STRANDED ASSETS

PROGRAMME

SMITH SCHOOL OF ENTERPRISE AND THE ENVIRONMENT

UNIVERSITY OF OXFORD

Stranded Assets and Subcritical Coal

The Risk to Companies and Investors

March 2015

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About the Stranded Asset Programme

Stranded assets are assets that have suffered from unanticipated or premature write-downs, devaluations, or conversion to liabilities and they can be caused by a variety of risks. Increasingly risk factors related to the environment are stranding assets and this trend is accelerating, potentially representing a discontinuity able to profoundly alter asset values across a wide range of sectors.

The Stranded Assets Programme at the University of Oxford's Smith School of Enterprise and the Environment was established in 2012 to understand environment-related risks driving asset stranding in different sectors and systemically. We research the materiality of environment-related risks over time, how different risks might be interrelated, and the potential impacts of stranded assets on investors, businesses, regulators, and policymakers. We also work with partners to develop strategies to manage the consequences of environment-related risks and stranded assets.

The programme is based in a world leading university with a global reach and reputation. We are the only academic institution conducting work in a significant and coordinated way on stranded assets. We work with leading practitioners from across the investment chain (e.g. actuaries, asset owners, asset managers, accountants, investment consultants, lawyers), with firms and their management, and with experts from a wide range of related subject areas (e.g. finance, economics, management, geography, anthropology, climate science, law, area studies) within the University of Oxford and beyond.

We have created the Stranded Assets Research Network, which brings together researchers, research institutions, and practitioners working on these and related issues internationally to share expertise. We have also created the Stranded Assets Forums, which are a series of private workshops to explore the issues involved. The Global Stranded Assets Advisory Council that guides the programme contains many of the key individuals and organisations involved in developing the emergent stranded assets agenda. The council also has a role in helping to informally co-ordinate and share information on stranded assets work internationally.

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The Programme is led by Ben Caldecott and its work is guided by the Global Stranded Assets Advisory Council chaired by Professor Gordon Clark, Director of the Smith School. The Council is also a high-level forum for work on stranded assets to be co-ordinated internationally. Members currently include:

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Executive Summary

Coal provides 40% of the world's electricity, with 1,617 GW of global capacity. Of this capacity, 75% is subcritical, 22% supercritical, and 3% ultra-supercritical. Subcritical is the least efficient and most polluting form of coal-fired generation - it requires more fuel and water to generate the same amount of power, and creates more pollution as a result. The average subcritical coal-fired power station (SCPS) emits 75% more carbon pollution than an average advanced ultra-supercritical - the most up-to-date form of coal-fired power station - and uses 67% more water. While the average age of all coal-fired power stations globally is 21 years, ultra-supercritical power stations are considerably younger, with an average age of just 5 years.

To limit global emissions to a level consistent with a 2°C future, the IEA estimates that it will be necessary to close 290 GW of subcritical generation worldwide by 2020. Subcritical coal accounted for 8.6 GtCO2 of emissions globally in 2009. For context, in 2010 annual gross greenhouse gas emissions globally totalled ~50 GtCO2-equivalent, with ocean and land sinks absorbing just over 50% of these emissions, resulting in net atmospheric emissions of around 22 GtCO2 per annum.

Since SCPSs are the least efficient and most greenhouse gas (GHG) intensive centralised generation technology, they are both vulnerable to regulation and a logical first step in any climate mitigation strategy. Furthermore, because subcritical plants are typically the oldest part of nations' power generation fleet, they may also represent a practical policy choice for closure by budget-constrained policymakers looking for cost-effective emissions reductions.

Coal-fired Environmental Effects by Generation Efficiency, Base-level = 100

Generation Efficiency	Carbon Intensity	Air Pollution	Water Stress
Old Inefficient Subcritical	100	100	100
Old Efficient Subcritical	84	84	85
New Subcritical	68	68	70
Supercritical	57	57	60
Ultra-Supercritical	52	52	55
Advanced Ultra-Supercritical	48	48	51

In addition to climate change policies targeting GHG emissions, due to their greater average fuel-burn, SCPSs are also more vulnerable to non-GHG policies, such as policies regulating the emission of PM, NOx, SOx, and mercury. SCPSs are also highly vulnerable to water policies. Given these three potential drivers of asset stranding - carbon intensity, air pollution, and water stress - we have examined the exposure of SCPSs to these risk factors. We have also examined which country and company SCPS portfolios are most exposed to these risks. As part of this process we have ranked company exposure to SCPSs affected by these three different environment-related risk factors. The full rankings of company exposure can be found in Section 5.

The objective of this research is to provide investors with the information required for screening, engagement, or divestment actions on the basis of exposure to the SCPS assets at most risk. SCPS assets are not identical, and investors (and companies) need the tools to identify which portfolios have assets with more (or less) exposure to environment-related risks.

Determining carbon, air pollution, and water stress exposure

We use the IEA's definition of SCPSs, which are power plants with carbon-intensity of ≥880kg CO2/MWh, with cutoffs of 880-1,120kg CO2/MWh defined for 'new subcritical', 1,120-1,340kg CO2/MWh for 'old efficient subcritical', and >1,340kg CO2/MWh for 'old inefficient subcritical'. To complete our analysis we have effectively defined the locations of all the world's power plants, the ownership of these plants, the annual megawatt hours of electricity produced at each plant, and the carbon intensity of each plant's electricity production.

To determine the potential vulnerability of SCPSs to air quality-related regulations, we took the 100km radius around each SCPS in the world and calculated the average satellite-based PM 2.5 observations within that area. Although we cannot directly attribute PM 2.5 levels measured to the corresponding SCPS, there is almost certainly a significant degree of causality, which may place plants in high PM 2.5 areas under greater risk from regulatory responses to air quality concerns.

Similarly, to determine the potential vulnerability of SCPSs to water-related regulations, we looked at the Baseline Water Stress (BWS) that SCPSs faced in their water catchment areas. SCPSs in extremely high water stress catchments, defined as watersheds with >80% withdrawal to available flow ratios, may be at more risk from water-related regulations or a shortage of water availability, than plants in areas with more water availability.

Company Portfolios

We analysed the world's 100 largest SCPS portfolios by total generation capacity - together these account for 66.2% of global subcritical generation. Globally, Chinese and US companies dominate in terms of size, with 7 out of the 10 largest SCPS portfolios being Chinese, and 6 of the largest 20 American. Government-owned companies[1] account for 59 of the world's 100 largest company SCPS portfolios, and over two-thirds of their generation. Among the remaining 41 non-government owned company portfolios, the United States (26), EU (5), and India (3) have the greatest number, whereas China[2], Indonesia, and South Africa have none. Where governments have a significant stake in SCPS portfolios, it is generally thought that they would be less likely to introduce policies that would directly strand their own assets. However, this view is being contradicted by recent policy tightening in both China and India.

We have identified the 20 most vulnerable large company portfolios according to carbon intensity, PM 2.5 pollution, and water stress. We find that Indian companies (5) dominate the tables for poor carbon efficiency, with former Soviet (6) and Chinese portfolios (5) also notable for their poor carbon performance. Chinese and Indian company portfolios monopolise the ranking for being located in areas with the worst PM 2.5 air pollution, with respectively, 15 and 5 firms in this largest 20. And China (6) and India (5) also have the greatest number of company portfolios that are under the most acute water stress.

Footnotes:

[1] Government-owned companies are defined as those for which a controlling interest in the company (>50%) is held by the state.

[2] With the exception of CLP from Hong Kong.

National Breakdown of the World's Company SCPS Portfolios

	Total number of companies with SCPS assets	Number of companies in the largest 100 company SCPS portfolios†	Percentage of companies in the largest 100 company SCPS portfolios that are government-owned
World	4,128	100	59%
China	368	19	95%‡
United States	391	29	10%
EU	899	12	58%
India	391	15	87%
Australia	19	4	50%
South Africa	9	1	100%
Indonesia	223	2	100%

† Largest 100 SCPS portfolios defined in terms of total MWh.

‡ The non-government owned company is CLP based in Hong Kong.

China: SCPS Fleet on the Wrong Side of the Kuznets Curve

The outlook for the Chinese SCPS fleet is poor. The GHG, non-GHG, and water regulatory regimes around coal-fired power generation in China are tightening. While it is likely that the impact on generation will be nationwide, SCPSs in the heavily polluted and water-scarce northeastern region will be most heavily impacted. Given the young age of Chinese SCPSs and enormous size of the SCPS stock in northeastern China, this may well create a significant number of stranded SCPS assets through forced closure and impairment of profitability.

In addition to regulatory risk, physical water scarcity is a serious risk to a significant portion of the SCPS fleet, with nearly 37% of the fleet located in watersheds with high water stress and 33% of the fleet in watersheds with both high water stress and mean 100km Radius PM 2.5 pollution above WHO levels. Because of the severity of this pollution, both water availability and air quality should be considered a significant direct risk to the profitability of plants and indirectly via reputation. Potential reputational risks will increase over the short term in northwestern provinces as a result of tightening regulatory regimes that will push coal-fired generation westward, away from population centres and water resources. Previous analysis suggests that this shift will cause severe supply capacity problems beginning in 2015.[3]

US and EU: Existing and Impending Regulations Close Ageing Generators

The US and EU SCPS fleets face similar and seemingly final challenges. Both fleets are ageing, significant amounts of subcritical generation capacity have recently been closed by regulation, and future regulations promise further closures.

Footnotes:

[3] Greenpeace (August 2012). Thirsty Coal: A Water Crisis Exacerbated by China's New Mega Coal Power Bases.

In the US, non-GHG policies will force the closure of at least 16% of SCPS capacity in 2015. Proposed regulations on maximum allowable GHG emissions will essentially preclude the construction of coal-fired power plants without carbon capture and storage. Furthermore, proposed state-based GHG emission reductions promise to put further pressure on existing SCPSs. Early analysis of this proposed regulation suggests that $28 billion in industry value will eventually be stranded, though immediate plant closures are expected to be minimal.

In the EU, little regulatory pressure is expected from the EU ETS. However, Europe's non-GHG emission policies have and will continue to close significant amounts of coal-fired generation. 35GW of capacity have been closed by the Large Combustion Plant Directive, an amount that may still increase by the end of 2015. This scheme will transition to the Industrial Emissions Directive, which has the potential to close up to 40GW of Europe's remaining 150GW of coal-fired capacity by 2023.

India: Water Already a Serious Risk Factor

The Indian SCPS fleet faces serious water-related risks that are threatened to worsen, with currently 33% of generators located in areas of extremely high water stress. Since 2010, water scarcity has forced significant plant suspensions, which greatly impact plant profitability and lead to rolling blackouts. While companies such as India's NTPC, state that they secure water guarantees from state governments for the lifetime of plants before construction, this can create direct competition with irrigation for agriculture. This competition has already resulted in political tensions and social unrest, and should be considered a serious reputational risk.

Nearly one in three Indian SCPSs are located in areas of water stress and also have mean 100km Radius PM 2.5 levels which exceed the WHO limit. Although no forthcoming direct regulatory policies that would require the installation of emission scrubbers, electrostatic precipitators, or FGD units were identified, the possibility of market-based mechanisms to control NOx and SO2 pollution should be considered a serious future risk to the Indian SCPS fleet.

