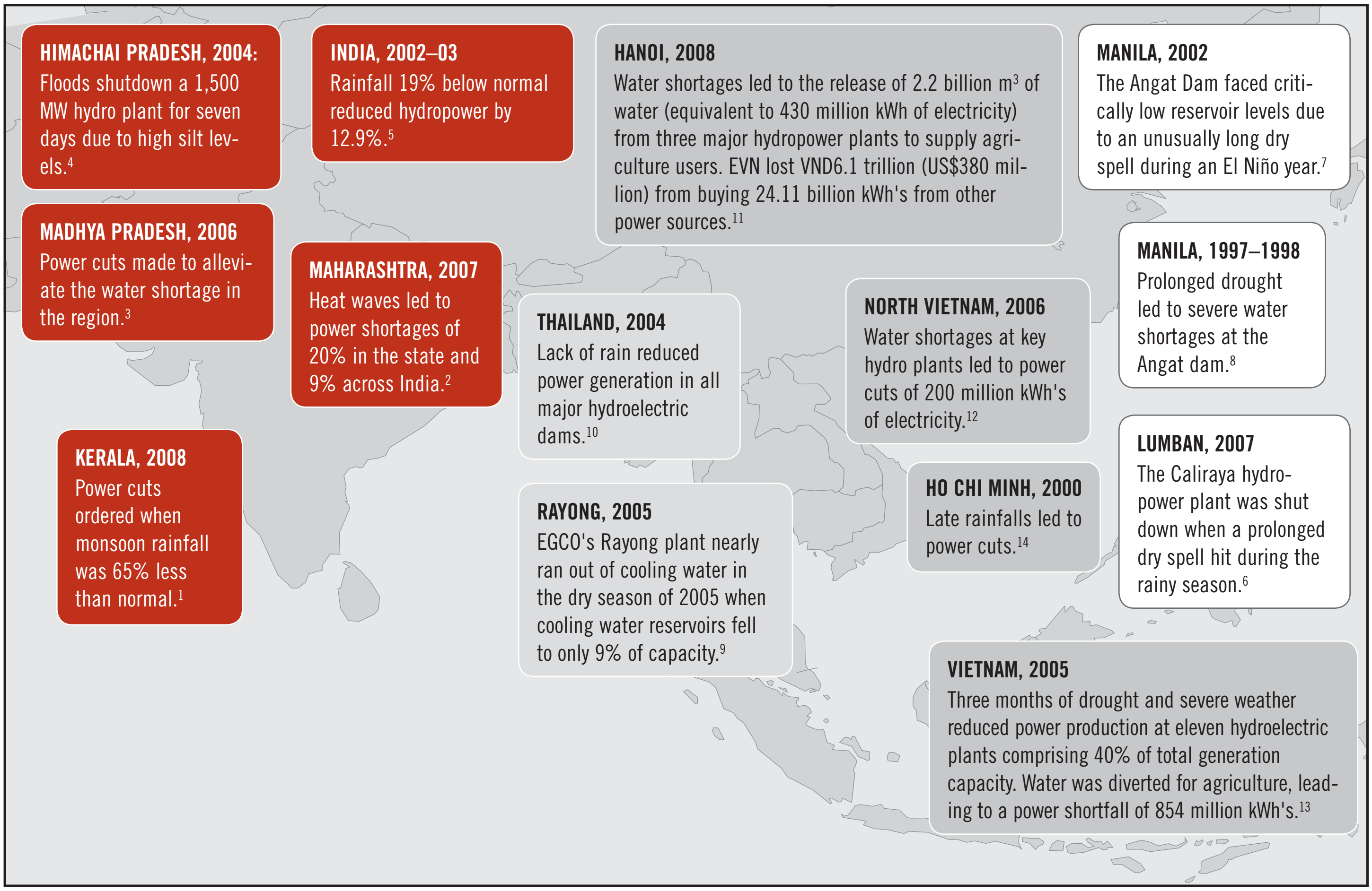
Hydroelectric plants are dependent on water for generation as maintenance of water reservoir or river levels is necessary for full capacity generation. Thermoelectric plants, including coal, natural gas, biomass, and nuclear, require varying amounts of water for steam, cooling, and other process uses. Fuel type, cooling system technology, and capacity are the greatest determinants of water use. Wind and solar photovoltaic power require very little water. See p 25 for more information on factors affecting a power plant's water requirements.

Water quality can affect the availability of water supplies for both thermal and hydroelectric plants. For example in the case of hydro, high turbidity (often linked to a flood event) can affect plant performance or cause plant shutdowns. The same consequences can happen to thermal plants when a heat wave increases the temperatures of intake cooling water supplies above an acceptable threshold. In addition to physical constraints, water quality regulations requiring temperature and/or pollution standards may force load losses or outages when these regulations cannot be met (such as a heat wave that increases effluent water temperatures above regulatory thresholds).

Water-related risks are emerging in South and Southeast Asian power markets.

Water scarcity and quality trends are decreasing the availability of suitable water supplies in key parts of India and metro areas in Southeast Asia, which will be discussed in Section III. The nature of water supply risk is similar to fuel supply risk given that lack of cooling water, poor water quality, and reduced reservoir levels can lead to reduced output or in the most extreme cases, power outages. This is true even in regions that are water abundant on average but where changes to the timing of water flows can create temporary water shortages. Figure 7 maps recent examples of water constraints to power generation in South and Southeast Asia.

FIGURE 7. **Examples of Water Constraints to Power Generation in India, Philippines, Thailand, and Vietnam**



HIMACHAI PRADESH, 2004: Floods shutdown a 1,500 MW hydro plant for seven days due to high silt levels.[4]

INDIA, 2002–03 Rainfall 19% below normal reduced hydropower by 12.9%.[5]

HANOI, 2008 Water shortages led to the release of 2.2 billion m^3 of water (equivalent to 430 million kWh of electricity) from three major hydropower plants to supply agriculture users. EVN lost VND6.1 trillion (US$380 million) from buying 24.11 billion kWh's from other power sources.[11]

MANILA, 2002 The Angat Dam faced critically low reservoir levels due to an unusually long dry spell during an El Niño year.[7]

MADHYA PRADESH, 2006 Power cuts made to alleviate the water shortage in the region.[3]

MAHARASHTRA, 2007 Heat waves led to power shortages of 20% in the state and 9% across India.[2]

THAILAND, 2004 Lack of rain reduced power generation in all major hydroelectric dams.[10]

NORTH VIETNAM, 2006 Water shortages at key hydro plants led to power cuts of 200 million kWh's of electricity.[12]

MANILA, 1997–1998 Prolonged drought led to severe water shortages at the Angat dam.[8]

KERALA, 2008 Power cuts ordered when monsoon rainfall was 65% less than normal.[1]

RAYONG, 2005 EGCO's Rayong plant nearly ran out of cooling water in the dry season of 2005 when cooling water reservoirs fell to only 9% of capacity.[9]

HO CHI MINH, 2000 Late rainfalls led to power cuts.[14]

LUMBAN, 2007 The Caliraya hydropower plant was shut down when a prolonged dry spell hit during the rainy season.[6]

VIETNAM, 2005 Three months of drought and severe weather reduced power production at eleven hydroelectric plants comprising 40% of total generation capacity. Water was diverted for agriculture, leading to a power shortfall of 854 million kWh's.[13]

Source: WRI.

Notes:

1. http://www.thaindian.com/newsportal/business/kerala-set-to-face-water-shortage-due-to-poor-monsoon_10068608.html.
2. The Australian, "India in Crisis as Heat Leads to Power Shortages" April 19, 2007.
3. Hindustan Times, "Power Cuts to Take Care of Water Scarcity" April 23, 2006.
4. China Daily, "Indian Power Plant Shuts Down" August 16, 2004.
5. Financial Express (India)-Hydro Logical – 29 June 2009.
6. Associated Press "Power cuts, water shortage hit Philippines as dry spell persists" July 27, 2007.
7. Manila Standard, "Power Outages Feared: Time to Tap IPPS" May 18, 2002.
8. Gemma G. Naling, "Dry Spell" Makati Business Club, No. 7, December 1998.
9. Marc Levinson, Watching Water, JPMorgan Global Equity Research April 2008.
10. Thai Press Reports – "Power Shortage Looms" – April 1, 2004.
11. Saigon Times Weekly -Power Cut To Last Until June- 19 April 2008.
12. Dow Jones & Company, Inc.- Vietnam Forecasts Electricity Shortage This Yr – Official- 10 February 2006.
13. Financial Times Information – "Industry: Vietnam Faces Power Shortage Following Drought" – April 28, 2005.
14. Industry – Electricity Shortage Haunting Vietnam – 16 May 2000.

III. Water Scarcity Analysis and Trends

KEY POINTS

- A significant proportion of power generation is located in areas at high risk of experiencing water-related issues.
- Higher temperatures, greater variability in precipitation, and increasing competition for water will increase the frequency and severity of water shortages in the region in the future.
- India is most at risk, although all countries are expected to experience longer dry seasons and more intense wet seasons.

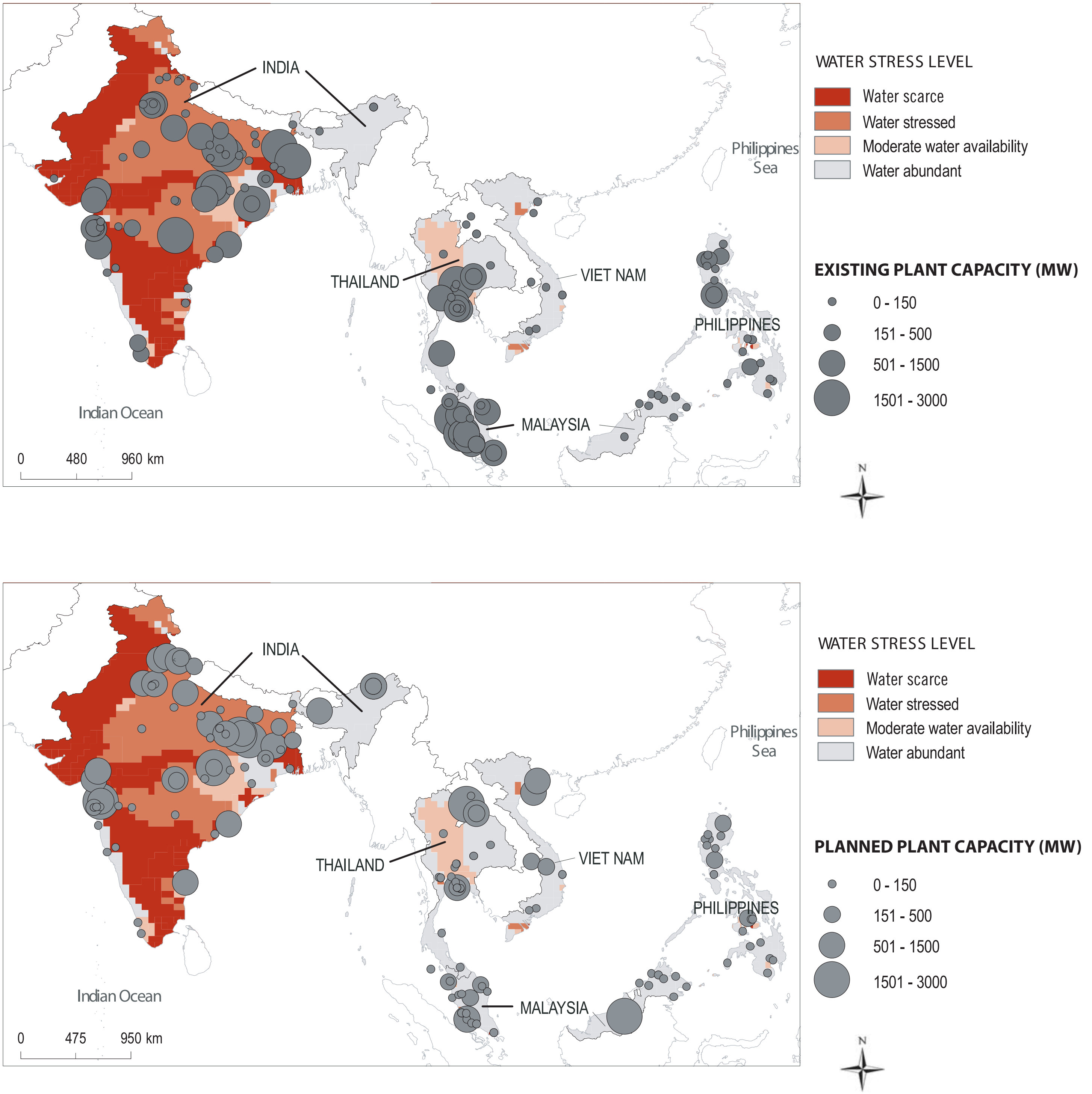
The majority of existing and new power generating capacity for publicly listed companies in South and Southeast Asia are located in areas classified as water scarce and stressed.

Figure 8 provides a preliminary picture of water scarcity in areas of power generation. WRI mapped over 150 existing and planned thermal and hydro power plants from the largest publicly listed power generation companies in the region by using data from corporate financial reports and carma.org. Planned capacity includes all stages of project development reported in corporate financial disclosures but not yet operational in 2009. Water scarcity data is from the International Water Management Institute, WRI, and the University of Kassel. These indicators do not include important elements of water risk, including future climatic changes and demographic trends. For example, plants located in regions classified as water abundant may face risks due to changes in the timing of precipitation patterns (as shown by examples in Figure 7). See Appendix A for more information.

The analysis found that new capacity will be increasingly located in areas already considered to be water stressed or scarce, as shown in Figure 9. India is the country of most concern for water constraints, as shown in Figure 10, with 73% of capacity (62% of existing and 79% of new capacity) of the three largest power generation companies — NTPC, Tata Power, and Reliance Infrastructure (including Reliance Power) — located in water scarce or stressed areas.

While the water stress index data used in this analysis is too coarse to provide insights at the plant level, it does highlight the areas considered to be of highest risk of water scarcity. However it does not provide information about changes in the timing and reliability of water flows, the most important factor when considering impacts to the power generation sector. As a result, it may understate water risks related to the timing of water flows in water abundant areas in Southeast Asia.