Beyond this risk, there are two additional regulatory risks to the Indian SCPS fleet. The first is the Perform, Achieve, Trade (PAT) mechanism, an energy efficiency trading scheme that is designed to financially disadvantage less efficient plants. Because this mechanism affects subcritical plants more severely than newer supercritical plants, this policy decreases the profitability of the least efficient and oldest portions of India's SCPS fleet. The second regulatory risk is India's 2012 National Water Policy; however, the Government of India has not specified mechanisms, tools, or charges related to this policy. Thus, there exists great uncertainty for SCPSs in water-stressed areas in terms of profitability and licenses to operate.

Implications for Investors, Companies, and NGOs

There is a strong case for financial institutions to utilise the information contained in this report to evaluate the risk of companies that hold subcritical assets and, where appropriate to then screen, engage, or divest. As part of further analysis and engagement with companies exposed to at risk subcritical assets, investors and civil society could encourage companies to: i) publicly confirm their exposure and the proportion of their total generation portfolio that is subcritical, ii) disclose what proportion of this is most at risk, for example, the bottom quartile in terms of carbon intensity, air pollution, and water stress, iii) disclose how much of their capex pipeline is subcritical and how this might change portfolio risk exposure, and iv) describe the strategies employed at an asset-level and across a portfolio to minimise carbon intensity and manage deleterious contributions to local air pollution and water stress.

Summary of Possible Responses

Relevant SCPS Stakeholders	Possible Responses
Fixed-Income Investors	Reassess required yields Divest if necessary
Ratings Agencies	Reassess company ratings
Equity Investors	Reassess required returns Demand that management reduce environmental and regulatory risks Divest if necessary
Bank Loan Assessment	Reassess lending rates Resell risky loans
Environmental Groups	Target environmentally irresponsible nations and companies for improvement

Research Extensions

This report has analysed the global stock of the world's most carbon inefficient and heavily polluting power stations. Refinement of this data, such as by developing a timeline for projected global SCPS capacity, or incorporating additional individual plant-level information on plant age, boiler type, installed pollution abatement technologies, coal-fuel specifications, cooling methods, and the percentages of total generation which consists of SCPS would allow for more fine-grained analyses of national fleets and company portfolios. Future research might also cast a critical eye on the relationship between SCPS and other coal pollutants, such as NOx, SOx and mercury. Another possible extension would be to assess the upstream constraints of further coal generation expansion by overlaying SCPSs against proximate coal mines and coal delivery infrastructure capacity.

1. Introduction

The international community needs options for addressing the most significant contributors to anthropogenic climate change. One option, presented publicly by Christiana Figueres, executive secretary of the United Nations Framework Convention on Climate Change (UNFCCC), is the closure of subcritical coal-fired power stations (SCPSs).[4] To limit global emissions to a level consistent with a 2°C future, it is necessary to close a quarter or 290 gigawatts (GW) of subcritical generation worldwide by 2020.[5]

Since SCPSs are the least efficient and most greenhouse gas (GHG) intensive centralised generation technology, they are both vulnerable to regulation and a logical first step in any climate mitigation strategy. Furthermore, because subcritical plants typically represent the oldest part of nations' power generation portfolios, they may also represent a practical policy choice for closure by budget-constrained policymakers looking for cost-effective emissions reductions.

This paper was written to provide analysis to support financial and company decision-making in relation to SCPSs. It will help investors to identify and screen specific companies with exposure to SCPS assets at particular risk from climate policy, air pollution, and water stress – which are the three environment-related risks that we concentrate on here. The paper is structured in the following way: in the next section we present an overview of SCPS technology and compare it with other forms of coal-fired generation technology. Section 3 outlines the most pressing environment-related risks to SCPSs, particularly CO2 intensity, Particulate Matter (PM) 2.5 pollution, and physical water scarcity. After assessing these issues at a global scale and seeing how they could affect SCPSs, Section 4 drills down to see how SCPSs could be affected in its largest markets, namely China, US, EU, India, Australia, South Africa, and Indonesia, which together account for 93% of global SCPS generation. Section 5 extends the analysis of SCPS to the world's 100 largest SCPS portfolios. Section 6 concludes.

Footnotes:

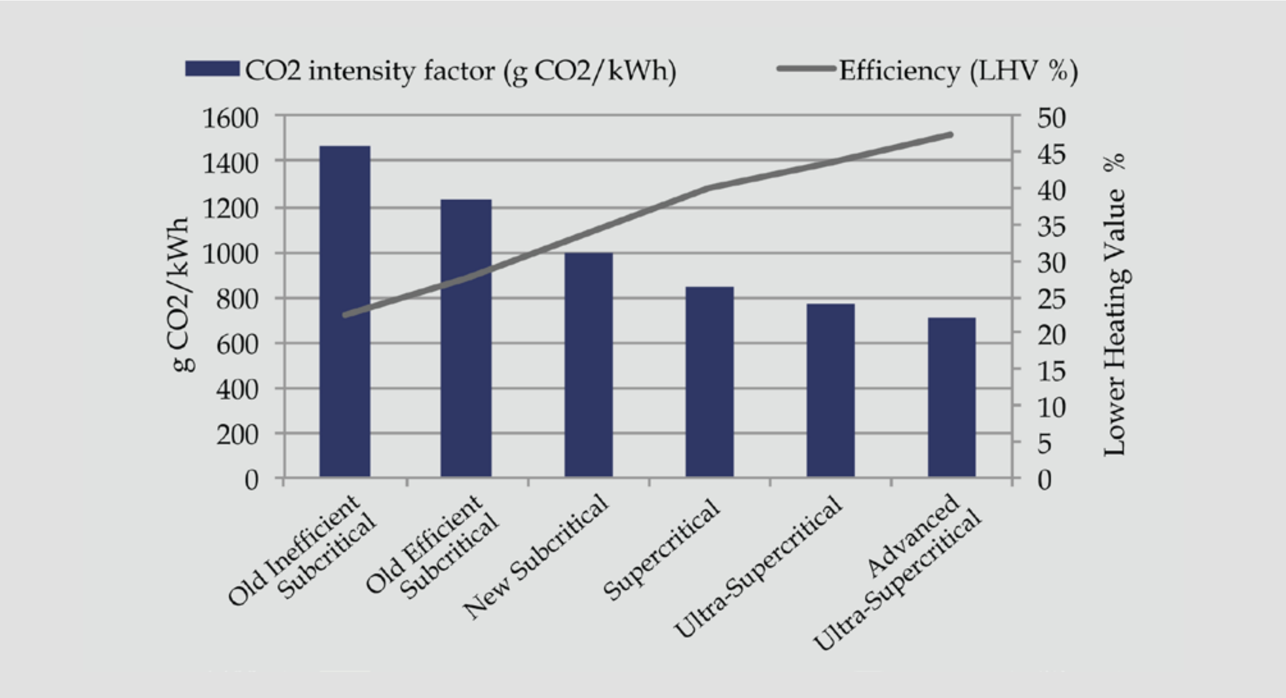
[4] HSBC (17 January 2014). "Coal and carbon revisited."
[5] IEA (2013). Redrawing the Energy Climate Map. Paris, France.

2. Subcritical Coal-Fired Technology

Technologically Vulnerable

Subcritical Coal-fired Power Stations (SCPSs) are generators that use subcritical boilers. These boilers operate at relatively lower pressures and temperatures, which leads to an inefficient steam cycle in generation because water is present both as liquid and gas.[6]

Figure 1: Average CO2 Intensity and Efficiency by Coal-fired Generation Boiler Type



Source: IEA (2013)

Table 1: Coal-fired Environmental Effects by Generation Efficiency, Base-level = 100

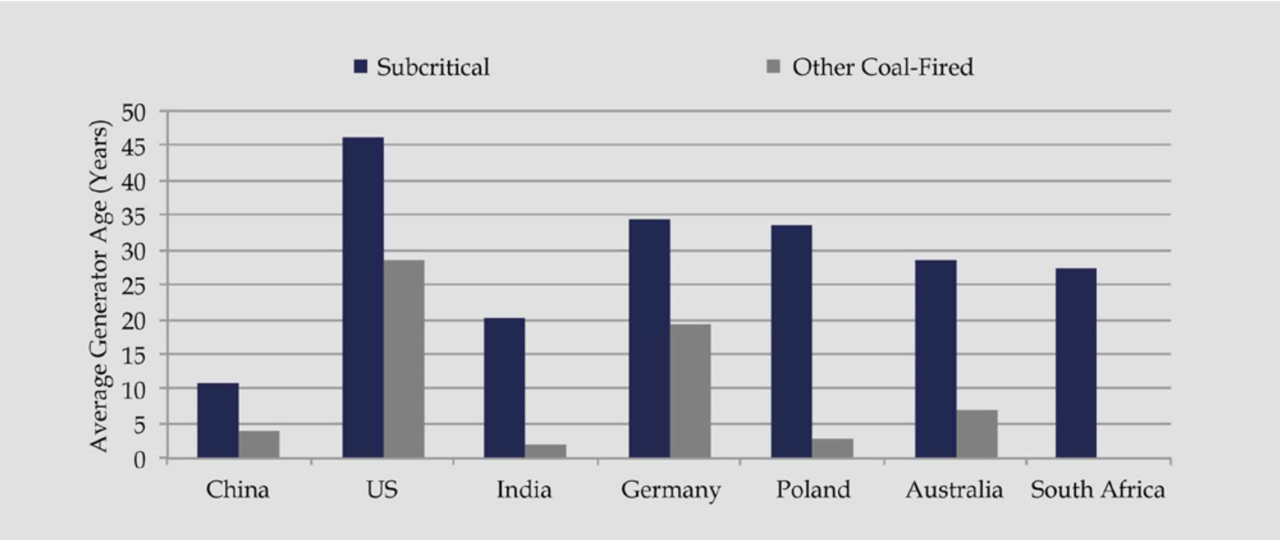
Generation Efficiency	Carbon Emissions	Air Pollution	Water Use
Old Inefficient Subcritical	100	100	100
Old Efficient Subcritical	84	84	85
New Subcritical	68	68	70
Supercritical	57	57	60
Ultra-Supercritical	52	52	55
Advanced Ultra-Supercritical	48	48	51

Note: Indicated levels of environmental effects based off of ceteris paribus generating conditions for a closed-cycle wet-cooled plant. Water stress levels based off of EPRI (2008).

Footnotes:

[6] Susta, M. and K. B. Seong (2004). Supercritical and Ultra-Supercritical Power Plants - SEA's Vision or Reality?, PowerGen Asia.

Figure 2: Age of Coal-Fired Generation Stock



Source: Caldecott and Mitchell (Forthcoming 2015)

In addition to efficiency, the age of generators also plays a role in their regulatory vulnerability. Because of the age of subcritical boiler technology, SCPSs represent the oldest part of national generation stocks. This is significant for two reasons.

- First, ageing stations are significantly less likely to have non-GHG emission abatement technologies installed or to use the most water-efficient or dry cooling systems, when compared with newer generation capacity. This increases their vulnerability to non-GHG and water-related regulations.[7]
- Second, it is financially (and potentially politically) simpler to regulate the closure of older power stations This is because capital costs have typically been recovered after 35 years[8] and when generators are near or past their technical lives, the financial need to compensate is greatly reduced or eliminated.[9]

Vulnerability: GHG Policies

Because coal is the most emissions-intensive form of generation,[10] subcritical coal-fired power stations are the most carbon-intensive form of centralised electricity generation. Consequently, carbon regulations more heavily impact SCPSs than any other form of generation.[11] Although the efficiency of these power stations has improved over time, even the newest and most efficient subcritical generators are significantly more carbon-intensive than existing supercritical, ultra-supercritical, and forthcoming advanced ultra-supercritical technology.

Footnotes:

[7] These assertions are based on analysis of recent station closures in the US and EU using non-GHG direct regulation.

[8] IEA (2014). Energy, Climate Change and Environment.

[9] Caldecott, B. and J. Mitchell (Forthcoming 2015). "Generating Implications for Climate Policy: The Premature Retirement of Subcritical Coal-Fired Generation and the Potential Role of Compensation." Stranded Assets Programme, Smith School for Enterprise and Environment, University of Oxford.

[10] Moomaw, W., G. Burgherr, M. Heath, M. Lenzen, J. Nyboer and A. Verbruggen (2011). 2011: Annex II: Methodology. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. O. Edenhofer, R. Pichs-Madruga, Y. Sokona et al. Cambridge, United Kingdom and New York USA, Cambridge University Press.

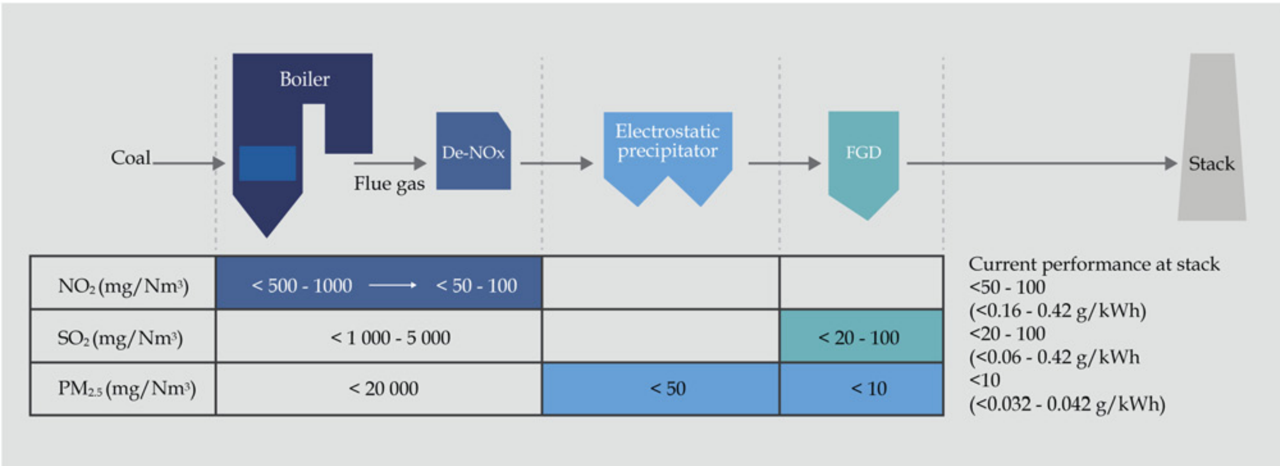
[11] Susta, M. and K. B. Seong (2004). Supercritical and Ultra-Supercritical Power Plants - SEA's Vision or Reality?, PowerGen Asia.

The limited work on subcritical coal-fired power generation thus far focuses on the role of SCPS closures in climate change mitigation scenarios.[12] Because they are the least efficient, in these scenarios SCPS are closed quickly and at large scales. For instance, IEA modelling of a power sector transition compatible with 2°C global warming suggests that it would rely on the closure of 25% of SCPS capacity (290GW) by 2020.[13]

Vulnerability: Non-GHG Policies

Because of their greater average age and fuel-burn requirements, SCPSs are typically also more vulnerable to non-GHG policies, such as policies regulating the emission of PM, NOx, SOx, and mercury. But the relationship between boiler efficiency and non-GHG emissions is not as straightforward as the relationship with CO2 emissions. The largest factor in determining station PM, NOx, and SOx emissions is whether emission abatement technologies have been installed.[14]

Figure 3: Effectiveness of Non-GHG Emission Abatement Technologies



Source: IEA (2012)

Technically the impact of station efficiency on pollutant emissions is small when compared with the installation of abatement technologies. However, experience provides strong evidence that because subcritical stations are older, they are less likely to have emission abatement technologies installed, and are therefore most likely to be closed by non-GHG emission policies.[15]

Two highly relevant examples of this are the planned closure of 16% of US subcritical capacity by the Mercury and Air Toxics Standard (MATS)[16] and the closure or planned closure of 8% of European coal-fired capacity (all of which is subcritical capacity) by the Large Combustion Plant Directive.[17]

Footnotes:

[12] IEA (2014). Energy, Climate Change and Environment.

[13] IEA (2013). Redrawing the Energy Climate Map. Paris, France.

[14] IEA (2012). Technology Roadmap: High Efficiency, Low-Emissions Coal-Fired Power Generation. Paris, France, OECD/IEA.

[15] MIT (2009). Retrofitting of Coal-Fired Power Plants for CO2 Emissions Reductions, MIT Energy Initiative Symposium.

[16] MATS was the main factor in station closures, however competition from gas was also a factor Johnson, E. (2014). Planned coal-fired power plant retirements continue to increase, U.S. Energy Information Administration.

[17] Sandbag (July 2014). "Europe's failure to tackle coal: Risks for the EU low-carbon transition."

Vulnerability: Water Policies

Coal-fired Rankine-cycle (steam) power stations are second only to nuclear power stations in water use. Cooling is by far the largest use of water in these power stations. The largest factor in determining the water-efficiency of stations is the type of cooling system installed. Secondary factors are the ambient temperature and station efficiency.

Table 2: Water Withdrawals (Litres/MWh)

Cooling Technology				
Fuel-Type	Once-Through	Closed-Cycle (Wet)	Hybrid (Wet/Dry)	Dry Cooling
Coal	95,000-171,000	2,090-3,040	1,045-2,755	~0
Gas	76,000-133,000	1,900-2,660	950-2,470	~0
Oil	76,000-133,000	1,900-2,660	950-2,470	~0
Nuclear	133,000-190,000	2,850-3,420	Applicability[1]	Applicability[1]

[1]Use of hybrid and dry cooling only recently considered for nuclear plants.

Source: EPRI (2008)

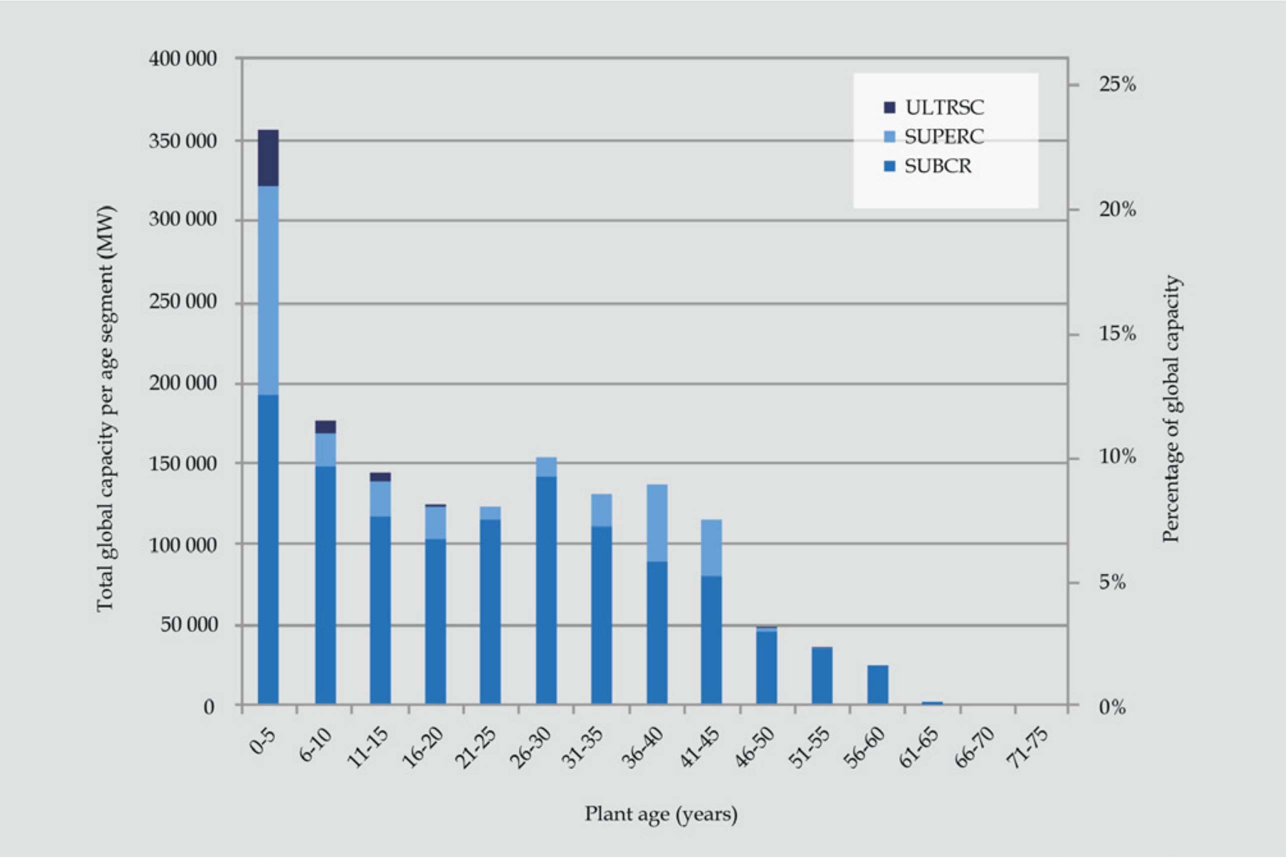
Within fossil-based power generation, SCPSs are highly vulnerable to water policies because of two factors. First, because subcritical stocks are older, they are less likely to have water-efficient or dry cooling technologies installed. Second, regardless of installation of water-efficient technologies, such as closed cycle or hybrid cooling systems, the higher heat rate (low-efficiency) of the boilers requires significantly more cooling water for a given unit of output.

3. Analysis of Global SCPS Capacity

Global SCPS Overview

Coal currently provides 40% of the world's electricity with 1,617GW of global capacity. It is also the world's fastest growing source of power, with an additional 1,112GW expected by 2035.[18,19] Coal-fired power plants that are both carbon-intensive and old are at the highest risk of compulsory closure because of their greater environmental impact and because less financial compensation would be required to induce closure.

Figure 4: Global Coal-fired Power Station Fleet Performance and Age



Source: IEA (2012)

Of total global coal-fired capacity, currently 75% is subcritical, 22% supercritical, and 3% ultra-supercritical. While the average age of the global coal-fired power plant fleet is 21 years, supercritical and ultra-supercritical power plants are considerably younger. While the average age of the global coal-fired power plant fleet is 21 years, supercritical and ultra-supercritical power plants are considerably younger.

Footnotes:

[18] IEA (2012). CCS Retrofit: Analysis of the Globally Installed Coal-Fired Power Station Fleet. Paris, France, OECD/IEA.

[19] World Coal Association (2014). Coal Facts 2014.