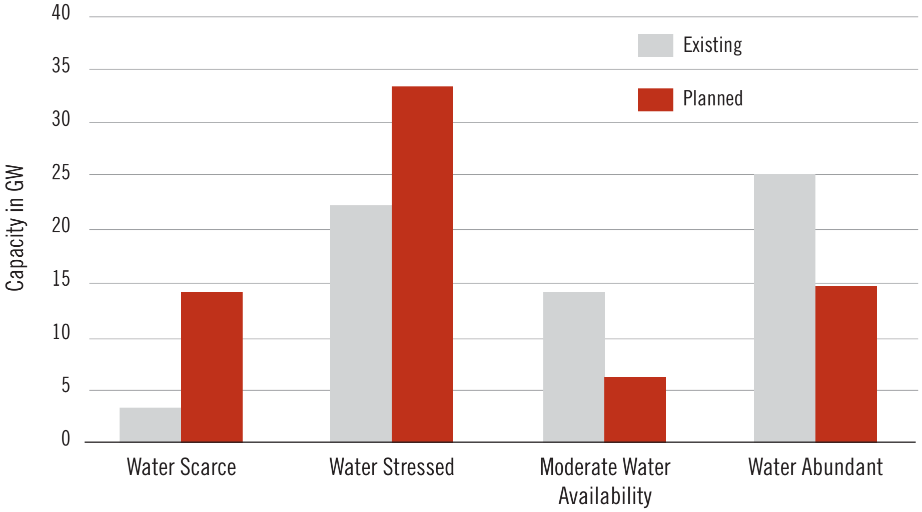
FIGURE 8. Existing and Planned Thermal Power and Hydropower Plants by Capacity and Water Stress Level



Source: WRI. Data for power plants are from carma.org and company reports and the water stress indicators are from CGIAR/WRI/University of Kassel 2002.

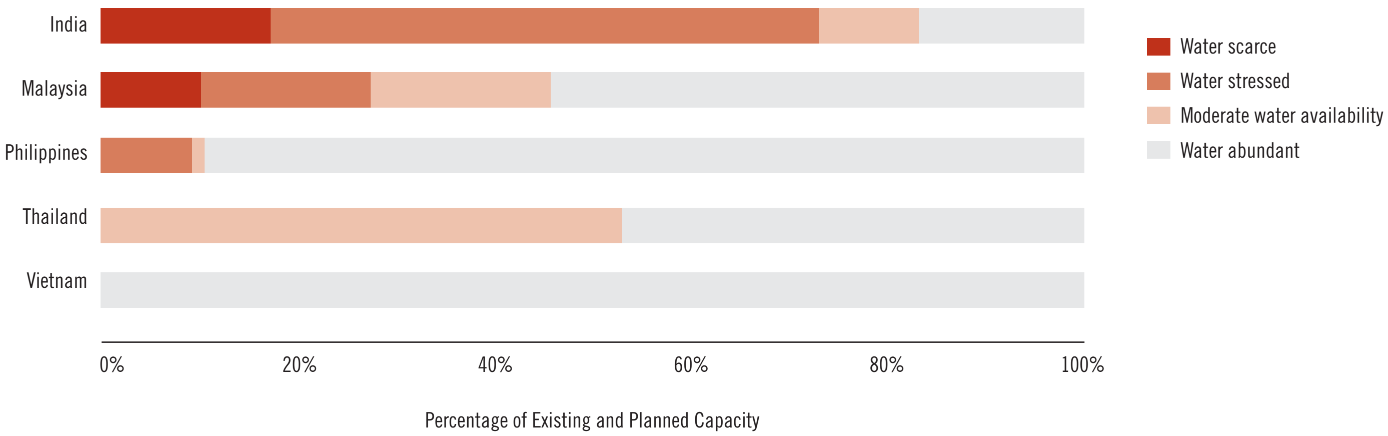
Note: Water stress indicators (WSIs) represent the ratio of total withdrawals to utilizable water. Water stress indicators (WSIs) represent the ratio of total withdrawals to utilizable water. These indicators do not reflect anticipated demographic or climate changes (such as the timing/quantity of precipitation) and therefore do not represent all facets of water-related risk. See Appendix A for information.

FIGURE 9. Existing and Planned Power Generation Capacity by Water Availability



Source: WRI. See Appendix A for more information.

FIGURE 10. Percent of Power Capacity by Water Availability for India, Malaysia, Philippines, Thailand, and Vietnam



Source: WRI. See Appendix A for information.

Climate change and increasing competition will exacerbate water constraints in the future.

Water scarcity is a growing concern for many parts of the world. In India in particular, and in parts of the other four countries, high demand for water, coupled with water pollution, means that available water supplies are declining. This trend will accelerate in the future as population and economic growth leads to higher per capita water consumption in the region.

India is by far the most water scarce country included in the analysis. In India, over 70% of water resources are inaccessible, not renewable, unreliable, or restricted due to environmental regulations.[14] Furthermore, water demand is expected to outgrow supply in India by 50% by 2030 and the World Bank estimates that India will exhaust all available water supplies by 2050.[15]

The other focus countries are in Southeast Asia, one of the water-rich regions in the world. With abundant rainfall, the volume of water available per person is higher than most other regions in the Asia-Pacific. However, much of the region's precipitation is seasonal and is expected to be impacted by climate change. For example, Thailand has abundant water resources but the problem is the timing and accessibility of water. Experts believe that in the northeast, where a third of the population lives, water will need to be transported from abundant to scarce areas, greatly increasing costs.[16]

The two primary drivers of increasing water scarcity and declining water quality, climate change and increased demand, are discussed in more detail in the following sections.

A. CLIMATE CHANGE

Climate change will continue to affect the quantity and quality of fresh water renewals in the region, with impacts increasing over time.

The primary impact of the heat-trapping gasses that contribute to global climate change is to increase the mean average temperature over time, as shown in Table 3 for countries included in this report. Higher temperatures can affect water availability in the following ways:

- Higher rates of evaporation
- Increased melting of snowpack and glaciers that feed river systems
- Changes to precipitation patterns
- Salt intrusion in coastal freshwater resources

TABLE 3. Projected Temperature Increases in Select Asian Countries

Country	Observed Temperature Increases (°C) (1979–2005)	Range of Projected Temperature Increases (mean surface temperature)* (°C)		
		2010–2039	2040–2069	2070–2099
India	0.68 per century	0.89–0.92	1.54–2.56	2.34–4.5
Indonesia	1.04–1.40 per century	0.75–0.87	1.32–2.01	1.96–3.77
Malaysia	Data not available			
Philippines	1.4 per century			
Thailand	1.04–1.80 per century			
Vietnam	1.0 per century			

* Range based on low and high emissions scenarios. Temperature increases for India are from data for South Asia averaged over 4 seasons. Baseline period is 1980–1999.

1. Asian Development Bank. April 2009. "The Economics of Climate Change in Southeast Asia: A Regional Review." Page 23.
2. Contribution of Working Group II to the Fourth Assessment Report, Climate Change 2007, Impacts, Adaptation and Vulnerability, p. 475.

Increased evaporation rates can directly affect the availability of water supplies. In Vietnam, increased evaporation due to higher temperatures has reduced the availability of water for agricultural and industrial purposes.[17]

The melting of mountain glaciers due to higher global temperature is expected to bring about major shifts in river flows.[18] This effect is predicted to reduce water supplies for more than one-sixth of the world's population that lives in glacier or snowmelt-fed river basins.[19] Asia will be dramatically impacted by changing hydrological patterns, particularly river runoff. The siting process for new power plants should consider these long-term changes, especially in the case of hydroelectric power.

India is one of the regions most at risk from this effect as climate change leads to the recession of the Himalayan glaciers. About 67% of Himalayan glaciers are reported to be receding. As the ice diminishes glacial flows will at first increase and then decrease over the long-term as the glaciers retreat. Nearly 70% of the water in the Ganges River system comes from these glaciers.[20]

Higher temperatures will impact precipitation patterns. From 1960-2000, Southeast Asia experienced a decrease in rainfall and a decreased number of rainy days. This trend is expected to continue with future projections, shown in Table 4. In the next 50 years, under a high greenhouse gas emissions (base case) scenario, precipitation in Southeast Asia is projected to decrease, but then to increase by the end of the century, with strong variation expected between March and May. In broad terms, the wet season will become wetter and the dry season drier. Southeast Asia has also experienced an increase in extreme events, including prolonged droughts. These events are predicted to occur with even greater frequency.

In India, precipitation is expected to increase more than in Southeast Asia. As with Southeast Asia, there will be increased seasonal variation. In northern India, precipitation is expected to decrease by 15–30 mm per month most of the year except with an upsurge dur-

TABLE 4. Projected Precipitation in Select Asian Countries

		Projected mean Change in Precipitation (%)**		
Country	**Observed Changes in Precipitation***	**2010–2039**	**2040–2069**	**2070–2099**
India***	Increase in extreme rains in North-West during summer monsoon in recent decades; lower number of rainy days along East coast.	2.5 to 5.5	10.25 to 11.75	9.75 to 6.75
Malaysia	Number of rainy days has declined throughout Southeast Asia.	0.25 to -1.00	1.00 to 2.25	3.00 to 8.00
Philippines	Increase in annual rainfall and in the number of rainy days.			
Thailand	Decreasing annual rainfall for the last five decades.			
Vietnam	Decrease in monthly rainfall in July-August and increase in September to November.			

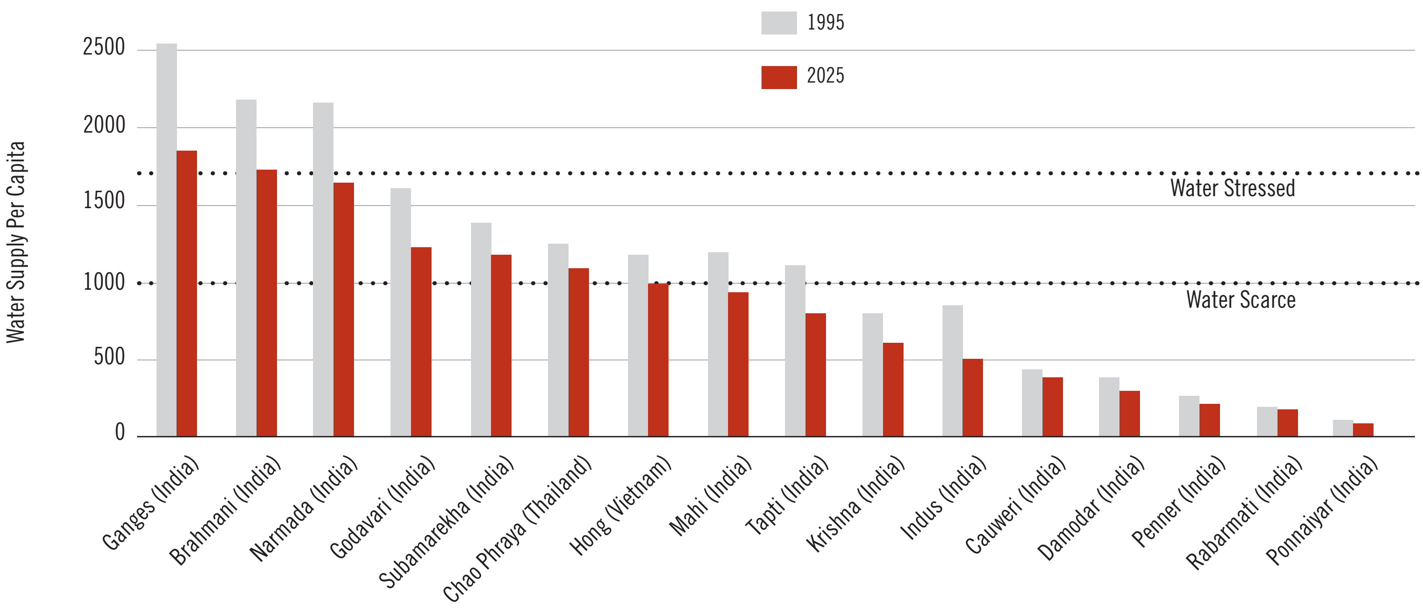
* Studies conducted over varying time periods.

** Range based on low and high emissions scenarios. Baseline period is 1961–1990.

*** Precipitation changes for India are from data for South Asia averaged over 4 seasons.

1. Asian Development Bank. April 2009. "The Economics of Climate Change in Southeast Asia: A Regional Review." Page 27.
2. Contribution of Working Group II to the Fourth Assessment Report, Climate Change 2007, Impacts, Adaptation and Vulnerability, p. 475.

FIGURE 11. **Major River Basins Facing Water Stress and Scarcity in South and Southeast Asia**



Source: WRI.

ing the rainy season. As a result, although overall precipitation will increase, it will be concentrated on the monsoon season with dryer months for the rest of the year.[21]

The vast majority of cooling water and water for hydroelectric generation is sourced from rivers, rather than groundwater. Impacts on power generation will need to be assessed at the river basin level. Figure 11 shows the rivers in the focus countries with the lowest projected water supply in 2025.

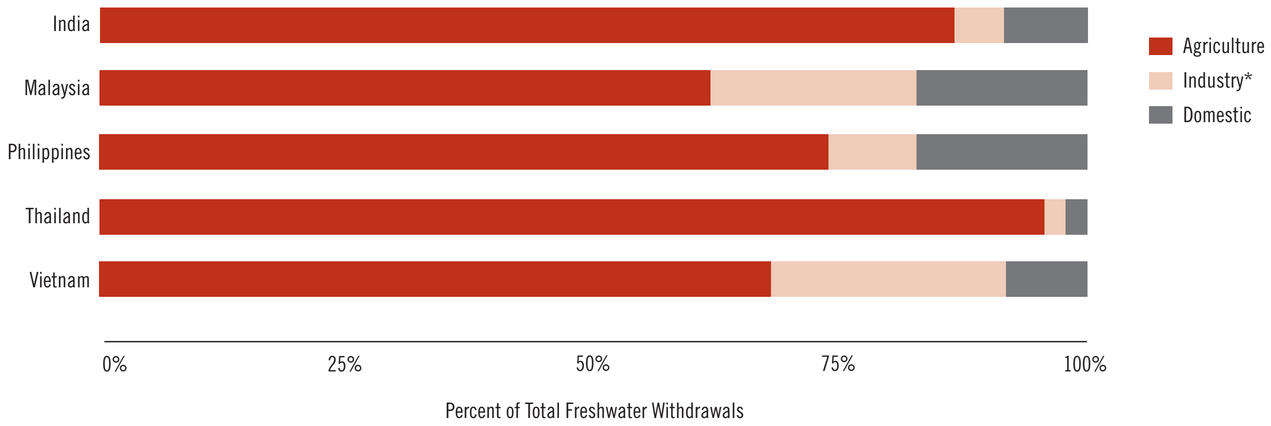
As with the water stress indicators shown in Figure 8 (on p 15), this metric does not capture changes in seasonal water flows. For example, the Mekong River is not categorized as a water scarce river basin using this metric, however the variability of water renewals is expected to increase. Compared with 1960-1990 levels, the maximum monthly flow of the Mekong River in Vietnam is projected to increase between 35% and 41% in the basin and the minimum monthly flow will fall by 17-24% in the basin.[22] By the end of the 21st century, the annual flow of the Mekong River is projected to decline by 16–24%.[23]

B. DEMAND FOR WATER RESOURCES

Demand for water will increase across the region as population grows and becomes wealthier, driving competition among domestic, industrial and agricultural uses.