Table 3: World Coal-fired Power Station Fleet Age

	Total capacity (GW)	Average age (years)	Subcritical average age (years)	Supercritical average age (years)	Ultra-supercritical average age (years)
World	1,617	21	23	18	5

Source: IEA (2012)

Table 4: World Coal-fired Power Station Fleet Performance

Share of Total Coal Power Stations that are...					
	Subcritical	Supercritical	Ultra-supercritical	Older than 35 years	Older than 35 years AND Subcritical
World	75%	22%	3%	23%	18%

Source: IEA (2012)

SCPS Carbon Intensity

Following the IEA, this report defines SCPS as power plants with carbon-intensity of ≥880kg CO2/MWh, with cutoffs of 880-1,120kg CO2/MWh defined for 'new subcritical' (coloured in yellow), 1,120-1,340kg CO2/MWh for 'old efficient subcritical'(orange), and >1,340kg CO2/MWh (red) for 'old inefficient subcritical'.[20]

Nationally, China and the United States have the largest SCPS fleets by total generation, but due to rapid growth India's fleet is scheduled to become a close second to China. Australia has by far the most carbon-intensive SCPS fleet, followed by India and Indonesia.

Table 5: National SCPS Fleet Generation and Carbon Intensity

	Number of SCPS	Total SCPS TWh	Percentage of world SCPS TWh	Mean SCPS carbon intensity (kg CO2/ MWh)†
World	7,446	7,349	100.00%	1,042
China	930	2,718	36.98%	1,048
United States	665	1,539	20.94%	1,040
EU	1,280‡	729	9.92%	1,051
India	608	783	10.65%	1,058
Australia	22	162	2.20%	1,132
South Africa	25	194	2.64%	1,034
Indonesia	337	87	1.18%	1,058

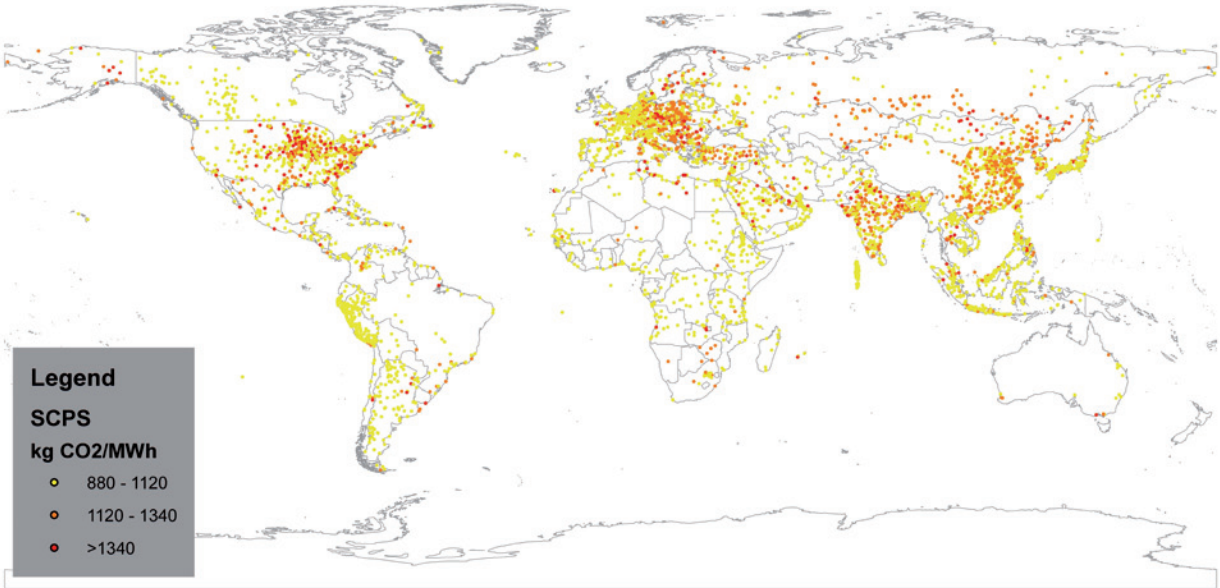
† SCPS mean carbon intensity is weighted by MWh of generation. The unweighted global SCPS mean carbon intensity is not materially different at 1,047 kg CO2/MWh.

‡ The EU has a particularly large number of micro power plants with poor carbon efficiency.

Footnotes:

[20] IEA (2012). Technology Roadmap: High Efficiency, Low-Emissions Coal-Fired Power Generation. Paris, France, OECD/IEA.

Figure 5: Existing SCPS by Carbon Intensity



SCPSs and PM 2.5 Air Pollution

As is discussed in Section 2, SCPSs are highly vulnerable to policies that mandate; (i) efficiency improvements, (ii) the installation of emission abatement technologies, or (iii) plant closure. In addition, SCPSs in locations with poor air quality are even more likely to come under regulatory pressure because, ceteris paribus, they must burn more coal for a given unit of output, and therefore contribute disproportionately to reducing local air quality.

Of the pollutants associated with coal combustion, particulate matter (PM) is considered to be the most hazardous to human health. PM consists of the fly ash and dust particles generated during coal combustion,[21] and is commonly classified into groups of either below 10 (PM 10) or below 2.5 (PM 2.5) microns in diameter,[22] with PM 2.5 considered to be the more dangerous of the two. These fine particles consist of a mixture of all the air pollutants associated with coal combustion,[23] and due to their small size can penetrate deep into the lungs and enter the bloodstream directly.

To determine the potential vulnerability of SCPSs to air quality-related regulations, we took the 100km radius around each SCPS in the world and calculated the average of the PM 2.5 observations from Boys, Martin et al. (2014) measured within that radius[24]. Although we cannot directly attribute PM 2.5 levels measured within each 100km radius to emissions from the corresponding SCPS, there is almost certainly a significant degree of causality relevant for policy makers.

Footnotes:

[21] These particles can contain noxious compounds such as: acid droplets, arsenic, beryllium, cadmium, chromium, lead, manganese, nickel, radium, selenium, and other metals.

[22] Micron = One millionth of a meter: about 1/20th the width of a human hair.

[23] PM particles can consist of noxious compounds such as: acid droplets, arsenic, beryllium, cadmium, chromium, lead, manganese, nickel, radium, selenium, and other metals.

[24] On average there were 270 PM 2.5 observations within each 100km radius. See appendix for PM 2.5 air pollution data sources and methods.

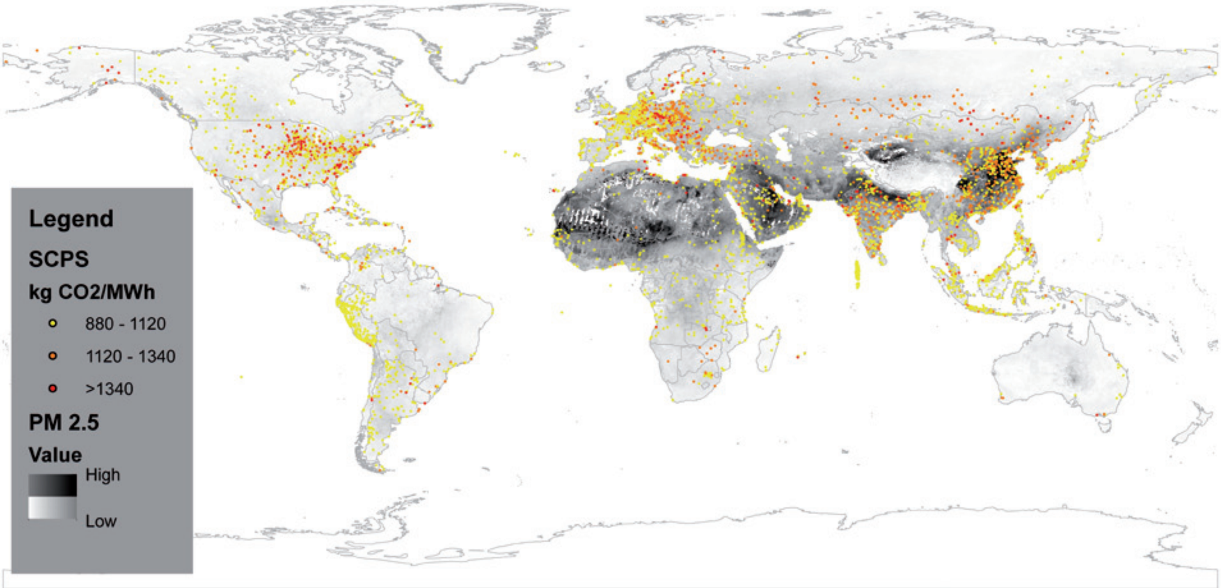
National analyses showed that almost 90% of SCPSs in India and China have average PM 2.5 pollution levels within a 100km radius of their plants which exceed the WHO sanctioned annual average limit (20 µg/m3). In the case of China, nearly two-thirds of all SCPSs are in locations which also exceed their own national PM 2.5 limit (35 µg/m3), while in India only about one-fifth of SCPSs violate the Indian national standard (40 µg/m3).

Table 6: National SCPS Fleet Ambient Air Pollution

	SCPS mean 100km Radius PM 2.5 Levels (µg/m3)	Number of SCPSs located in areas with air pollution exceeding the WHO PM 2.5 limit	Percentage of SCPSs located in areas with air pollution exceeding the WHO PM 2.5 limit	National PM 2.5 Limit (µg/m3)	Number of SCPSs located in areas with air pollution exceeding their national PM 2.5 limits	Percentage of SCPSs located in areas with air pollution exceeding their national PM 2.5 limits
World	15	2,092	28.10%	20	n/a	n/a
China	50	825	88.71%	35	618	66.45%
United States	7	0	0.00%	12	0	0.00%
EU	12	38	2.97%	25	0	0.00%
India	32	539	88.65	40	115	18.91%
Australia	2	0	0.00%	8	0	0.00%
South Africa	8	0	0.00%	25	0	0.00%
Indonesia	8	0	0.00%	none	n/a	n/a

Note: The WHO Annual Average PM 2.5 limit is 20 µg/m3. Indonesia lacks a PM 2.5 limit. The South African PM 2.5 limit is scheduled to be tightened from 25 to 20 µg/m3 beginning January 2016. 'SCPSs located in areas with air pollution exceeding [specified] PM 2.5 limits' consist of SCPSs which have average observed PM 2.5 levels within 100km which exceed the specified limits.

Figure 6: Existing SCPS by Carbon Intensity and PM 2.5 Air Pollution



Desert conditions produce natural PM 2.5 that is also recorded by satellites as pollution. This effect is responsible for the high levels of PM 2.5 measured across the Sahara, Arabian, and Taklamakan deserts. Natural PM 2.5 is not as deleterious to human health as by-products of coal combustion.

SCPSs and Water Stress

Because SCPSs require greater water inputs for a given amount of generation, local water stress is also a factor that may affect the vulnerability of SCPSs to regulation. The measure for water stress used in this report is Baseline Water Stress (BWS) from Aqueduct created by the World Resources Institute (WRI). BWS is defined as total annual water withdrawals (municipal, industrial, and agricultural) expressed as a percent of the total annual available flow within the given catchment area. Higher values indicate greater competition for water among users. Extremely high water stress areas are defined by WRI as watersheds with >80% withdrawal to available flow ratios, 80-40% as high water stress, 40-20% as high to medium, 20-10% as medium to low, and <10% as low.

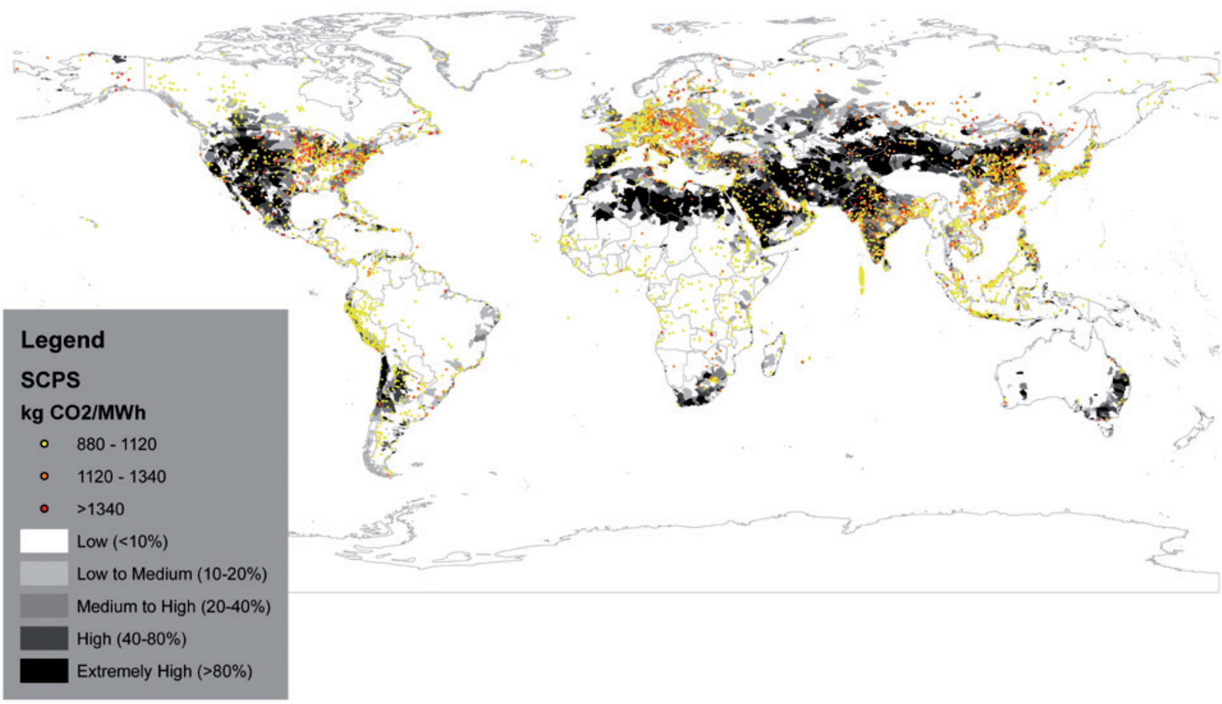
In addition to severe air pollution problems, SCPSs in China and India are also subject to some of the highest levels of water stress globally, with over one-third of SCPSs located in areas defined by Aqueduct as under 'extremely high water stress'. In India and particularly in China, power plants under 'extremely high water stress' also tend to be located in areas with poor air quality – compounding the total environmental impact of each SCPS.

Table 7: National SCPS Portfolios Water Stress and Combined Air Pollution

	Mean SCPSs catchment area water stress	Percentage of SCPSs in extremely high water stress catchments	Number of SCPSs in extremely high water stress catchments AND located in areas with air pollution exceeding WHO PM 2.5 limits	Percentage of SCPSs in extremely high water stress catchments AND located in areas with air pollution exceeding the WHO PM 2.5 limit	Number of SCPSs in extremely high water stress catchments AND located in areas with air pollution exceeding their national PM 2.5 limits	Percentage of SCPSs in extremely high water stress catchments AND located in areas with air pollution exceeding their national PM 2.5 limits
World	28.59%	20.64%	837	11.24%	n/a	n/a
China	54.44%	37.10%	311	33.44%	259	27.85%
US	32.33%	14.74%	0	0.00%	0	0.00%
EU	31.64%	7.58%	0	0.00%	0	0.00%
India	51.31%	33.06%	195	32.07%	65	10.69%
Australia	40.69%	13.64%	0	0.00%	0	0.00%
South Africa	36.43%	24.00%	0	0.00%	0	0.00%
Indonesia	36.54%	31.16%	0	0.00%	n/a	n/a

Note: Extremely High Water Stress is defined as BWS>80%. 'SCPSs located in areas with air pollution exceeding [specified] PM 2.5 limits' consist of SCPSs which have average observed PM 2.5 levels within 100km which exceed the specified limits.

Figure 7: Existing SCPSs by Carbon Intensity and Baseline Water Stress



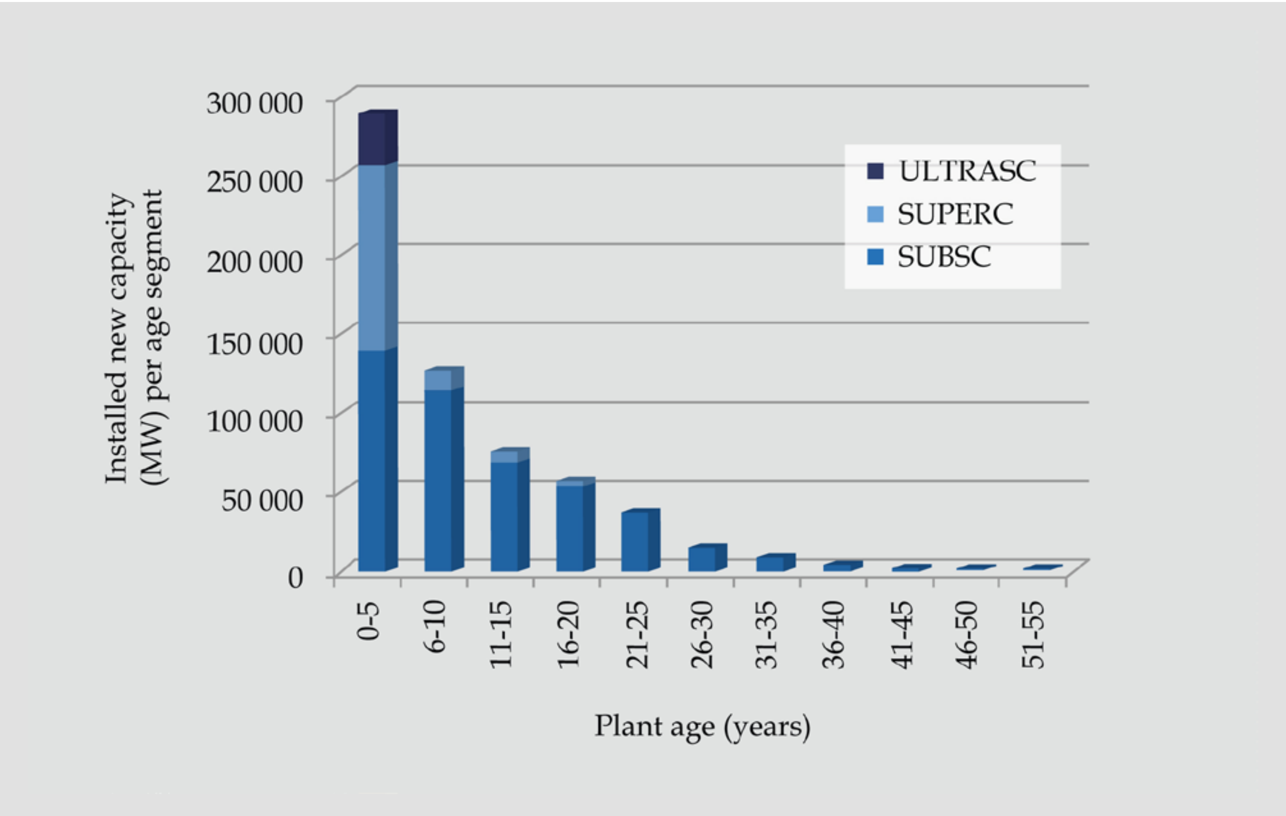
4. Analysis of National SCPS Fleets

Here we analyse some of the largest national SCPS portfolios in countries that together account for 83% of global SCPS capacity. These are: China (34% of global capacity), United States (26%), EU (9%), India (7%), Australia (3%), South Africa (3%), and Indonesia (1%). For each country we; (i) provide an overview of the makeup of national coal-fired power generation, (ii) examine the efficiency of SCPSs and identify and discuss the implications of forthcoming GHG policies, (iii) overlay PM 2.5 pollution and discuss forthcoming non-GHG emission regulations, and (iv) gauge water stress and forthcoming water policies that might impact SCPSs.

China

Overview of Subcritical Stock and Trends

Figure 8: Chinese Coal-Fired Generation by Age and Boiler Technology



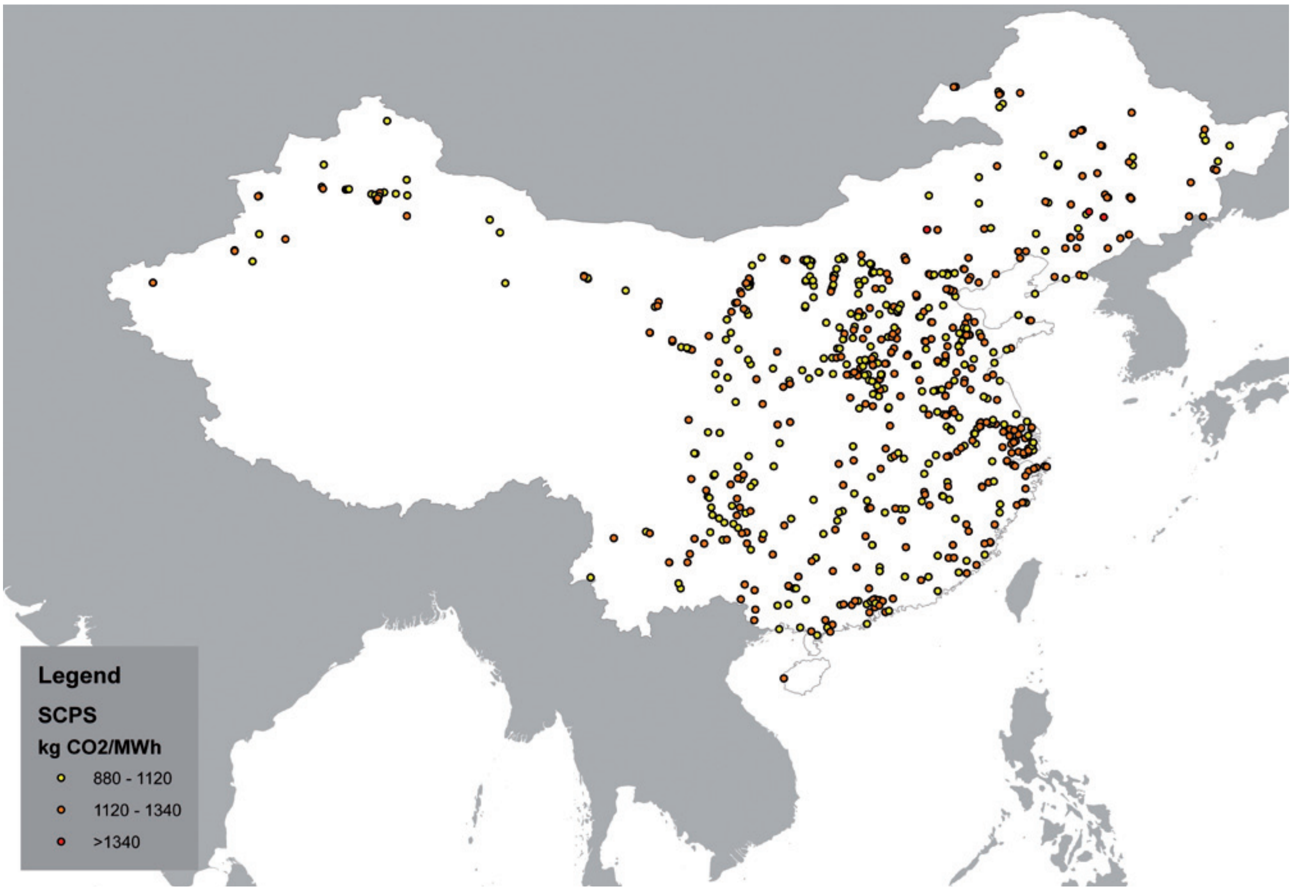
Source: IEA (2012)

China's operational coal-fired capacity is 669 GW, with around 25% of that capacity utilising supercritical and ultra-supercritical boilers. Its coal fleet is also very young compared with other large nations.