Population and economic growth will increase demands for food production globally. The Food and Agriculture Organization of the United Nations estimates that by 2050 food production will need to increase by 100% in developing countries to meet population demands. As the primary water user, food production will increase demands on renewable freshwater sources. In India, water demand is expected to increase by 32% by 2050 due to increased food production.[24]

FIGURE 12. **Water Withdrawals by Use, 2004**



* Power generation falls under Industry in this classification.
Source: FAO 2004

Irrigated agriculture, which serves as the backbone of food production in the region, is the main water user in each of the focus countries, as shown in Figure 12. Climate change will likely increase demand for irrigated agriculture due to changes in precipitation patterns resulting in prolonged dry periods. One study forecasts an increase in demand by 10% to irrigate crops for every 1 degree Celsius rise in temperature in Asia. This research estimates an increase of over 40% in irrigated land by 2080.[25] However, there is great potential to improve the efficiency and productivity of agricultural and irrigation systems, and therefore improve water availability, through technological innovations, increased investment, crop choice and improved drought resistant plants, and better regulations and oversight of water use.

Hydroelectric power plants in particular watersheds may face risks from the increasingly difficult trade-offs in reservoir management, where power and irrigation demands compete for the same stored water resources. While the bulk of hydropower water use is non-consumptive and can be used for other purposes downstream, competition occurs over the right to withdraw water from the reservoir. Most large hydropower plants are multipurpose dams utilized for power generation, flood control, irrigation, water storage, and recreational activities.

Thermoelectric plants along Thailand's eastern seaboard, a heavily industrialized region with many of the country's power plants, receive little rainfall and rely on a small number of reservoirs and pipelines to meet freshwater demand. However, there has been increasing conflict between agricultural and industrial users over water resources – particularly during times of drought. The issue has become increasingly politicized as government officials face pressure from the farmer's demands to protect agricultural water allocations.[26]

The impacts of water scarcity are expected to be most dramatic in India. India's National Water Policy outlines water allocation priorities as drinking water, irrigation, hydropower, ecology, industry, and navigation.[27] However there is no consistent framework for dealing with water users' rights, especially when priority uses are in competition. There is social pressure to favor people over industrial users in conflict situations.[28] More broadly, the status of rural and agricultural populations' water rights will likely heighten political tensions between water users in the region as water becomes scarcer in the future.

IV. Water Risk Exposure Framework

KEY POINTS

- A plant's regulatory protection from shareholder risk, water dependency, and the security of water supplies should be considered when assessing exposure to water constraints.
- Important data and information are rarely publicly reported; therefore investors and analysts will need to engage with companies to understand risk exposure.

Exposure to water constraints can be assessed using the following risk factors:

A. **Business Model:** Given the heavy regulation of the power generation sector in South and Southeast Asia, the primary determinant of water risk lies in the terms of the power purchase agreement (PPA, also called an off-take agreement).

B. **Water Dependency:** A plant's water requirements are primarily influenced by fuel type/ technology and cooling system water source and technology.

C. **Water Security:** Future risks to water supplies, including shortages and/or declining quality, must be assessed at the local level with consideration to changes in climate and hydrological patterns as well as trends affecting competing uses. The relative strength and timeframe of water allocations and contracts must also be considered.

Table 5 presents a framework for evaluating exposure to water-related risks. These risk levels provide guidance for analysts and investors to assess risk exposure, but each plant should be considered on a case-by-case basis.

TABLE 5. Water Risk Framework for the Power Generation Sector

		Business Model *Are shareholder returns protected from falling output?*	**Water Dependency** *How much water is required to maintain loads?*	**Water Security** *Is the plant in a water scarce region?* *How are the plant's water supplies secured?*
Risk Level	High	• Merchant	• Open-loop thermal • Run-of-the-river hydro	• Water scarce or stressed area • History of water-related events • High rate of urbanization/ industrialization in watershed
	Medium	• Hybrid (Regulated/ Merchant) • Regulated (high utilization rate required)	• Closed-loop thermal • Reservoir hydro • Supercritical coal • Combined cycle gas	• Reservoir with irrigation commitments • Dependence on seasonal precipitation
	Low	• Regulated (no risk from falling output) • Captive • Competitive tariff	• Renewables (excluding biomass and concentrated solar thermal) • Seawater cooling • Wastewater cooling • Air cooling	• Water abundant area • Long-term water contract

Source: WRI

Shareholder risk to water-related disruptions will primarily be determined by the plant's business model.

In general, shareholder risks are currently minimal for most power plants due to existing power purchase agreements that allow generators to pass costs through while guaranteeing a level of power demand or even a return on equity. However, there are circumstances today where water scarcity risk will affect shareholders. Plants without off-take agreements that guarantee returns or cost pass-throughs are at highest risk. Even for regulated plants, supply disruption may void terms of some PPAs that require utilization or generation levels to remain in effect.

Determining a plant's water dependency and water security risks can be difficult due to lack of publicly available data.

Information on purchasing contracts and water allocations is generally accessible. However, information on water usage varies while there is very limited data available on water availability at the level of detail required to properly assess risk. As a result, investors and analysts can use the questions and metrics outlined in Figures 13, 16, and 19 to engage companies on potential exposure to regulatory, water dependency, and water security risks. These three dimensions of water-related risks must be considered together in order to assess exposure at the plant or company level.

The following presents more information on each dimension of water scarcity risk.

A. BUSINESS MODEL

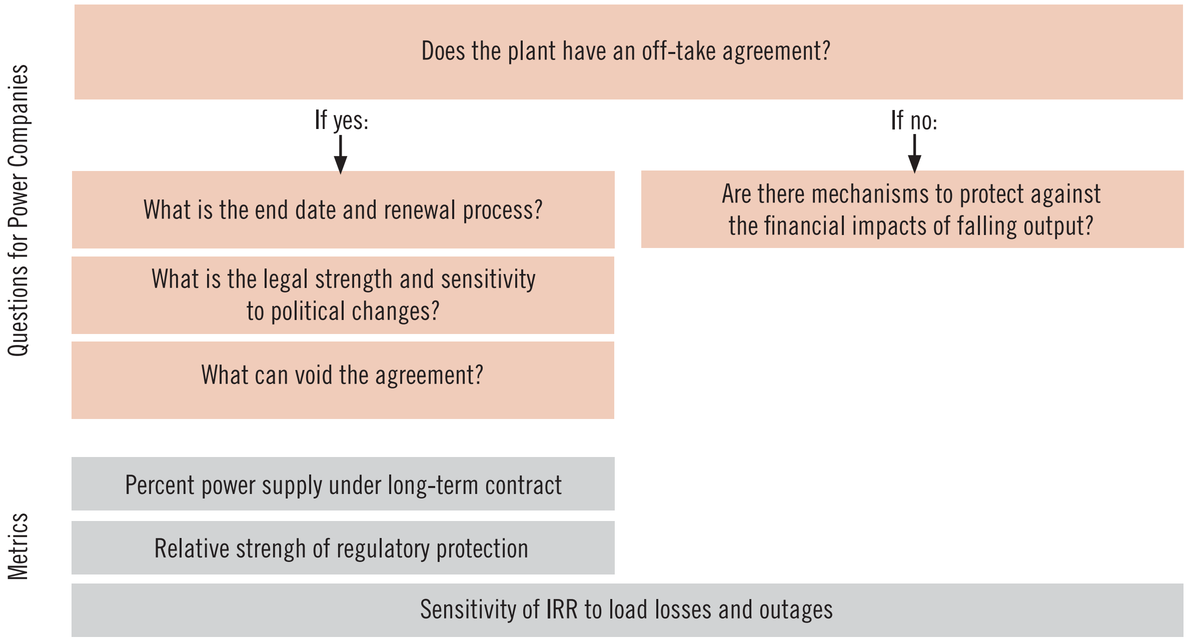
Currently, shareholder risk to water scarcity is largely minimized by protective regulations.

As discussed in Section II, electric power generation is heavily regulated and closely tied to national economic development plans in all focus countries. Much of the power sector in Asia (and certainly in the five focus countries) is state-owned and heavily regulated. In a regulated environment, valuation is driven primarily by the need to maintain reliability and ability to pass their costs through to the end user. The IPPs typically depend on PPAs which cover their fixed costs. Financiers and investors often rely more heavily on a strong power off-take agreement than on their assessment of the plant's stand-alone value.

Regulated power plants typically have long-term PPAs with state entities with some combination of guaranteed rates of return, cost pass-through mechanisms, and/or tariff/subsidies. Competitive tariff is a model emerging in India where the developer sets the PPA terms through a bidding process. Captive power plants are those with a dedicated private sector buyer, often industrial, with a long-term contract for a specified percentage of the power produced. Merchant power plants are those that do not have PPAs and instead sell electricity to wholesale markets.

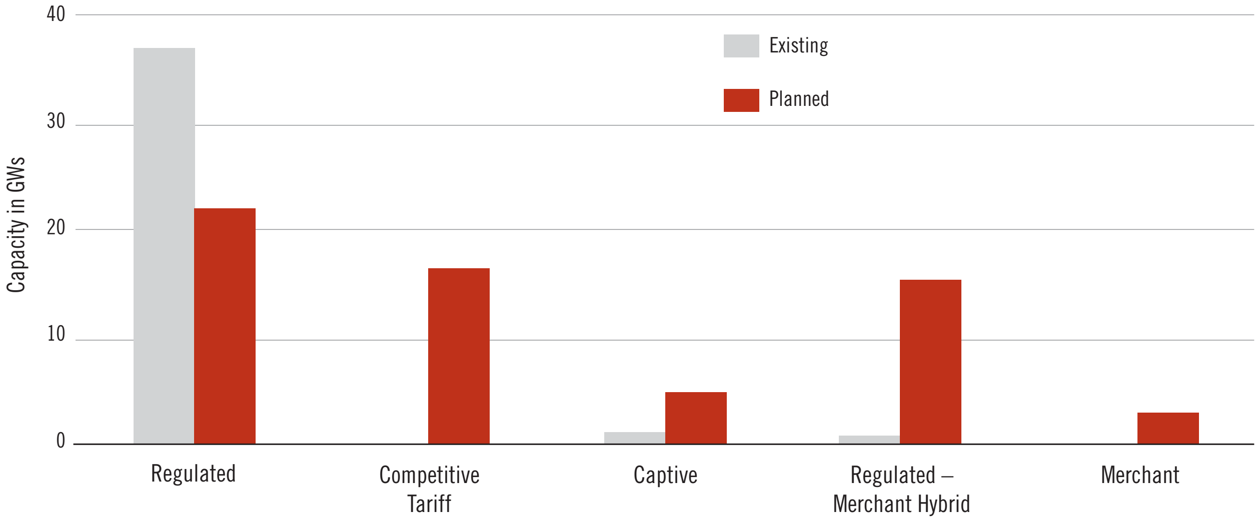
Most, but not all, power produced in the region is regulated. An unregulated example is Aboitiz Power's 360MW Magat hydro facility, a pure merchant power plant that sells power to the Philippine electricity spot market.[29] India has one of the most deregulated markets in the region, with unregulated projects representing a small but growing market share.[30] In 2009, merchant plants represented about 6% of total power sold in India yet this share is predicted to increase to over 30% by 2017.[31] See Figure 14 for a comparison of Indian capacity by business model and Figure 15 for a comparison of India's largest power companies.

FIGURE 13. **Questions and Metrics to Determine Business Model Risk**



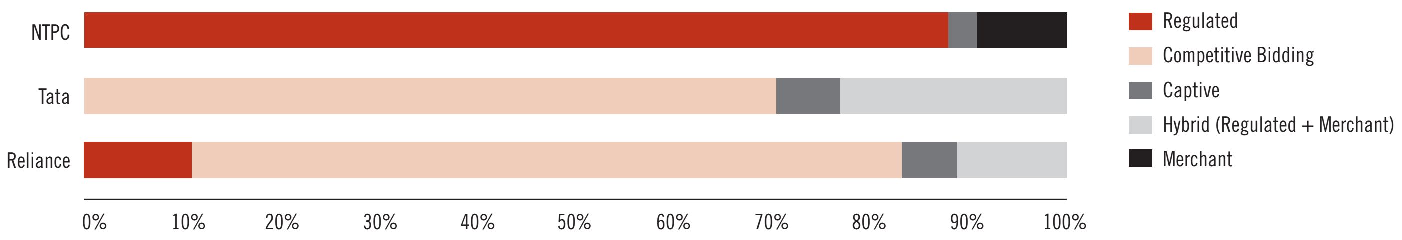
Source: WRI

FIGURE 14. **Existing and New Capacity by Business Model in India (GWs)**



Source: DB Securities, 2009

FIGURE 15. Percent of New Capacity by Business Model for NTPC, Tata Power, and Reliance Infrastructure in India



Source: DB Securities, 2009

Despite regulatory protection, water risk may become material under certain circumstances if:

1. Unregulated plants (without PPA's) do not have the ability to pass costs onto consumers; or
2. Load losses or outages caused by water shortages violate the terms of the purchase agreements; or
3. The regulatory framework changes.

Water scarcity risk is most prominent for merchant plants that rely on spot electricity markets and do not have regulated returns. However, even regulated plants may not be immune to water scarcity risk. If a severe drought or heat wave results in a load loss or outage that violates the PPA plant load factor requirements, they may be exposed. Risk associated with competitive tariff and captive business models must be assessed on a case-by-case basis depending on PPA terms. See Table 6 for a comparison of relevant shareholder risk protections across the region.

TABLE 6. Comparison of Regulatory Protection against Shareholder Risks from Falling Output by Country

Country	Business Model		Shareholder Protections against Falling Output	Utilization Rate Required
India	Utility	Partial	14.0%/15.5% RoE for existing/new plants	80%/85%
	Regulated IPP	Partial		
	Competitive Tariff/Captive		Determined by developer on case-by-case basis	
	Merchant	None	No shareholder protection	—
Malaysia	Utility	None	No shareholder protection	—
	IPP	Partial	Capacity payments cushion IPP's to some extent, most recent PPA's share more risk	70%
Philippines	IPP	Partial	Must meet utilization threshold	83%
	Merchant	None	No shareholder protection	—
Thailand	IPP	Full	No shareholder risk	—
	SPP	Partial	Must supply contracted capacity and minimum efficiency requirements.	85%
Vietnam	IPP	None	No shareholder protection	—

Note: IPP (Independent Power Producer); SPP (Small Power Producer)

Source: Adapted from JPMorgan, Deutsche Bank, VinaSecurities 2009

B. WATER DEPENDENCY

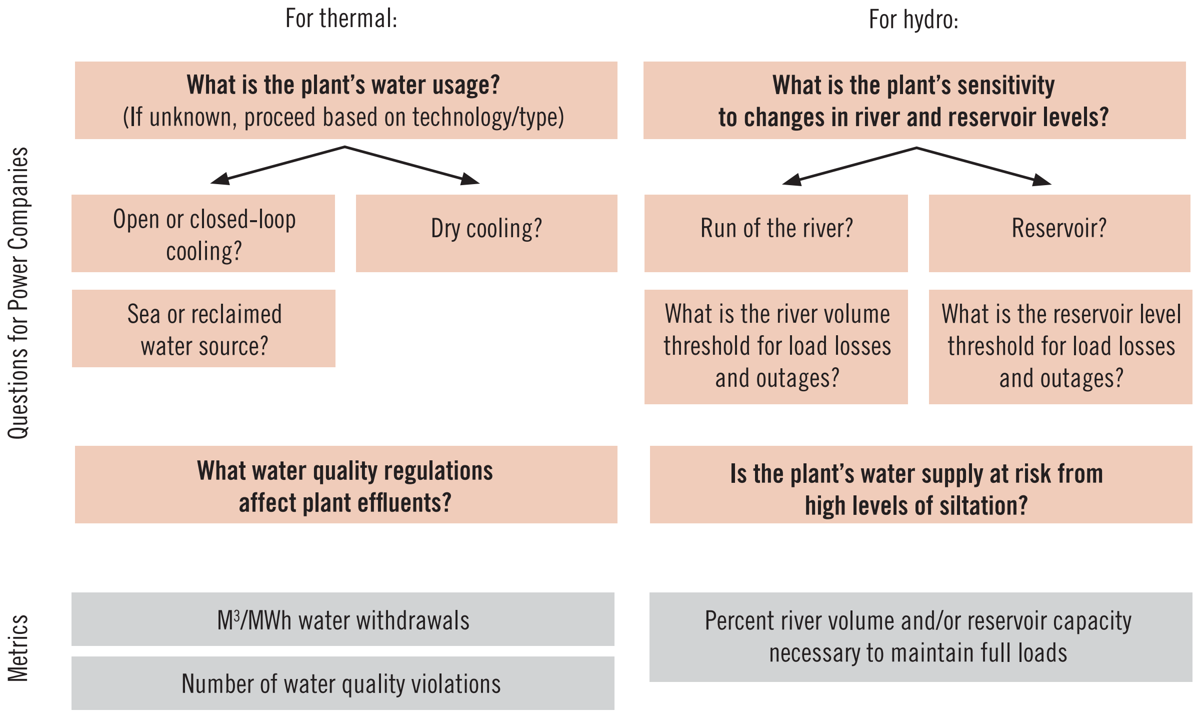
As water usage by the power sector is rarely publicly reported in Asia, knowledge of key plant design characteristics is necessary to understand water dependency.

Water is used by power plants in two ways: (1) Withdrawals, water that is used and then returned to its source, and (2) consumption, water that is lost from the system (primarily through evaporation). The ratio of water withdrawals to consumption can vary greatly by plant type and technology. Water withdrawals determine a plant's dependency on steady water supplies and are therefore the most relevant for understanding exposure to water-related risks.

Combined cycle natural gas power plants are less water intensive than pulverized coal and nuclear plants, while nuclear requires the most steam and cooling water relative to power produced of any thermoelectric technology.[32] Hydropower is most dependent on reliable and renewable water flows for generation, although the water per unit of output varies greatly. Hydropower also consumes the most water through evaporative losses from reservoirs.

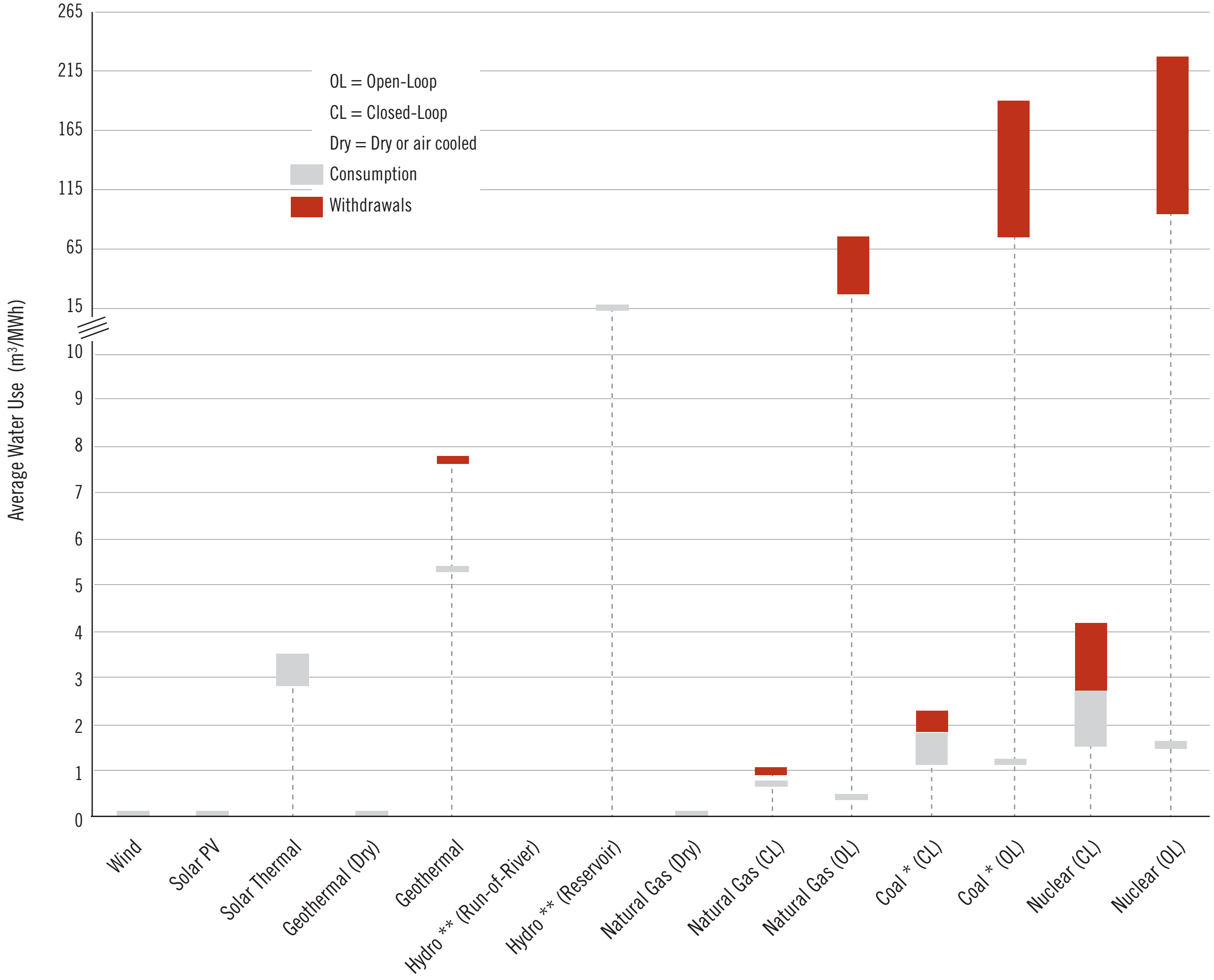
When comparing power generation in about half of U.S. states, hydro plants consumed a weighted average of 69 m^3/MWh while thermoelectric plants consumed 1.8 m^3/MWh.[33] Figure 17 shows water withdrawals and consumption for major fuel and cooling system combinations based on data from the United States (this data is not available for Asia).

FIGURE 16. Questions and Metrics to Determine Water Dependency



Source: WRI

FIGURE 17. Typical Range of Water Withdrawals and Consumption for Power Generation in the United States



* Also includes Biomass and Waste Power Generation

** Hydroelectric water withdrawals vary by site and design and therefore cannot be averaged.

Note: This data is not currently available for power plants in Asia. As a result, this figure is useful to show the relative ranges of water consumption and withdrawals by plant and cooling system type but actual values may vary for plants in South and Southeast Asia.

Source: DOE Report to Congress on the Interdependency of Energy and Water, 2006

Thermoelectric water usage

For thermoelectric plants, water is primarily used to cool and condense the steam used to drive the turbines while smaller amounts of water are used for steam ‘make-up’ and for other processes. Water usage is largely determined by:

- Cooling and process water needs, and
- The system used to provide the cooling water.

There are two basic water cooling system configurations, open-loop (also called 'once-through') and closed-loop (also called 'recirculating'). Open-loop systems withdraw the most water, requiring 30 to 50 times more water than their closed-loop counterparts, while air cooling systems (also called 'dry cooling') require virtually no water and are used primarily for combined cycle gas plants.[34]

There is a tradeoff between water withdrawals, water consumption, energy efficiency, and cost between open-loop, closed-loop, and air cooling systems. Closed-loop systems dramatically reduce water withdrawals with increases in water consumption due to higher evaporative rates. Closed-loop systems may use cooling towers to reduce evaporative losses (and therefore water consumption) by returning the water to the source at a lower temperature. However the water effluents from closed-loop systems are more concentrated than open-loop effluents and generally require greater treatment before release. The cost of water treatment systems for effluents will depend on the stringency of water quality regulations.

Closed-loop water cooling systems cost roughly 40% more than their open-loop counterparts. Air cooling systems are 3 to 4 times more expensive than closed-loop systems and are less energy efficient.[35]

The risk of water shortages for thermal plants can be significantly mitigated by technology choice.

New thermoelectric power projects in water scarce regions often use closed-loop or air cooling technologies. Seawater cooling, for coastal plants, and wastewater cooling are options to reduce freshwater dependency. However both of these alternative water sources increase cost. Open-loop systems may also be subject to environmental regulations to minimize the thermal impacts of water discharges on aquatic life. There is a moratorium on seawater cooling systems in the state of California for this reason.

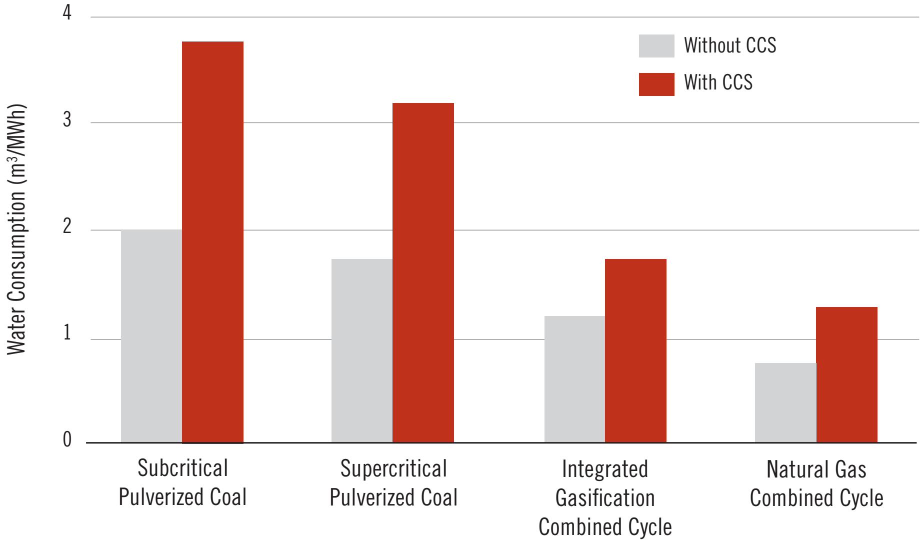
Fossil-fuel based power generation is a major contributor to global greenhouse gas emissions that are creating climate change, with electric power and heat comprising 25% of global greenhouse gas emissions. As a result, there is great interest in new technologies to reduce carbon dioxide emissions from the power sector, particularly from coal power plants. Carbon capture and storage (CCS) is an emerging technology that is generating interest from policymakers, although it still at an early stage of development. One of the drawbacks to CCS is that it increases the water intensity of power production. See Figure 18 for a comparison of water usage with and without deploying CCS technology.[36]

Hydroelectric water usage

Water scarcity risk for hydroelectric plants is primarily determined by water availability (discussed in the *Water Security* section).

There is some variability in exposure by the type and design of hydroelectric facilities. Run-of-the-river plants do not have water storage capabilities and therefore are directly exposed to changes in water availability. For hydro plants with water storage capacity, the following factors determine the ratio of water usage to electricity generation:

FIGURE 18. **Water Consumption With and Without Carbon Capture and Storage (CCS) Based on Closed-Loop Cooling Tower System**



Source: DOE/NETL–402/080108, "Water Requirements for Existing and Emerging Thermoelectric Plant Technologies, August 2008 (April 2009 Revision).