Coal-fired power companies in China have suffered significant financial losses in recent years – a reality that receives little attention outside of China. According to a State Electricity Regulatory Commission report, the largest five Chinese power companies lost a total of RMB 15 billion (USD2.4 billion) in their coal-power generation businesses in 2011. This was due to two factors. Coal prices were relatively high due to domestic production and transport constraints and electricity prices were capped in 2007 by the Chinese government to ease the effects of 6.5% inflation. Though coal prices have since dropped, the economic slowdown, a suite of new regulations to control air pollution, and a large increase in clean energy sources now puts pressure on the Chinese coal-fired power generation sector.[25]

Station Efficiency and Forthcoming GHG Policies

Figure 9: SCPS in China by Carbon Intensity



While SCPSs are concentrated in the more heavily industrialised east, carbon intensity is generally uniform across the country and China has notably few plants with emissions greater than 1,340kg CO2/MWh. This is likely due to the success of the Large Substitutes Small program, which required generating companies to close smaller, inefficient generators in order to build new generators.

Footnotes:

[25] Cornot-Gandolphe, S. (2014). Generating Implications for Cimate Policy: China's Coal Market: Can Beijing Tame King Coal? University of Oxford, The Oxford Institute for Energy Studies.

China is trialling policies to reduce the carbon-intensity of its economy and control GHG emissions. Existing and forthcoming policies suggest that China has both the will and capacity to regulate carbon. These policies will impact the Chinese SCPS fleet heavily.

- First, in 2013, China began piloting an Emissions Trading Scheme (ETS) in seven provinces. This is a core strategy for achieving the stated goal of a 40-45% reduction of 2005 carbon intensity of GDP by 2020.[26]
- Second, these pilot ETSs are intended to provide experience for the implementation of a national ETS in 2016[26] and potentially a nationwide carbon taxation scheme in 2018.[28] Although it remains unclear how a carbon taxation scheme might interact with the ETS, it will provide much broader coverage than the local ETSs, which currently cover 7% of Chinese GHG emissions.[29]
- Third, China has pledged to cap total emissions by 2030 in an agreement with the US. Although certain media outlets have stated that the implementation of this emission cap could occur as early as the 13th FYP (2016-2020), these reports could not be verified.[30]
- Fourth, China has capped domestic coal production at 3.9 Mt as well as established an import levy on coal. The short-term purpose of these policies is to stabilise falling coal prices, which will in turn affect the profits of generators.

Footnotes:

[26] Carbon Tracker (2014). The Great Coal Gap: China's energy policies and the financial implications for thermal coal, ibid.

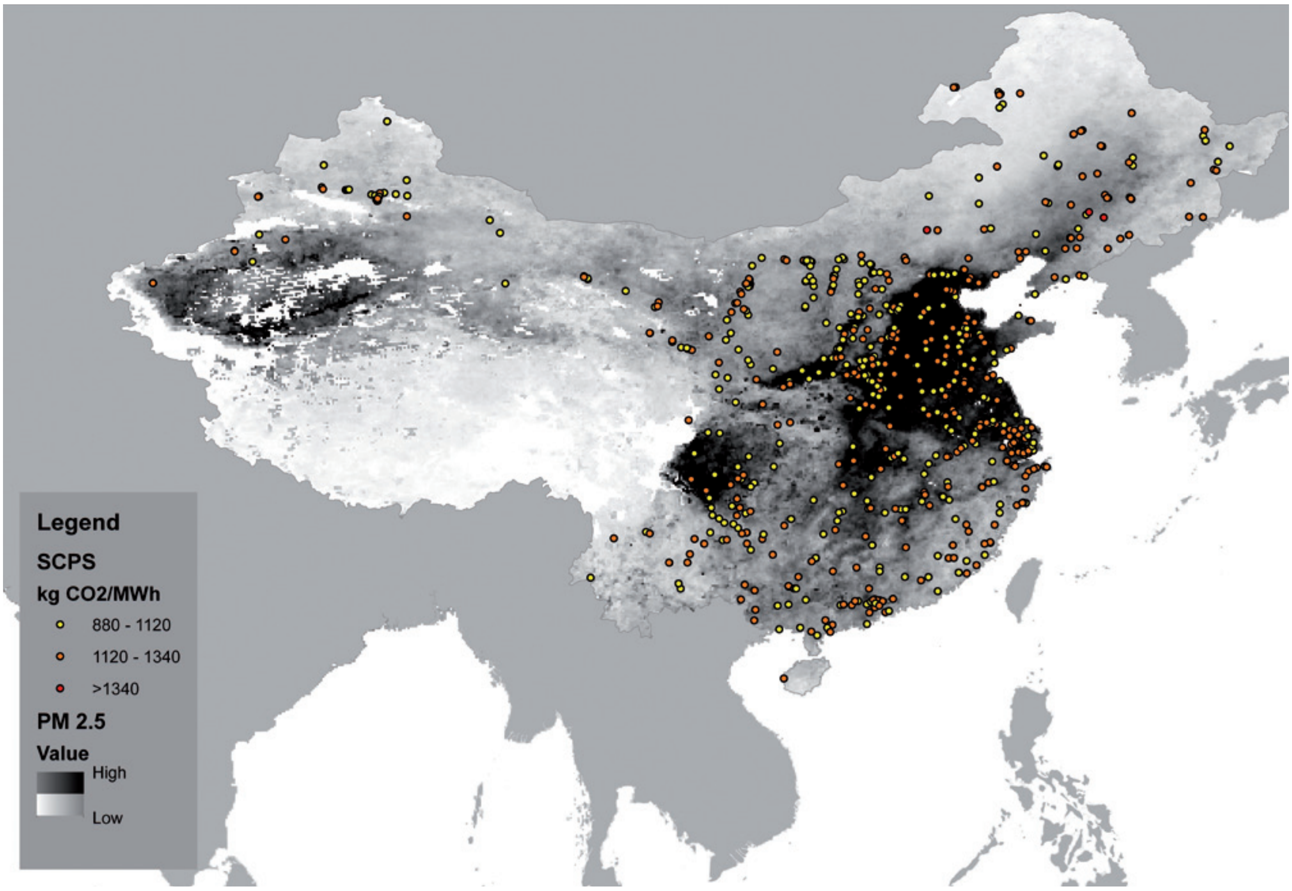
[27] Cornot-Gandolphe, S. (2014). Generating Implications for Cimate Policy: China's Coal Market: Can Beijing Tame King Coal? University of Oxford, The Oxford Institute for Energy Studies.

[28] ICAP (January 2014). Emissions Trading Worldwide: International Carbon Action Partnership (ICAP) Status Report 2014.

[29] Carbon Tracker (2014). The Great Coal Gap: China's energy policies and the financial implications for thermal coal, ibid.

[30] Taylor, L. and T. Branigan (12 Nov, 2014). US and China strike deal on carbon cuts in push for global climate change pact. The Guardian. London. http://www.theguardian.com/environment/2014/nov/12/china-and-us-make-carbon-pledge.

Figure 10: SCPS by Carbon Intensity with PM 2.5 Pollution in China



PM 2.5 Pollution and Forthcoming Non-GHG Emission Policies

In an effort to reduce air pollution, China has introduced air quality targets for PM 2.5 and PM 10 for all provinces through the 2013 Action Plan for Air Pollution Prevention and Control. The targets, which are meant to be met by 2017, are generally most stringent in areas with large amounts of coal-fired generation. For example, in the heavily industrialised northeast, Beijing, Tianjin, Hebei are expected to improve PM 10 levels by 10% and PM 2.5 by 25%; whereas Sichuan, Guizhou, and Yunnan are expected to improve PM 10 levels by only 0-5%.

In reaction to air pollution measures, 12 provinces, which account for 44% of Chinese coal consumption, have pledged to measure and reduce coal consumption.

- Provinces with absolute coal consumption reduction targets include Beijing, Tianjin, Hebei, Shandong, Shanxi, and Chongqing. These targets range from 5-50%.
- Other areas that have pledged 'negative growth' are the Yangtze River Delta and the Pearl River Delta.
- Jilin and Liaoning have pledged no more than 2% growth in coal consumption per year.[31]