- Climatic conditions including temperature, precipitation, and wind
- Reservoir surface area
- Reservoir porosity and seepage loss
- Power generation capacity
- Dam height

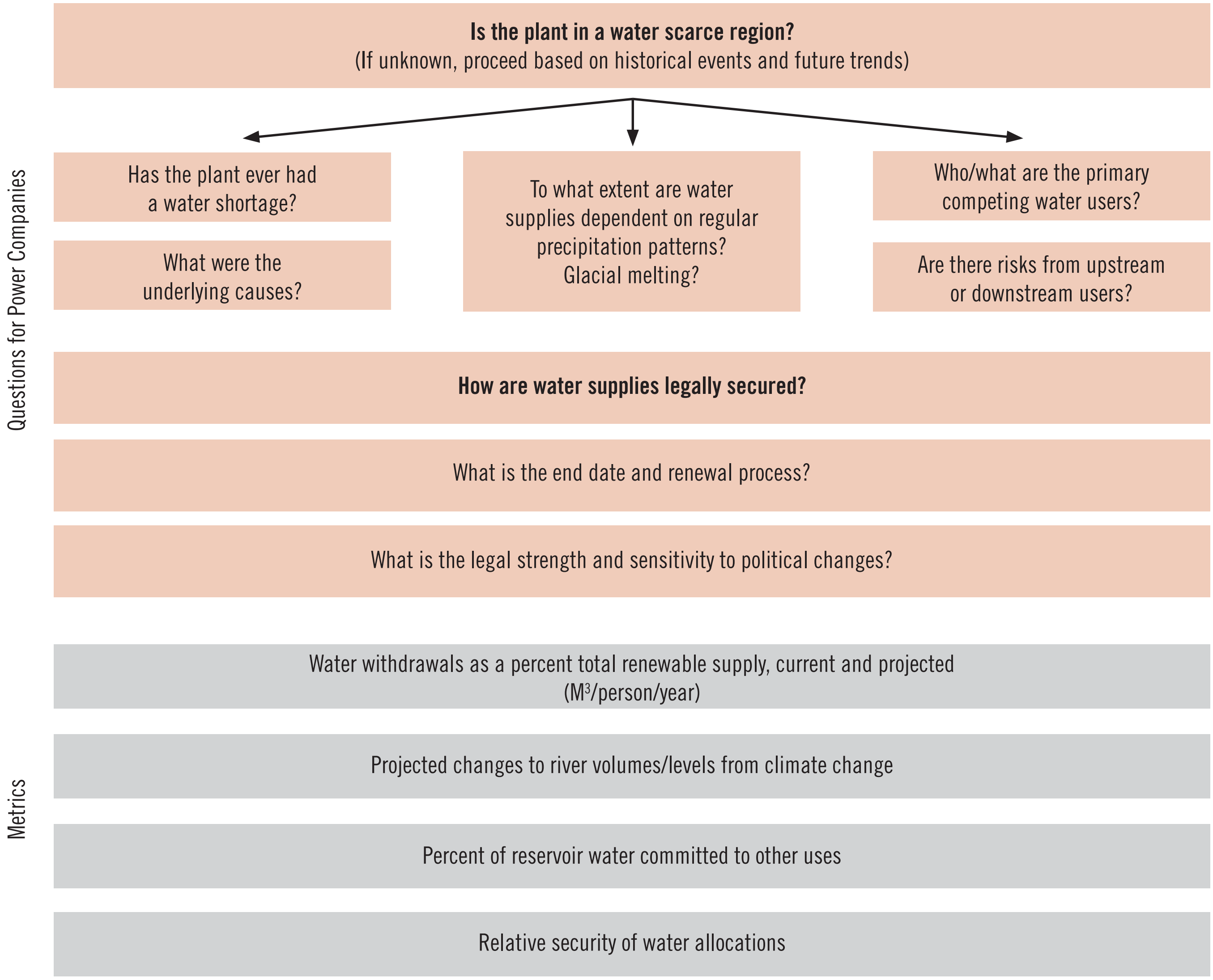
C. WATER SECURITY

Water availability must be assessed at the local level.

Water security risks consider the quality, quantity and timing of water resources that are required for a plant to run at optimal performance, as well as the legal dimensions of securing water allocations. As discussed in Section III, water security will be influenced over the long-term by the impacts of global climate change and increasing demand from competing users.

Reliable data on current water availability at the sub-basin level is not consistently available. It is even more difficult to assess projections of potential climate change and demographic impacts on local water resources, or more importantly, on changes to the likelihood of a drought or flood event. For example, the water scarcity index used in Figures 8, 9 and 10

FIGURE 19. **Questions and Metrics to Determine Water Security Risk**



Source: WRI

only consider average water withdrawal to renewal ratios across large river basins, such as the Ganges. Unfortunately this data is not of high enough resolution to understand impacts for a particular plant.

Some useful information may be available for new plants through water permitting and plant siting processes, however unless future climate change impacts are considered, important questions about future risks are left unanswered. In light of the difficulty in obtaining reliable data on future water availability, investors and analysts should engage plant managers using the questions outlined in Figure 19.

Water quality can limit the availability of water supplies.

Water quality is an important consideration that is not included in water scarcity data. High temperatures can create issues for power generation by raising water temperatures above the threshold allowed for cooling purposes or permitted by law for effluents. For example in the southeastern United States, Brown's Ferry nuclear plant had to be shut down during a heat-wave in August 2007 that increased the river temperatures and led to record power demands. Several other nuclear power plants in this region had to reduce their output by up to 50% due to low river levels during this drought.[37]

In addition, poor water quality can have adverse effects on plant performance. Water quality impacts on power plants include:[38]

- Calcium and phosphate increase mineral scaling.
- Biological Oxygen Demand (BOD), phosphate, and ammonia "biofoul" heat transfer surfaces and biological growth on cooling tower fill material surfaces.
- Ammonia increases corrosion, pitting, and stress cracking damage to metal and heat transfer surfaces and to metal structure.
- High turbidity (TSS and TDS) affects performance of the power plant.
- Higher water temperatures require increased cooling water requirements and lower efficiency for power production.

Hydropower is among the most vulnerable energy sectors to the impacts of climate change because of its direct tie to the timing and quality of water supply.[39]

Hydro plants generally have a long life span (around 80 years). As a result, the impacts of climate change may dramatically change local water flows from when they were first studied during project development. There are three main climate change impacts on hydroelectric power plants:

1. **Changes in river volumes:** Changes in temperature and precipitation in the catchment area impact the volume of stream flow and will directly influence the financial viability of the plant. Operations may need to be reconsidered to adapt to hydrological periodicities and seasonal changes in order to maintain base and peak loads. Power plant design will need to be flexible for the future, using adaptive, rather than optimized, modular designs.
2. **Increased incidence of extreme weather:** Unexpected variability may trigger extreme climate events, most notably floods and droughts. For example, Bangladesh is expected to suffer from extreme flooding due to substantial increases in discharge from three

major rivers; Ganges, Brahmaputra, and Meghna. One study found that the volume of water in the Ganges would increase by 5 to 15 percent, depending on temperature changes.[40]

3. **Changes to water quality:** Changing hydrology and possible extreme events will impact sediment risks and measures. Increased sediment and changes to water composition raise the probability of turbine erosion and can lower turbine efficiency, leading to declines in output.

In Vietnam, hydroelectric power is considered an ideal and logical power source. However the country has experienced increasing power outages during the dry season because water is scarce. Normally, during the wet season power is sent to the south from the north, but in recent years power has had to be sent to the north from the south to meet growing demand.[41]

The governance of water supplies, including long-term contracts and allocation rights, will grow more important in water scarce regions as competition increases.

Upstream activities and competing water uses can dramatically alter water availability. Therefore the position of a plant within the river watershed is an important indicator of potential risk. Plants in river basins contained within one political regime are less at risk than those that cross international boundaries. The political and economic power of competing water users are another indicator of potential risks to securing water supplies. In all focus countries, irrigated agriculture is the dominant user of water resources and accounts for a majority of withdrawals from freshwater sources, including rivers and groundwater.

V. Impacts on Financial Value

KEY POINTS

- Water-related disruptions can cause load losses or outages, possibly reducing revenues and increasing costs.
- To mitigate water-related disruptions, investments in water supply and treatment systems will need to increase in new and existing plants.
- Decreasing water availability may lead to financing and permitting problems for new projects, potentially constraining power sector growth over the longer-term.

Water-related issues are both physical and regulatory in nature.

To date, most of the financial impacts on the power generation sector from environmental issues have been through regulation, particularly pollution control standards. There are many examples of how environmental regulations have impacted shareholder value in the power generation sector, including the recent ruling in Thailand to declare Map Ta Phut and four other districts in Rayong pollution control zones. As the new, stricter standards will take time to be developed, they could cause new projects to be cancelled or delayed if investors lack confidence in the upcoming regulations.[42]

The financial consequences of water-related impacts range in timeframe and potential magnitude.

Severe water shortages will reduce hydro and thermoelectric power output due to low reservoir levels and inadequate cooling water, potentially reducing revenues and increasing production costs. Intense flooding can also affect power generation by increasing turbidity levels in intake water. Hydroelectric facilities are most affected and over the long term, increased siltation can reduce reservoir capacity and compromise generator performance.

These water events are episodic in nature and their frequency and severity are projected to increase over time.[43] The other financial impacts of water constraints may be more structural and play out in the medium to long-term as the lack of water availability evokes regulatory responses that reshape project finance and execution processes while prescribing technology use. In the most serious case, water availability may constrain growth in new capacity. See Table 7.

The financial impacts and likelihood of occurrence of water-related issues will vary at the geographic, plant, and company levels. The magnitude of the financial impacts will depend on the risk factors discussed in Section IV.

TABLE 7. Potential Impacts of Water Constraints on Shareholder Value

Value Driver		Impact	Description	Key Variables
Operating Efficiency	Revenues	Revenues	Lost revenues from reduced output or outages	PPA terms
	Cost of Goods Sold (COGS)	Costs	Increased costs for temporary water supplies	
Capital Investments	Capital Expenditures (CAPEX)	Costs	Increased capital expenditures for supply infrastructure (reservoirs, dam height, pipelines), water treatment, and cooling systems	Cost-sharing and financing terms
Strategic Positioning	Project Execution	Costs	Project execution delays from financing problems, longer project development periods, more expensive permitting processes	Length of delay
	Growth Potential	Revenues	Constraints on growth due to lack of financing, inability to secure permits, or policies restricting/ prohibiting new power projects	Degree to which competitors are affected

Source: WRI

The following presents more information on the shareholder impacts identified in Table 7.

A. OPERATING EFFICIENCY

Water scarcity episodes, such as droughts or prolonged dry seasons, occur in South and Southeast Asia during El Niño years but are likely to increase in frequency and intensity due to climate change.

Insufficient cooling water (thermal) or water reserves (hydro) may lead to load losses or power outages, potentially resulting in lost revenues. If temporary water supply measures are required, production costs will increase.

The same is true when less efficient generators are employed to meet electricity demand. For example, the 2003 heat wave in France led to increased demand for air conditioning, as well as river water temperatures above thresholds acceptable for cooling purposes. For environmental reasons, even after the government softened water-temperature regulations, the generation from nuclear power plants had to be reduced (around 25%) and compensated by electricity importation. The average electricity price spiked 1,300% on the spot market and EDF lost approximately EUR 300 millions.

In addition to water scarcity episodes, long-term hydrological changes and increased freshwater demand from demographic changes may impact water availability.

A World Bank study showed that due to the impacts of climate change, the water supply forecast for 2025 looks very different from today's supply, meaning that the standard 90% dependable water level used for planning purposes will no longer be accurate. This may represent a pitfall in assessing hydropower projects as future climate change impacts hardly register in current IRR projections, even if future power generation may face significant impacts from lower water levels. See Box A.

Box A. Analysis of Climate Change Impacts on Hydropower in India and Vietnam

The baseline used to determine water resources when assessing a hydro project is the water level available 90% of the year. This is a conservative approach, yet it is just one data point and leaves most hydrological information, including the timing of water resources, unused. A case study looking at the Vishnugad Pipalkoti 400 MW project in Northern India and a 75 MW dam on the Thac Mo river in Vietnam found that in 2025, the rainy season will have higher levels of water than the baselines used during planning, while water resources become more limited during the dry seasons.

The study found that in the Vishnugad Pipalkoti project, electricity generation would increase in 2025 by about 7.5% due to increased reservoir volumes during the rainy season. This translates to a small positive impact on IRR of 0.3 percentage points. However, because this project does not have large storage capacity, it cannot exploit all of the additional precipitation during the rainy season for power generation. The same study looked at a hydro project in Sri Lanka that would experience a 45% increase in power generation because the installed reservoir capacity is large enough to absorb the additional precipitation. This would increase the project's IRR by 1.7%.

The Thac Mo project in Vietnam is a run-of-the-river system and therefore would produce 14% less electricity per year due to increased volatility and the inability to take advantage of increased precipitation during the rainy season. This would lead to a loss in IRR of 0.2%. However, if a reservoir were constructed, the project could increase generation from 383 GWh to 524 GWh per year with the IRR increasing by 0.7% over the additional project costs associated with the reservoir construction. It should be noted that run-of-the-river systems are considered to be more environmentally friendly than reservoirs because they have a smaller impact on river ecosystems. Therefore the addition of reservoir capacity presents an environmental tradeoff.

The timing of climate change impacts on precipitation is crucial to the financial impacts. In the Vietnam example, if climate change affected hydrology from the beginning of operation, the IRR would rise from 21.9% to 35%. This may represent a pitfall in assessing hydropower projects as future climate change impacts hardly register in current IRR projections, even though it may have significant impact on future generation levels.

Source: Atsushi IIMI, "Estimating Global Climate Change Impacts on Hydropower Projects: Applications in India, Sri Lanka and Vietnam" World Bank, Washington, DC September 2007.

B. CAPITAL INVESTMENTS

Climate change induced changes in future water availability may require increased capital expenditures for quantity and quality supply measures.

On the supply side, infrastructure investments may be required for plants to survive longer dry periods and increased occurrences of droughts. Water infrastructure projects such as pipelines, reservoirs, dams, and desalinization facilities are expensive undertakings to increase water supplies. In many situations, these investments in water storage and supply infrastructure would benefit multiple users. Therefore it is unlikely that a power company would bear the entire cost and the financial implications would depend on cost-sharing and financing arrangements.

For new thermal plants, water efficiency may be improved by advanced technologies, including air cooling systems for gas plants. Freshwater dependency can also be reduced through use of seawater or wastewater for cooling purposes. Technology mitigation options for thermal cooling systems include:

- Dry cooling (air is used to condense steam in turbines)
- Wastewater reuse (wastewater is treated onsite to be returned to the power plant)
- Condensed water cooling (water vapor is recovered via the flue gas exiting power plants and condensed back into water)
- Ultra-super critical (USC) technology (advanced steam generation with supercritical steam pressure and temperatures > 1,100°F)
- Seawater use (intake water from marine sources used with open or closed-loop system)

Investments in more water efficient cooling systems and water supply measures may reduce water risk but at high cost. The state of California conducted a cost analysis comparing water-saving cooling systems at four different sites for the construction of a new, gas-fired, combined-cycle 500 MW plant. Capital costs ranged from $2.7 to $4.1 million for wet systems and from $18 to $47 million for dry systems.[44] Dry systems also require four to six times more energy than wet systems, thereby reducing efficiency and in some cases, limiting capacity.[45] Retro-fits to existing plants tend to be cost prohibitive.

Degraded water quality may also lead to increased capital expenditures. For example, increased sediment caused by more frequent flooding may require pre-treatment through water treatment systems. If pre-treatment options or alternative water supplies are not available, there could be disruptions or the need to relocate the facility.[46]

C. STRATEGIC POSITIONING

The physical and regulatory limitations on water availability may shape future power markets in water scarce regions.