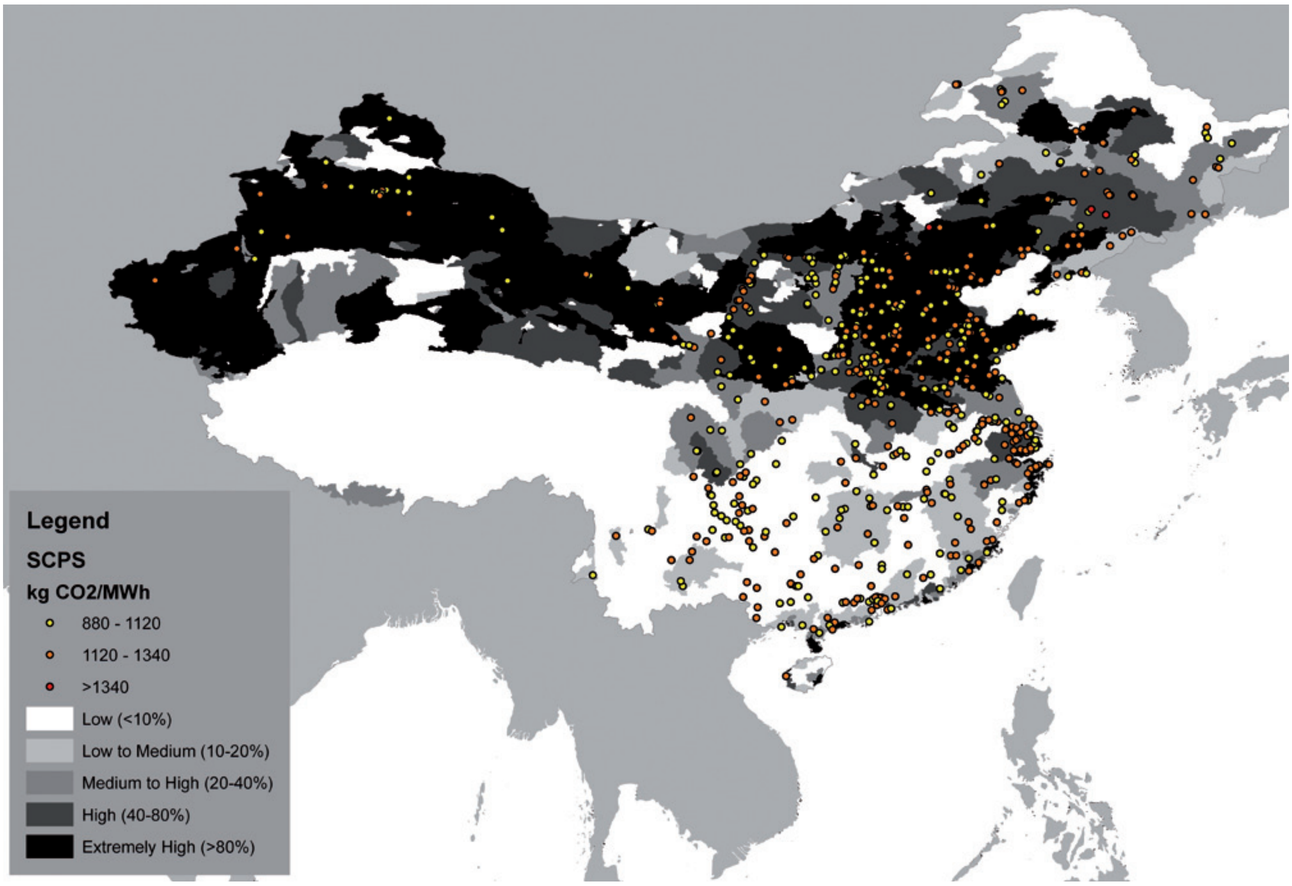
Footnotes:

[31] TShuo, L. and L. Myllyvirta (April 2014). The End of China's Coal Boom - 6 Facts You Should Know, Greenpeace.

These measures are expected to decrease coal consumption by an average of around 10% in these provinces,[32] likely negatively impacting SCPSs. China's Ministry of Finance and Environmental Protection has also submitted draft regulations to operate NOx and SO2 trading schemes, though it is not known when these would come into effect.[33]

Water Stress and Forthcoming Water Policies

Figure 11: SCPS by Carbon Intensity with Water Stress in China



Due to the geographical mismatch between water resources and industrialised centres, much of China's existing and planned future coal-fired capacity is in areas experiencing water stress (1,000-1,700 m3 per capita p.a.), scarcity (500-1,000 m3 per capita p.a.), or extreme scarcity (<500 m3 per capita p.a.).[34]

China's 12th FYP introduces provincial water quotas through the 'Most Stringent Water Management System Methods' programme. These quotas are most stringent in regions with highest water stress. This is likely to cause difficulties for water-intensive coal-fired generators in regions such as Shanghai, where a negative water consumption growth rate has been applied.[35]

Footnotes:

[32] Carbon Tracker (2014). The Great Coal Gap: China's energy policies and the financial implications for thermal coal, ibid.

[33] China Coal Resource (2014). A summary of local governments' recent measures to support the coal sector.

[34] Carbon Tracker (2014). The Great Coal Gap: China's energy policies and the financial implications for thermal coal, ibid.

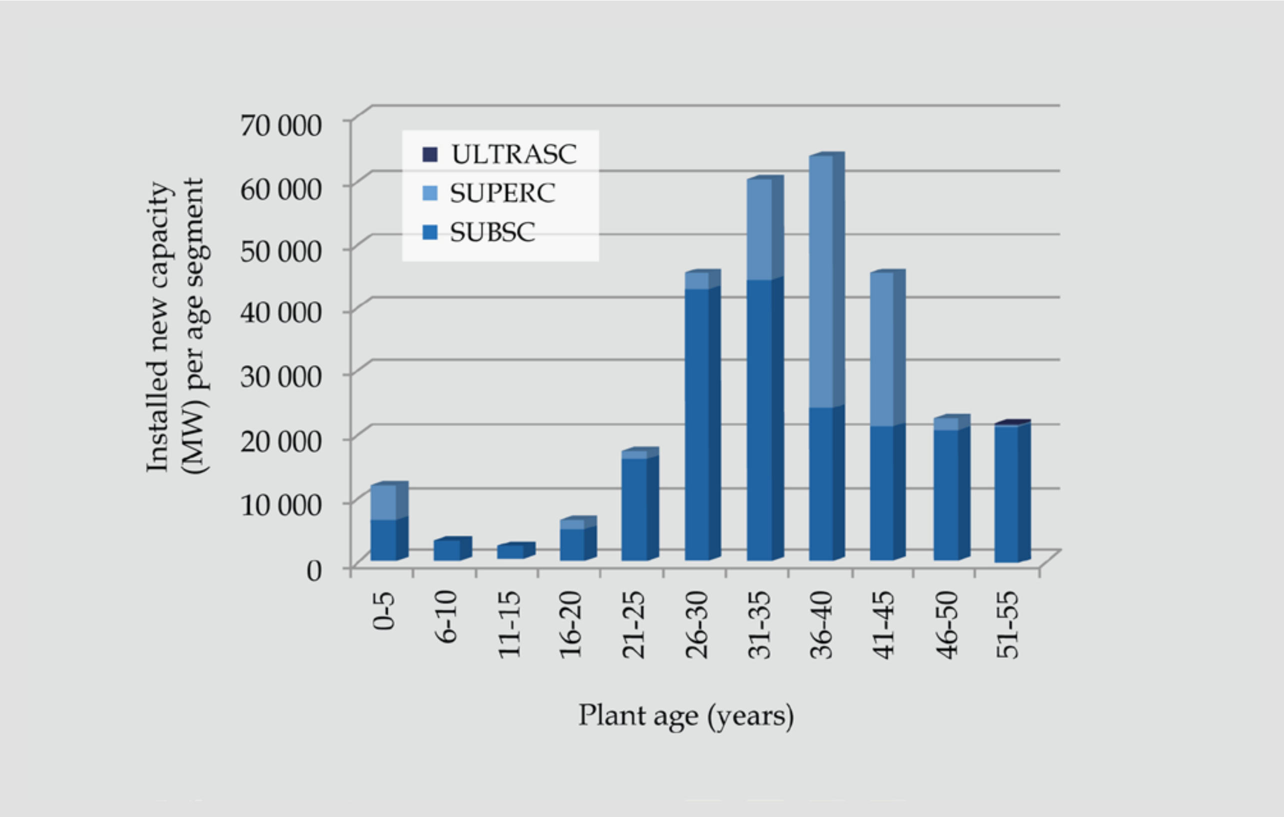
[35] Tan, D. (2013) "Water Fees & Quotas: Set for Economic Growth?".

Further water risks include the joint release of the Water Resources Fee by the Ministry of Finance and the Ministry of Water Resources. This scheme aims to balance local economic development with available water resources through a pricing scheme, strict controls on groundwater exploitation, and punitive measures for excess consumption.[36]

United States

Overview of Subcritical Stock and Trends

Figure 12: United States Coal-Fired Generation by Age and Boiler Technology



Source: IEA (2012).

Note: US coal-fired stations older than 55 years are not shown.

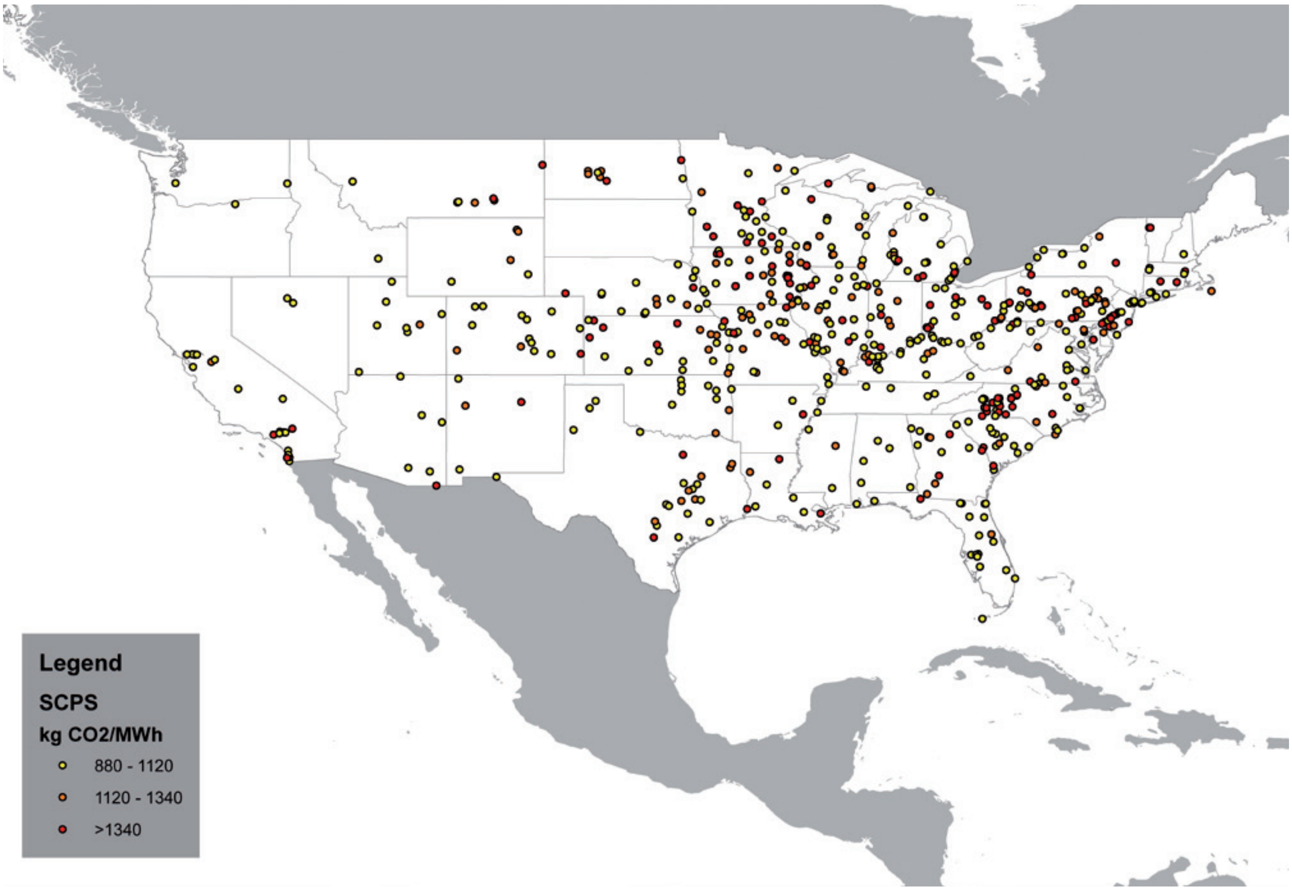
The US coal-fired capacity is 336GW, the second largest national fleet. Of this coal-fired capacity, 73% is subcritical. The US also has the oldest stock of SCPSs with an average age of 40 years, and the largest share of plants older than 35 years of the countries/regions studied. The advanced age of US plants increases the regulatory vulnerability of its existing SCPS stock. There is currently only one coal-fired plant without CCS either planned for or currently under construction.