Water usage and the securing of water supplies will play a larger role in the ability to finance and permit new projects. Increased water scarcity will likely invoke a regulatory response, especially as competition for water resources increases across sectors and regions. In agricultural and urban regions, competition for water resources may create a complex and challenging political climate for the power industry.

Increased government intervention and competition for water resources will likely lead to longer project development periods that will affect costs and profitability if cost overruns are not allowed by regulators. Risks of execution delays are usually higher for private sector projects as state sponsored projects can receive faster clearances and streamlined permitting processes.

New plants may be restricted or even banned in water scarce regions by government decree or by lack of financing if water supply cannot be secured at a dependable level and attractive rate. For example, the nuclear shutdowns during the heat wave in 2007 in the Southeastern U.S. have spurred the state governments to impose a moratorium on the installation of new merchant power plants because of cooling constraints.[47]

There is evidence that water scarcity is already constraining power development in India. Some analysts believe that certain Indian states (such as Chattisgarh) have already entered into more MOUs for new power capacity than land and water resources allow to be implemented.[48] As a result, not all planned capacity will necessarily be realized, presenting a potentially significant risk to those companies valued for their high growth strategies.

WRI partnered with HSBC to assess the potential impacts of water scarcity on the power generating sector in India. The following is a case study authored by HSBC.

The case study is written by an HSBC equity research analyst and is based on his/her knowledge of the climatic and environmental factors that have an impact on the business of companies in this sector. It does not constitute investment research and is not part of the analyst's ongoing research coverage. Readers of this report, whether existing clients of HSBC or not, should in no circumstances rely on this material when making investment decisions or use it as the basis of an investment strategy.

Please see http://wri.org/project/envest for more information on the assumptions and methodology used in this analysis.

HSBC INDIA CASE STUDY

Water scarcity is already impacting power projects in India, causing delays and operational losses. For example, the **NTPC's** (National Thermal Power Corporation's) **Sipat** plant was shut down in 2008 due to lack of water supplies from the state of Chattisgarh. Thermal plants under construction in Orissa state are also reportedly witnessing delays due to water allocation problems.

Utilities can take a range of measures to protect themselves from water scarcity risks. They could, for instance, incur capital costs that include building back-up supply resources such as canal network or pipelines. Another approach is to identify coastal locations for future plants to tackle the problem of increasing freshwater shortage by installation of desalination plants. However, such measures are costly and affect a company's bottom line.

The financial impact of these additional costs may be limited if they can be passed on to end-customers through tariffs. This case study assesses the financial impact of water scarcity on the internal rate of return (IRR) of a typical coal-based plant at two stages of the project life cycle:

1) Project development stage, when water scarcity can delay project execution, leading to loss of revenues, profits and hence project IRR; and
2) Operating life of the project, when water scarcity can reduce the plant load factor, thereby affecting profitability and valuation.

These risks were assessed from both a short/medium-term perspective as well as a longer-term view, as the regulatory framework within which the sector operates today may change over time, resulting in a different risk-reward equation.

1. IRR Impacts of Project Execution Delays Due to Water Scarcity

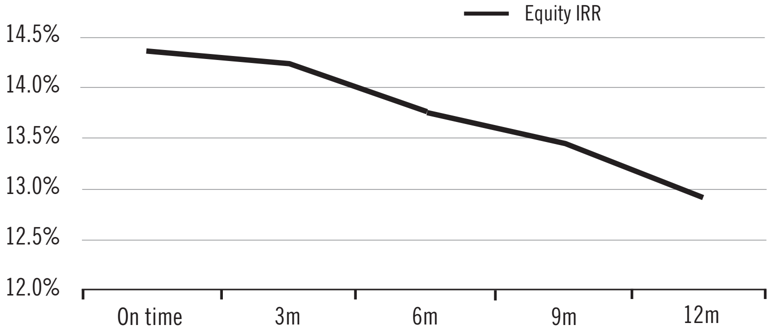
In order to ascertain the impact of water scarcity at the project development stage, it is important to understand the overall project award process. The use of water and land by power plants in India is screened at a very early stage. The government's decision to allow use of water from a particular source takes into account water requirements for other critical uses such as irrigation in and around the region.

This water allocation system will be further strengthened under the National Action Plan on Climate Change launched by the Prime Minister of India on June 30, 2009. The Plan includes a national water mission to ensure that integrated policies are put in place for resource management to help conserve water, minimize wastage and allow for the most equitable distribution of scarce water supplies both across and within states. Additional national level initiatives will also be undertaken to deal with the impact of climate change.

In power projects launched as a joint venture between the central and state governments, the state approves water allocation and benefits from a share of the power production as well as local employment generation during construction and operation. Alternatively, water allocation for projects can be drawn from interstate rivers at the decision of the Central Water Commission (CWC). Typically, water allocation clearances require 3-6 months from the relevant State government and another 3-6 months from the CWC.

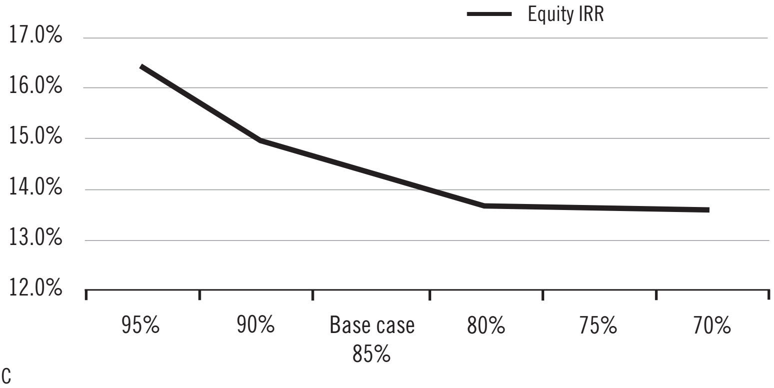
Clearances on all aspects of a project, including water allocation, are required for achieving financial closure on projects and developers typically will not invest in a project without financial closure. Scarcity of water or delay in water allocation for a project could result in a delay in financial closure, and thus in commencement of construction, which can lead to delayed operations, and loss of revenues, profits, cash flows, and hence, depressed valuation. Based on our assumptions, a delay of three months will result in a power plant's IRR dropping by a mere 25 basis points (bps). However, a 12-month delay in commercial operation results in a drop of nearly 150 bps. Figure 20 illustrates the sensitivity of the IRR of a standard project to delay in project commissioning.

FIGURE 20. **IRR Sensitivity to Delay in Commercial Operations (months)**



Source: HSBC

FIGURE 21. **IRR Sensitivity to Loss in Plant Load Factor (%)**



Source: HSBC

There are no firm examples to demonstrate the length of delay on account of water scarcity at the project construction stage. Construction typically happens only after water has been allocated for the project and the decision is typically irreversible.

2. IRR impacts of loss of output due to water scarcity

Power is bought and sold under long-term contracts in India. While typical buyers include unlisted state-owned distribution companies, sellers include listed players such as NTPC and private listed developers such as Reliance Infrastructure, Tata Power, and Lanco Infratech.

Under current regulations, the risk of revenue loss due to water scarcity may be limited over the short-term as power is sold under long-term contracts, and virtually all costs - operating as well as capital-related - can be passed on to the buyer. Power purchase agreements (PPAs) typically compensate the power generator if it is unable to operate a plant due to water scarcity, which is deemed to be the responsibility of the State electricity board (SEB). (For other inputs such as fuel, a utility will typically sign a back-to-back agreement with the fuel supplier for making up for any losses that may occur due to a disruption in fuel supply.)

Scarcity of water could result in reduced power output, or even shut downs. If water supply is the responsibility of the operator and the state does not compensate for any loss of revenue associated with reduced water flow, and therefore profits, the drop in output will result in loss of revenues, profits and cash flows and hence lower the valuation of the project.

Based on our assumptions, each 5% drop in the plant load factor over the life of a plant results in a drop of nearly 75 bps in the project IRR. Figure 21 shows the sensitivity of the IRR of a standard project to a fall in the plant load factor.

3. Additional capital spending to secure water supply

To avoid costly and disruptive scenarios such as those outlined above, power companies may choose to incur additional capital expenditure to provide for a backup source of water supply, such as pipelines or a canal. It is possible that the additional cost for constructing pipelines or a canal might be borne by the State government. If, instead, utilities incur this additional cost, they will pass it on, through tariffs, to end-customers.

In order to reduce overall project cost, new power plant sites are typically identified after taking into account their proximity to natural resources such as water and fuel in order to minimize potential cost escalation due to the need for additional infrastructure.

As the impacts of climate change, including water scarcity, intensify, analysts expect planning agencies to focus on identifying more power project sites at coastal locations. While this could help meet water needs for cooling purposes, the use of more desalination plants will have the drawback of adding to both project costs and operating costs.

VI. Recommendations

Water scarcity risks are receiving more attention than in the past, yet the connection to power sector development does not appear to be well understood by investors, governments, and companies in the region. A recent assessment from the Asian Development Bank could find no evidence that any Asian developing country has seriously assessed the current and future water requirements of its energy sector.[49] In addition, a survey of power sector equity research reports shows scarce mention of water supply related issues.

This is due in part to the limited affect of water scarcity issues on the power sector in Asia to date.[50] However, this has not been the case in other water scarce regions around the world. The confluence of increasing water demands associated with the projected growth in the power sector and other water intensive sectors such as agriculture coupled with a changing climate will create a very different operating environment in the future.

Unfortunately important data to understand water dependency and supply risks is not readily available in the focus countries. The physical impacts of climate change are complicated to predict at the level of detail necessary for planning purposes. Beyond scientific limitations, the political and social dimensions of water allocations and regulatory changes also make it difficult to predict how water scarcity issues will play out across sectors at the local level.

This does not mean that there is nothing for companies, investors, and analysts to do to assess potential water scarcity risks. The potential magnitude and scale of water scarcity risks, especially in electricity hungry regions such as India, requires forward-looking strategies by stakeholders in the industry. Specifically:

- **Investors and analysts should engage with companies to learn more about their exposure to water scarcity risks and their ability to mitigate these risks.**

Because of the lack of publicly available data, the best way for investors and analysts to gauge a company's exposure to water scarcity risk is to open a dialogue with the companies on these issues. Section IV includes questions and indicators for investors to engage with companies to assess their exposure to water scarcity risk.

- **With this information, investors and analysts should integrate current and future water risks into their evaluation of power generation companies.**

See the "Next Steps" outlined on p. 7 for suggestions on approaches and techniques for evaluating water risks to inform investment perspectives.

- **Power companies should focus on reducing water consumption and dependency in existing and new facilities where required, while planning for increased uncertainty and stress on water resources in the future.**

New plant site selection, technology choice, negotiating long-term access rights to water resources and contingency planning will be key to mitigating risks.

- **The private sector should work together with the public sector and NGOs to improve planning processes and data availability for critical aspects of water scarcity.**

Such efforts could include integrating an assessment of climate change impacts on water resources with long-term energy and water planning. Water and power are not usually governed by the same agency and therefore most countries lack a coordinated approach to water and energy issues. Yet these issues are deeply related, with power development having significant impacts on water management. India, which stands out as the most electric power-demanding and water scarce country in focus, has much at stake over how power and water resources are developed. If not managed well, water could become a major constraint on power production and economic development.

Necessity may force governments to think about long-term energy and water issues together, a departure from today's mindset, which could result in a very different approach to power sector development. Ideally this approach would reduce water-related risks for companies in the planning and development process and minimize exposure to water-related disruptions during operation. On the other hand, shareholder protections enjoyed today that are dependent on public subsidies may not be fiscally sustainable over the long-term. The magnitude of the challenge of meeting growing water demand in the future will require a business model for power development that more accurately prices water risk.

Appendix A: Methodology and Data Tables

WRI mapped power plant locations against water scarcity data to assess the potential for water constraints to affect the power generation sector in South and Southeast Asia.

SCOPE

The analysis included over 150 existing and planned thermal and hydroelectric plants (totaling 137 GW) owned by major publicly listed companies. See Tables A and B. More specifically, the analysis included the following parameters:

Geographic:

- Domestic plants owned by companies in India, Malaysia, Philippines, Thailand, and Vietnam.
- Plants owned outside these countries were not included (i.e. Ratch's hydro facilities in Laos).
- Indonesia was not included because it has no publicly listed companies.

Power Plants:

- Thermal (all fuel types, including coal, natural gas, and biomass)
- Hydro
- No nuclear plants are currently owned or planned by publicly listed companies in the region.
- Existing and planned (to the extent reported by companies in press releases and annual reports as of August 2009).

Companies:

- NPTC, Tata Power, Reliance Infrastructure (including Reliance Power), Tenaga Nasional Berhad, Tanjong, YTL, First Generating Company, Energy Development Corp, Aboitiz, Ratch, Electric Generating Company, Glow Energy, Pha Lai Thermal, and Vinh Son – Song.

DATA SOURCES

Plant Data

Plant data are from company reports, press releases, and equity research reports. Plant locations are from CARMA (www.carma.org). When not available on CARMA, the XY coordinates for the closest district, town, or city were used.

Water Stress Indicators

Water scarcity data is from the International Water Management Institute (IWMI), WRI, and the University of Kassel: Vladimir Smakhtin, Carmen Revenga and Petrol Doll, 2004. "Taking into Account Environmental Water Requirements in Global-scale Water Resources Assessment." Comprehensive Assessment of Water Management in Agriculture, Research Report 2. International Water Management Institute, Colombo, Sri Lanka.

The IWMI water stress indicators (WSI's) represent the ratio of total withdrawals (including all water users) to utilizable water, which is considered to be the river's resource capacity less the minimum amount of water used by the ecosystem. This is illustrated below:

$$\text{WSI} = \frac{\text{Withdrawals}}{\text{Total available water} - \text{Environmental needs}}$$

The WSI has the following classifications:

Water scarce: $\text{WSI} > 1$
Water stressed: $0.6 \leq \text{WSI} < 1$
Moderate water availability: $0.3 \leq \text{WSI} < 0.6$
Water abundant: $\text{WSI} < 0.3$

The WSI has several important limitations in this application:

- First, it does not considering the timing or frequency of water flows in its assessment of available water. As a result it does not predict the likelihood of a water scarcity event, an important consideration for power generation.
- Second, it does not account for water quality, meaning that river basins that appear to be "safe" may in reality face water shortages due to pollution, siltation, or other causes.
- Third, it assigns one water stress indicator to an entire river basin, such as the Ganges, which is not specific enough to accurately assess water stress at the plant level. Instead it provides an overall illustration of the level of water stress in a watershed.
- Lastly, it only considers current water stress and does not account for future changes due to demographic and climate change pressures.

DATA TABLES

TABLE A. Power Generating Companies Included in Analysis

Company	Reuters/ Bloomberg Ticker	Country	Type	Market Cap ($US Million)	Plants in Focus Region	Installed MW's	Planned MW's
National Thermal Power Corporation (NTPC)	NTPC.BO NATP IN	India	Utility	36,550	53	29,737	24,727
Tata Power	TTPW.BO TPWR IN	India	IPP	6,970	19	2,405	5,536
Reliance Infrastructure	RLIN.BO RELI IN	India	IPP	5,020	19	941	28,320
Tenaga Nasional Berhad	TENA.KL TNB MK	Malaysia	Utility	10,380	27	10,854	3,992
YTL Power International	YTLP.KL YTLP MK	Malaysia	IPP	4,230	2	1,212	0
Tanjong Public Limited Company	TJPL.KL TJN MK	Malaysia	IPP	2,150	3	1,490	0
First Gen Corporation	FGEN.PS FGEN PM	Philippines	IPP	736	26	1,846	192
Aboitiz Power	AP.PS AP PM	Philippines	IPP	2,050	21	578	1,807
Ratchaburi Electricity Generating Holding	RATC.BK RATCH TB	Thailand	IPP	1,640	4	4,347	1,085
Glow Energy	GLOW.BK GLOW TB	Thailand	IPP	1,700	7	1,708	929
Electric Generating Company	EGCO.BK EGCO TB	Thailand	IPP	1,290	11	3,821	272
Pha Lai Thermal	PPC.VM PPC VN	Vietnam	IPP	288	4	1,040	370
Vinh Son - Song	VSH.VM VSH VN	Vietnam	IPP	166	6	136	470

Source: Bloomberg (as of 03/22/10), 2008 company reports. Plant data limited by parameters described on p. 41.

TABLE B. Power Plant Data Used in Water Stress Mapping

Company	Name	% Ownership	Type	Current Capacity (MW)	Planned Capacity (MW)	Country	Latitude	Longitude	Water Stress Level
		Company Data					*CARMA, Maplandia, Google Earth*		*IWMI 2004*
ABOITIZ	Ambuklao-Blinga	50%	hydro	175.0	50.0	Philippines	16.5000	120.6667	Abundant
ABOITIZ	Angat	100%	hydro		246.0	Philippines	14.9130	121.0490	Abundant
ABOITIZ	Backup plants	100%	oil	60.0		Philippines	7.0731	125.6128	Abundant
ABOITIZ	Bakun	50%	hydro	70.0		Philippines	16.8881	120.5292	Abundant
ABOITIZ	Cebu	26%	coal		246.0	Philippines	10.3792	123.6419	Stressed
ABOITIZ	Cebu Private Power Corporation	60%	oil	70.0		Philippines	10.3070	123.8980	Stressed
ABOITIZ	East Asia Utilities Corporation	50%	oil	50.0		Philippines	10.3000	124.0000	Stressed
ABOITIZ	Magat	50%	hydro	360.0		Philippines	16.7833	121.5333	Abundant
ABOITIZ	Mini-projects	100%	hydro	38.2		Philippines	16.0333	120.4500	Abundant
ABOITIZ	Redondo Peninsula Energy, Inc.	50%	coal		300.0	Philippines	17.7500	121.7333	Abundant
ABOITIZ	Sibulan	100%	hydro		42.5	Philippines	9.3580	123.2850	Moderate
ABOITIZ	Southern Philippine Power Corporation	20%	oil	55.0		Philippines	6.1128	125.1717	Abundant
ABOITIZ	STEAG State Power Incorporated	34%	coal	232.0		Philippines	8.1683	123.8475	Abundant
ABOITIZ	Tamugan	100%	hydro		27.5	Philippines	7.2308	125.3764	Abundant
ABOITIZ	Western Mindanao Power Corporation	20%	oil	100.0		Philippines	6.9060	122.0690	Abundant
EGCO	BLCP	50%	coal	1434.0		Thailand	12.7170	101.0540	Moderate
EGCO	ECGO Green Cogen	80%	gas	117.0		Thailand	12.6756	101.2783	Moderate
EGCO	Gulf Cogeneration Co	50%	gas	110.0		Thailand	14.5864	100.9978	Moderate
EGCO	Gulf Power Gen Co (Kaeng Kong 2)	50%	gas	1510.0		Thailand	14.5833	101.0167	Moderate
EGCO	Gulf Yala Green Co	50%	biomass	23.0		Thailand	6.5425	101.2831	Abundant
EGCO	Khanom (Kegco)	100%	gas	824.0		Thailand	9.2047	99.8611	Abundant
EGCO	Nong Khae Cogernation Co	50%	gas	126.0		Thailand	14.3333	100.8667	Moderate
EGCO	Rayong Electric Gen Co (Regco)	100%	gas	1232.0		Thailand	12.6683	101.2750	Moderate
EGCO	Roi-et Green	70%	biomass	9.9		Thailand	16.0533	103.6525	Abundant
EGCO	Samutprakarn Cogeneration Co	50%	gas	126.0		Thailand	13.6000	100.6000	Moderate
FGEN	Agusan	100%	hydro	1.6		Philippines	8.4822	124.6472	Abundant
FGEN	Bauang	37%	diesel	225.0		Philippines	16.4944	120.3281	Abundant
FGEN	Masiway	100%	hydro	12.0		Philippines	15.8114	121.1436	Abundant
FGEN	Pantabangan	100%	hydro	100.0		Philippines	15.8114	121.1436	Abundant
FGEN	San Lorenzo	60%	gas	500.0		Philippines	13.7781	121.0431	Abundant
FGEN	Santa Rita	60%	gas	1000.0		Philippines	13.7781	121.0431	Abundant

TABLE B. **Power Plant Data Used in Water Stress Mapping** *(cont.)*

Company	Name	% Ownership	Type	Current Capacity (MW)	Planned Capacity (MW)	Country	Latitude	Longitude	Water Stress Level
		Company Data					*CARMA, Maplandia, Google Earth*		*IWMI 2004*
GLOW	CFB 3	100%	coal		115.0	Thailand	12.7170	101.0540	Moderate
GLOW	GHECO-One	65%	coal		660.0	Thailand	12.7170	101.0540	Moderate
GLOW	Glow IPP Power Plant	100%	gas/ diesel	713.0		Thailand	13.1744	100.9306	Moderate
GLOW	Glow SPP 1 Central Utilities Cogeneration Plant	100%	gas/ diesel	124.0		Thailand	12.7170	101.0540	Moderate
GLOW	Phase 2 Central Utilities Cogeneration Plant	100%	gas/ diesel	281.0		Thailand	12.7170	101.0540	Moderate
GLOW	Phase 3 & 4 Hybrid Cogeneration Plant	100%	gas/ coal	590.0		Thailand	12.7170	101.0540	Moderate
GLOW	Phase 5	100%	gas		385.0	Thailand	12.7170	101.0540	Moderate
NTPC	Anta	100%	gas	413.0		India	25.1000	76.5167	Stressed
NTPC	Auraiya	100%	gas	652.0		India	26.7700	79.0100	Stressed
NTPC	Badarpur	100%	coal	705.0		India	28.5167	77.3333	Stressed
NTPC	Barh	100%	coal	0.0	3300.0	India	25.5544	85.4177	Stressed
NTPC	Bhilai	50%	coal	574.0		India	21.2200	81.4300	Moderate
NTPC	Bihar State Electricty Board	100%	coal		1980.0	India	24.6060	84.1250	Stressed
NTPC	Bongaigaon	100%	coal		750.0	India	26.4933	90.3625	Abundant
NTPC	Dadri	100%	coal	840.0	980.0	India	28.5700	77.5500	Stressed
NTPC	Dadri	100%	gas	817.0		India	28.5700	77.5500	Stressed
NTPC	Durgapur	50%	coal	120.0		India	23.4800	87.3200	Scarce
NTPC	Farakka	100%	coal	1600.0	500.0	India	24.1800	88.2600	Stressed
NTPC	Faridabad	100%	gas	430.0		India	28.4333	77.3167	Stressed
NTPC	Indira Ghandi	50%	coal		1500.0	India	28.6200	76.6500	Scarce
NTPC	Jhanor-Gandhar	100%	gas/ liquids	648.0	1300.0	India	21.8339	73.1111	Scarce
NTPC	Kahalgaon	100%	coal	1840.0	500.0	India	25.2700	87.2200	Stressed
NTPC	Kanti Bijlee Utpadan Nigam	50%	coal		220.0	India	26.2167	85.3000	Stressed
NTPC	Kawas	100%	gas	645.0	1300.0	India	21.1600	72.8300	Scarce
NTPC	Koldam	100%	hydro		800.0	India	30.4978	77.9217	Stressed
NTPC	Korba	100%	coal	2100.0	500.0	India	22.0833	82.1500	Moderate
NTPC	Lata-Tapovan	100%	hydro		171.0	India	30.5700	79.5700	Stressed
NTPC	Loharinag Pala	100%	hydro		600.0	India	30.7333	78.4500	Stressed
NTPC	Mauda	100%	coal		1000.0	India	21.1560	79.0890	Stressed
NTPC	Meja	50%	coal		1320.0	India	25.4430	81.8280	Stressed
NTPC	Nabinagar	74%	coal		1000.0	India	24.7500	84.3700	Stressed
NTPC	North Karanpura	100%	coal		1980.0	India	24.2167	84.8667	Stressed
NTPC	Rajiv Gandhi CCPP Kayamkulam	100%	gas/ liquids	350.0		India	9.1700	76.4900	Moderate

TABLE B. Power Plant Data Used in Water Stress Mapping *(cont.)*

Company	Name	% Ownership	Type	Current Capacity (MW)	Planned Capacity (MW)	Country	Latitude	Longitude	Water Stress Level
		Company Data					*CARMA, Maplandia, Google Earth*		*IWMI 2004*
NTPC	Ramagundam	100%	coal	2600.0		India	18.4333	79.1500	Stressed
NTPC	Rammam-3	100%	hydro		120.0	India	27.0333	88.2667	Abundant
NTPC	Ratnagiri Gas and Power Private limited (RGPPL)	100%	gas/ liquids	1480.0		India	17.6000	73.1667	Abundant
NTPC	Rihand	100%	coal	2000.0	1000.0	India	24.6828	83.0656	Stressed
NTPC	Rihand	100%	hydro		4.0	India	24.6828	83.0656	Stressed
NTPC	Rourkela	50%	coal	120.0		India	22.1200	84.5400	Abundant
NTPC	Simhadri	100%	coal	1000.0	1000.0	India	17.7000	83.3000	Moderate
NTPC	Singrauli	100%	coal	2000.0		India	25.1500	82.5833	Stressed
NTPC	Singrauli	100%	hydro		8.0	India	25.1500	82.5833	Stressed
NTPC	Sipat	100%	coal	1000.0	2480.0	India	22.0833	82.1500	Moderate
NTPC	Talcher STPS	100%	coal	3000.0		India	20.8500	85.1000	Abundant
NTPC	Talcher STPS	100%	coal	460.0		India	20.8500	85.1000	Abundant
NTPC	Tanda	100%	coal	440.0		India	26.5500	82.6500	Stressed
NTPC	Tapovan Vishnugad	100%	hydro		520.0	India	30.4000	79.3500	Stressed
NTPC	Unchahar	100%	coal	1050.0		India	26.1300	81.1300	Stressed
NTPC	Vallur	50%	coal		1000.0	India	13.1500	79.9100	Scarce
NTPC	Vindhyachal	100%	biomass		1.5	India	24.4100	81.8800	Stressed
NTPC	Vindhyachal	100%	coal	3260.0		India	24.4100	81.8800	Stressed
PPS	Mong Duong	25%	coal		1000.0	Vietnam	21.0167	107.3167	Abundant
PPS	Pha Lai-1	100%	coal	440.0		Vietnam	15.2167	102.3333	Abundant
PPS	Pha Lai-2	100%	coal	600.0		Vietnam	15.2167	102.3333	Abundant
PPS	Quang Ninh	10%	coal		1200.0	Vietnam	20.1500	107.0000	Abundant
RATCH	Pratu Toa-A Field	100%	gas	1.8		Thailand	16.9525	99.9761	Moderate
RATCH	Ratchaburi	100%	gas	3645.0		Thailand	13.5463	99.6182	Abundant
RATCH	Ratchaburi Power	25%	gas	1400.0		Thailand	13.5300	99.8000	Abundant
RATCH	Ratchaburi Tri Energy	50%	gas	700.0		Thailand	13.5300	99.8000	Abundant
RELIANCE	Amulin	100%	hydro		420.0	India	28.4000	94.5500	Abundant
RELIANCE	Butibori-Hinga	100%	coal		300.0	India	21.0700	79.2700	Stressed
RELIANCE	Dadri	100%	gas		7480.0	India	28.6667	77.4333	Stressed
RELIANCE	Dahanu	100%	thermal	500.0		India	19.0000	73.0000	Abundant
RELIANCE	Emini	100%	hydro		500.0	India	28.4000	94.5500	Abundant
RELIANCE	Kochi-Kerala	100%	naphtha	165.0		India	10.0200	76.2300	Moderate
RELIANCE	Krishnapatnam	100%	coal		4000.0	India	14.2833	80.1167	Scarce
RELIANCE	Mithundon	100%	hydro		400.0	India	28.4000	94.5500	Abundant
RELIANCE	MP Power	100%	coal		3960.0	India	24.4167	81.8833	Stressed
RELIANCE	Peddapuram SamalKot	100%	gas	220.0		India	16.9333	82.2167	Scarce

TABLE B. Power Plant Data Used in Water Stress Mapping *(cont.)*

		% Ownership	Type	Current Capacity (MW)	Planned Capacity (MW)		Latitude	Longitude	Water Stress Level
Company	**Name**	*Company Data*				**Country**	*CARMA, Maplandia, Google Earth*		*IWMI 2004*
RELIANCE	Rosa Power	100%	coal		1200.0	India	27.8833	79.9167	Stressed
RELIANCE	Salgaonkar	100%	gas	48.0		India	15.4930	73.8180	Abundant
RELIANCE	Sasan	100%	coal		3960.0	India	24.4667	75.0667	Stressed
RELIANCE	Shahapur	100%	coal		1200.0	India	19.4500	73.3333	Abundant
RELIANCE	Shahapur	100%	gas		2800.0	India	19.4500	73.3333	Abundant
RELIANCE	Siyom	100%	hydro		1000.0	India	28.4000	94.5500	Abundant
RELIANCE	Tato II	100%	hydro		700.0	India	28.4000	94.5500	Abundant
RELIANCE	Urthing Sobla	100%	hydro		400.0	India	29.9667	80.6167	Stressed
TANJONG	Powertek	100%	gas	440.0		Malaysia	2.1500	102.5333	Abundant
TANJONG	Tanjong Kling	100%	gas	330.0		Malaysia	2.1500	102.5333	Abundant
TANJONG	Teluk Gong (Panglima)	100%	gas	720.0		Malaysia	2.2275	102.1769	Scarce
TATA	Ahmednagar	100%	thermal	17.0		India	19.0800	74.7300	Stressed
TATA	Belgaum	100%	oil	81.0		India	15.8600	74.5000	Scarce
TATA	Bhira	100%	hydro	300.0		India	18.9833	75.7667	Stressed
TATA	Bhivpuri	100%	hydro	72.0		India	19.0300	73.3100	Abundant
TATA	Haldia Coke Unit	100%	coal		120.0	India	22.0200	88.0500	Scarce
TATA	Jojobera	100%	coal	428.0		India	22.8000	86.1833	Abundant
TATA	Jojobera/Jamshedpur	100%	thermal		240.0	India	22.8000	86.1833	Abundant
TATA	Khopoli	100%	hydro	75.0		India	21.9000	83.4000	Moderate
TATA	Maithon	74%	coal		1050.0	India	23.7767	86.8067	Scarce
TATA	Mundra	100%	coal		4000.0	India	22.8377	69.7106	Scarce
TATA	Trombay	100%	coal	500.0	250.0	India	18.9750	72.8258	Abundant
TATA	Trombay	100%	gas	180.0		India	18.9750	72.8258	Abundant
TATA	Trombay	100%	oil	650.0		India	18.9750	72.8258	Abundant
TNB	Bakun	100%	hydro		2400.0	Malaysia	2.7564	114.0631	Abundant
TNB	Cameron Highlands	100%	hydro	262.0		Malaysia	4.4650	101.3800	Abundant
TNB	Connaught Bridge	100%	gas	832.0		Malaysia	3.0000	101.4000	Stressed
TNB	Gelugor	100%	gas	330.0		Malaysia	5.4800	100.5000	Moderate
TNB	Hulu Terengganu	100%	hydro		250.0	Malaysia	5.1889	102.8808	Abundant
TNB	Malawa	80%	thermal	50.0		Malaysia	6.0833	116.1500	Abundant
TNB	Manjung	100%	coal	2070.0		Malaysia	4.1667	100.6833	Abundant
TNB	Mini-hydro	80%	hydro	8.3		Malaysia	5.9500	116.6800	Abundant
TNB	Pasir Gudang	100%	gas/ oil/ dist	729.0		Malaysia	1.4667	103.8833	Scarce
TNB	Patau-Patau	80%	thermal	60.0		Malaysia	5.3203	115.2112	Abundant
TNB	Prai	100%	gas		220.0	Malaysia	5.3833	100.3833	Moderate
TNB	Ranau	80%	thermal	13.2		Malaysia	5.9500	116.6800	Abundant

TABLE B. Power Plant Data Used in Water Stress Mapping *(cont.)*

		% Ownership	Type	Current Capacity (MW)	Planned Capacity (MW)		Latitude	Longitude	Water Stress Level
Company	**Name**	*Company Data*				**Country**	*CARMA, Maplandia, Google Earth*		*IWMI 2004*
TNB	Sandakan	80%	thermal	34.0		Malaysia	5.8600	118.0500	Abundant
TNB	Serdang	100%	gas/ dist	625.0		Malaysia	2.9800	101.7800	Moderate
TNB	Sultan Aziz (Kapar)	60%	coal	1600.0		Malaysia	3.0000	101.4000	Stressed
TNB	Sultan Aziz (Kapar)	60%	gas	820.0		Malaysia	3.0000	101.4000	Stressed
TNB	Sultan Ismail (Paka)	100%	gas/ dist	1139.0		Malaysia	4.6500	103.4300	Abundant
TNB	Sultan Mahmud (Kenyir)	100%	hydro	400.0		Malaysia	5.0667	103.0167	Abundant
TNB	Sungai Piah Ulu (Perak)	100%	hydro	1248.0		Malaysia	4.4000	101.1833	Abundant
TNB	Tawau	80%	thermal	36.0		Malaysia	4.2500	117.9000	Abundant
TNB	Teluk Ewa	100%	dist	68.0		Malaysia	6.4250	99.0128	Abundant
TNB	Telupid	80%	thermal	13.2		Malaysia	5.6500	117.1167	Abundant
TNB	Tenom-Pangi	80%	hydro	66.0		Malaysia	5.1333	115.9500	Abundant
TNB	TJGS	100%	gas	714.0		Malaysia	2.5230	101.8000	Moderate
TNB	Tuanku Jaafar	100%	gas	750.0	750.0	Malaysia	2.5230	101.8000	Moderate
TNB	Tungku	80%	thermal	13.2		Malaysia	5.0186	118.8839	Abundant
TNB	Ulu Jelai	100%	hydro		372.0	Malaysia	4.1833	102.0500	Abundant
VSH	Dong Cam	0%	hydro		120.0	Vietnam	11.1103	107.1811	Abundant
VSH	Song Hinh	0%	hydro	70.0		Vietnam	10.9667	106.6500	Abundant
VSH	Upper Kon Tum	0%	hydro		220.0	Vietnam	14.3833	107.9833	Abundant
VSH	Vihn Son (Song Kon)	0%	hydro	66.0		Vietnam	13.7667	109.2333	Abundant
VSH	Vihn Son-2	0%	hydro		100.0	Vietnam	13.7667	109.2333	Abundant
VSH	Vihn Son-3	0%	hydro		30.0	Vietnam	13.7667	109.2333	Abundant
YTLP	Paka	100%	gas	808.0		Malaysia	4.6500	103.4300	Abundant
YTLP	Pasir Gudang	100%	gas	404.0		Malaysia	1.4667	103.8833	Scarce

Notes

1. U.S. Energy Information Administration, International Energy Outlook 2006.
2. The most recent IMF and ADB economic forecasts project improved GDP growth rates in 2010. See IMF World Economic Outlook: Crisis and Recovery, 2009 and Asian Development Bank Outlook 2009: Rebalancing Asia's Growth (updated May 7, 2009).
3. Tata 89th Annual Report 2007-2008 p.45.
4. Syriyan Pietersz, Company Visit Note: Vihn Son Song Hinh Hydropower Joint Stock Company, JPMorgan, June 8, 2009.
5. Edmond Lee, Positioning for Further Recovery, JPMorgan Asia Pacific Equity research, May 7 2009.
6. Energy Information Administration website: http://www.eia.doe.gov/emeu/cabs/India/Electricity.html.
7. NTPC Annual Report 2007-2008 p.34.
8. Tata Power Annual Report 2008 p. 46.
9. Sumeet Agrawal, Indian Power Utilities: A new, competitive landscape. HSBC Global Research, August 29, 2008.
10. CEA's executive summary, Economic Survey 2007-2008.
11. Amish Shah and Sagar Rastogi, "India Utilities Sector: Plans versus Plants" Credit Suisse Equity Research, October 3, 2009.
12. Edmond Lee, Positioning for Further Recovery, JPMorgan Asia Pacific Equity research, May 7 2009.
13. EVN website. http://www.evn.com.vn/
14. 2030 Water Resources Group. "Charting Our Water Future: Economic Frameworks to Inform Decision-Making." 2009.
15. Gleick,, P. 2007. The World's Water 2006-2007: A Biennial Report on Freshwater Resources.
16. FAO, "Thailand's Water Vision: A Case Study" 2001.
17. Cuong, N 2008. Viet Nam Country Report – A Regional Review on the Economics of Climate Change in Southeast Asia. Report submitted for RETA 6427: A Regional Review of the Economics of Climate Change in Southeast Asia. Asian Development Bank, Manilla. 2009.
18. Mukherji A et al 2009. "Revitalizing Asia's Irrigation: to sustainably meet tomorrow's food needs. Colombo, Sri Lanka: International Water Management Institute, Rome, Italy: Food and Agriculture Organization of the United Nations.
19. Jason Morrison et al., "Water Scarcity & Climate Change: Growing Risks for Businesses & Investors" CERES, Boston February 2009.
20. United Nations Environment Programme and the Asian Institute of Technology, "Freshwater Under Threat: South Asia" Nairobi: 2008.
21. Contribution of Working Group II to the Fourth Assessment Report, *Climate Change 2007, Impacts, Adaptation and Vulnerability.*
22. Hoanh et al "Will we produce sufficient food under climate change? Mekong Basin (South-east Asia)." In J.C.J.H. Aerts and P.Droogers, eds. Climate Change in Contrasting River Basins: Adaptation Strategies for Water, Food, and Environment. CABI Publishing, Wallingford 2004.
23. ADB 2004. Climate Change in Asia: Viet Nam Country Report. Manila.
24. Mukherji A et al 2009. "Revitalizing Asia's Irrigation: to sustainably meet tomorrow's food needs. Colombo, Sri Lanka: International Water Management Institute, Rome, Italy: Food and Agriculture Organization of the United Nations.
25. Guenther Fischer et al, "Climate Change Impacts on Irrigation Water Requirements: Effects of Mitigation, 1990-2080." Technological Forecasting and Social Change 74, no.7 (September 2007): 1083-1107.
26. Marc Levinson, Watching Water, JPMorgan Global Equity Research April 2008.
27. Government of India, Ministry of Water Resources, "National Water Policy" New Delhi, April 2002. http://wrmin.nic.in/writereaddata/linkimages/nwp20025617515534.pdf.

28. "Forum on Clean Energy, Good Governance and Regulation" Materials, March 16-18 2008. Hosted by Centre on Asia and Globalisation, Lee Kuan Yew School of Public Policy National University of Singapore.
29. Gio Dela-Rosa, Philippine Power Sector, The next wave. Deutsche Bank, April 24, 2008.
30. Manish Saxena, Deepak Agrawala, Sandeep Palgota, "Is this the first sign of cracks for power utilities in India?" Deutsche Bank, June 2, 2009.
31. Amish Shah and Sagar Rastogi, "India Utilities Sector: Plans versus Plants" Credit Suisse Equity Research, October 3, 2009.
32. DOE Report to Congress on the Interdependency of Energy and Water, 2006.
33. P. Torcellini, N. Long, and R. Judkoff, "Consumptive Water Use for U.S. Power Production" NREL, 2003. NREL/TP-550-33905.
34. Powerscorecard.org, "How does electric power production use and consume water."
35. National Energy Technology Laboratory, "Water Requirements for Existing and Emerging Thermoelectric Plant Technologies" DOE/NETL-402/080108. April 2009 revision.
36. It's worth noting that the data presented in Figure 18 is specific to one technology (a monoethanolamine (MEA) recovery unit based on the fluor econamine FG technology). However, research in this area is ongoing and systems with improved efficiency, costs and/or water balances are being pursued.
37. Energy Velocity Suite, Nuclear Regulatory Commission Outage query. http://www1.ventyx.com/velocity/vs-overview.asp.
38. Argonne National Laboratory. "Use of Reclaimed Water for Power Plant Cooling," 2007.
39. Atsushi IIMI, "Estimating Global Climate Change Impacts on Hydropower Projects: Applications in India, Sri Lanka and Vietnam" World Bank, Washington DC September 2007.
40. M. Monirul Qader Mirza , R. A. Warrick and N. J. Ericksen, "The Implications of Climate Change on Floods of the Ganges, Brahmaputra and Meghna Rivers in Bangladesh" *Climatic Change*, Volume 57, Number 3 / April, 2003. Pp. 287-318.
41. Viet Nam: Mong Duong Thermal Power Project Environmental Assessment Report #39595. Prepared by the Government of Vietnam for the Asian Development Bank August 2006.
42. Thaniya Kevalee and Siriporn Sothikul, "Thailand Power Sector: Bottom-fish the beta play" Credit Suisse Equity Research, March 20, 2009.
43. Working Group II Contribution to the IPCC, 4th Assessment Report, Climate Change Impacts, Adaptation and Vulnerability, Summary for Policy Makers.
44. California Energy Commission, "Comparison of Alternate Cooling Technologies for California Power Plants: Economic, Environmental, and Other Tradeoffs. 500-02-079F. February 2002.
45. California Energy Commission, "Comparison of Alternate Cooling Technologies for California Power Plants: Economic, Environmental, and Other Tradeoffs. 500-02-079F. February 2002.
46. Pacific Institute. "Water Scarcity and Climate Change: Growing Risks for Businesses and Investors," February 2009. Page 12.
47. Running Dry, EPRI Journal Summer 2007.
48. Amish Shah and Sagar Rastogi, "India Utilities Sector: Plans versus Plants" Credit Suisse Equity Research, October 3, 2009.
49. Asian Water Development Outlook 2007.
50. Marc Levinson, Watching Water, JPMorgan Global Equity Research April 2008.

WORLD
RESOURCES
INSTITUTE

10 G Street, NE
Suite 800
Washington, DC 20002
www.wri.org

ABOUT WRI

The **World Resources Institute (WRI)** is an environmental think tank that goes beyond research to create practical ways to protect the Earth and improve people's lives. Our mission is to move human society to live in ways that protect the Earth's environment for current and future generations.

Our programs meet global challenges by using knowledge to catalyze public and private action.

- To reverse damage to ecosystems. We protect the capacity of ecosystems to sustain life and prosperity.
- To expand participation in environmental decisions. We collaborate with partners worldwide to increase people's access to information and influence over decisions about natural resources.
- To avert dangerous climate change. We promote public and private action to ensure a safe climate and a sound world economy.
- To increase prosperity while improving the environment. We challenge the private sector to grow by improving environmental and community well-being.

In all its policy research, and work with institutions, WRI tries to build bridges between ideas and actions, meshing the insights of scientific research, economic and institutional analyses, and practical experience with the need for open and participatory decision making.

HSBC Climate Change

ABOUT HSBC CLIMATE CHANGE CENTRE OF EXCELLENCE

The HSBC Climate Change Centre of Excellence was created in 2007, to help advise HSBC and its clients on the evolution and impacts of climate change. The team performs macro research on climate change science, policies and markets.

The Centre also publishes joint research pieces in collaboration with fundamental analysts, helping highlight valuation impacts of climate change. Global and country-specific reports highlight investment potential related to policy and market changes.

ISBN: 978-1-56973-742-2