Footnotes:

[36] Ibid.

Station Efficiency and Forthcoming GHG Policies

Figure 13: SCPS in the United States by Carbon Intensity



The US does not have a legislated nationwide climate policy or a legislative branch at the federal level that might approve one in the foreseeable future. Yet, two proposed regulations are likely to ban the construction of new coal-fired generation and strand some subcritical assets.

Using the Clean Air Act, the Environmental Protection Agency has proposed the following regulations:

- Standards of Performance for Greenhouse Gas Emissions From New Stationary Sources: Electric Utility Generating Units
- Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units

Currently in draft form, a final version of the Standards of Performance for Greenhouse Gas Emissions from New Stationary Sources: Electric Utility Generating Units is expected in June 2015. It currently requires that all new coal-fired power stations emit no more than an average of 1,100 lbs CO2/MWh (500kg/MWh) per calendar year. This effectively bars the construction of new coal-fired stations without carbon capture and storage.[37]

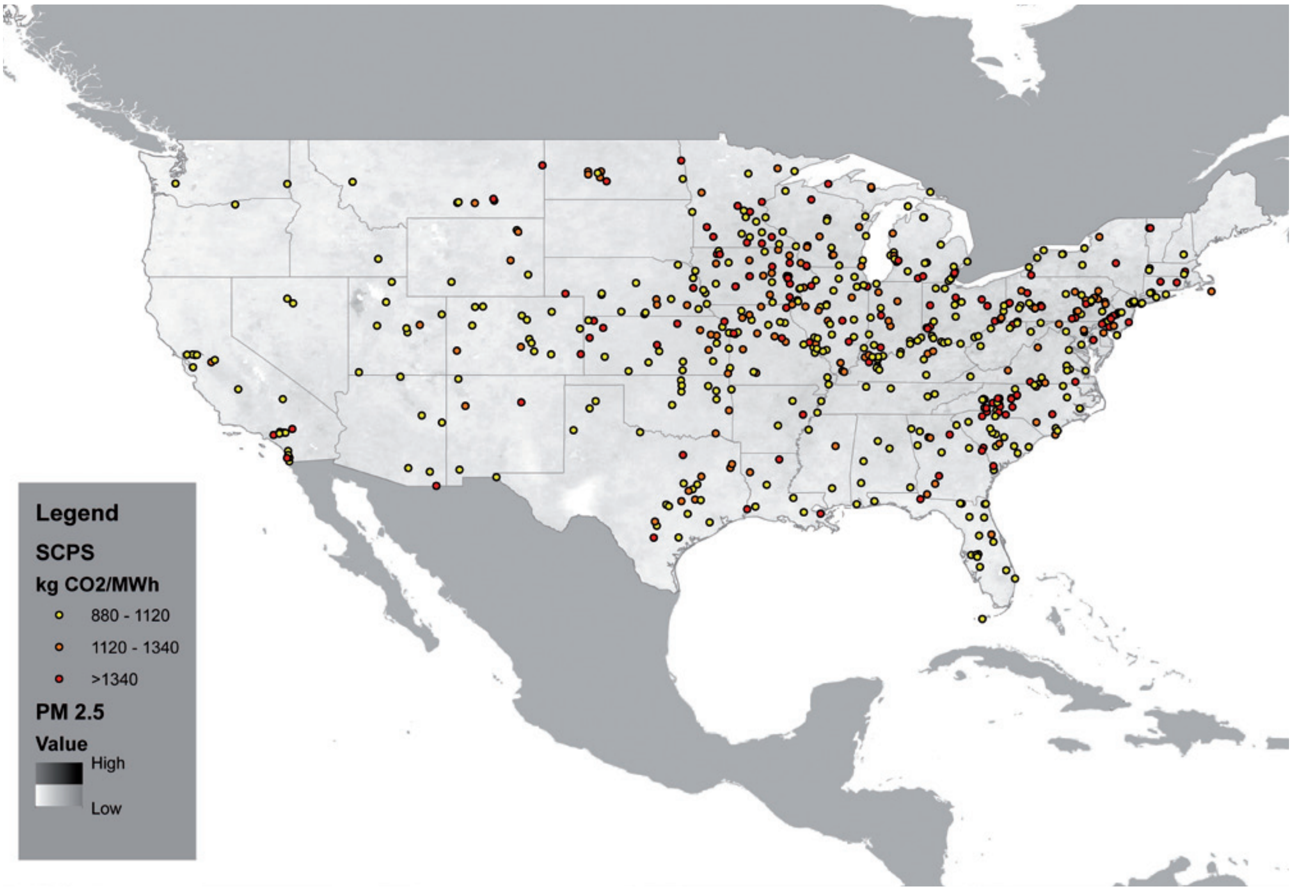
Footnotes:

[37] C2ES (November 2013). EPA Regulation of Greenhouse Gas Emissions from New Power Plants. U.S. Policy. Arlington, VA.

The proposed Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Unit seeks to reduce U.S. power sector emissions by setting state-specific emission reduction goals based on current generation mixes and renewable energy resources. CPI (2014) reported that if implemented this regulation would lead to USD28bn in lost value within the coal sector.[38]

PM 2.5 Pollution and Forthcoming Non-GHG Emission Policies

Figure 14: SCPS by Carbon Intensity with PM 2.5 Pollution in the United States



The Mercury Air Toxics Standard (MATS) limit emissions of mercury, toxic metals, and acidic gases from power stations. US power stations must meet these standards by 2016 if they wish to continue operation.

As of 2014, 70% of coal-fired generators have installed necessary abatement technologies and another 6% have plans to install abatement technologies necessary to operate past 2015. 16% of U.S. CSCPSs have announced plans for retirement by 2015. A further 16% of all coal-fired generators have yet to announce whether they plan to install abatement technologies or close prior to 2016.[39] The EIA attributes these closures to competition from gas-fired production as well as the MATS.[40]

Footnotes:

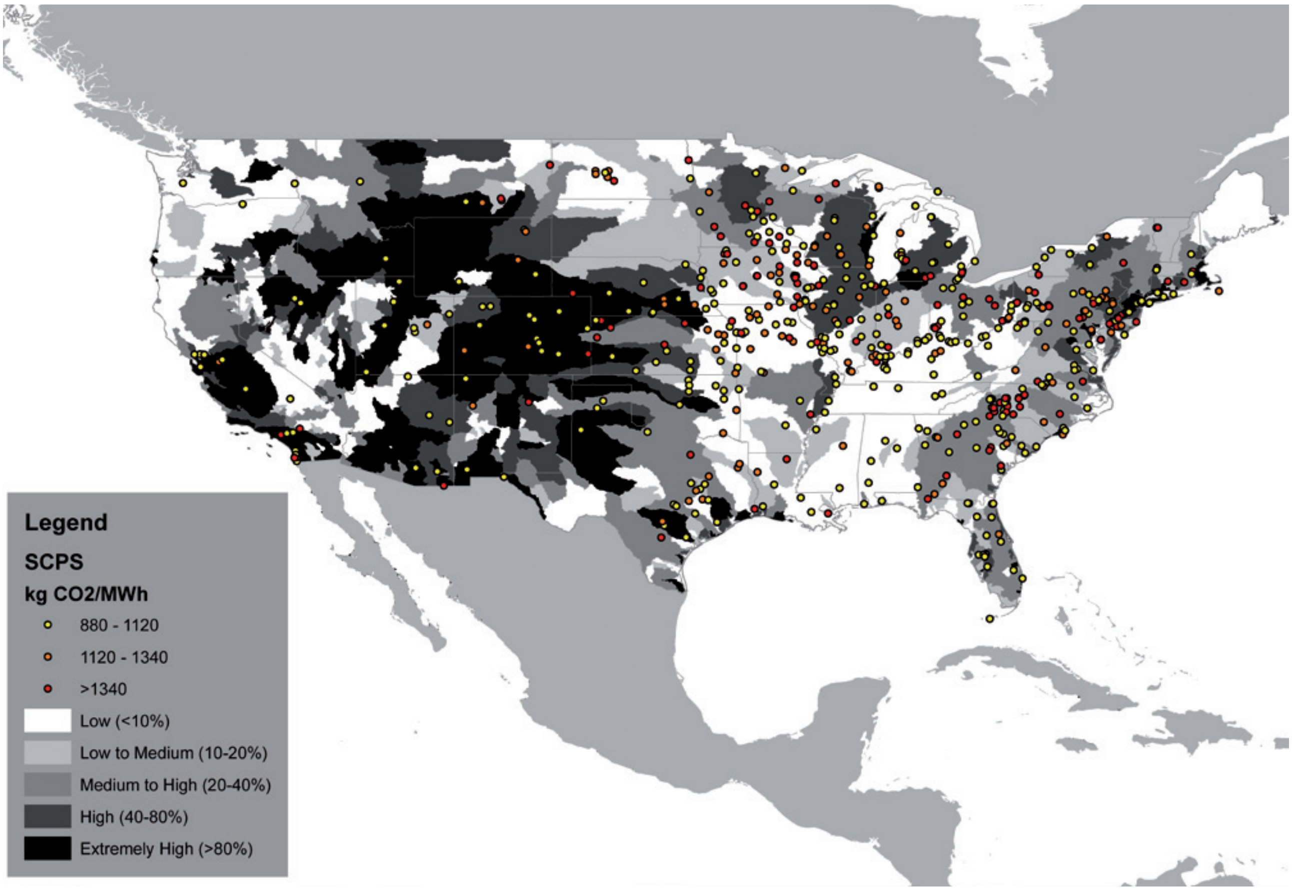
[38] Climate Policy Initiative (2014) "Moving to a Low-Carbon Economy: The Financial Impact of the Low-Carbon Transition.".

[39] Mitchell, J. (2014). Premature retirement of sub-critical coal assets: the potential role of compensation and the implications for climate policy, University of Oxford.

[40] IEA (2010). World Energy Outlook 2010. R. Priddle. Paris, France, OECD/IEA.

Water Stress and Forthcoming Water Policies

Figure 15: SCPS by Carbon Intensity with Water Stress in the United States



While 52% of US coal-fired power stations use once-through cooling systems,[41] there are no known forthcoming federal regulations on further regulating quantity of water withdrawal. Proposed regulations on cooling water intakes are expected to have minimal impacts on the financial sustainability of power stations in the US.[42] Water shortages is the western US, particularly in California, are of concern, however.

As the western US faces increasingly severe water shortages, it should be expected that states follow California's lead. In 2010, the California State Water Resources Control Board approved a measure to ban the use of once through cooling technology on coal-fired power plants. This will force 19 plants to retrofit their cooling systems between 2010 and 2024.[43] While no plants have announced closure plans due to the cost of retrofits, this should be considered yet another risk factor for the ageing US SCPS fleet, which is facing an increasingly inhospitable regulatory environment.

Footnotes:

41 EIA (2014). Many newer plants have cooling systems that reuse water. U. S. E. I. Administration.

42 EPA (2014). Cooling Water Intakes. U. S. E. P. Agency.

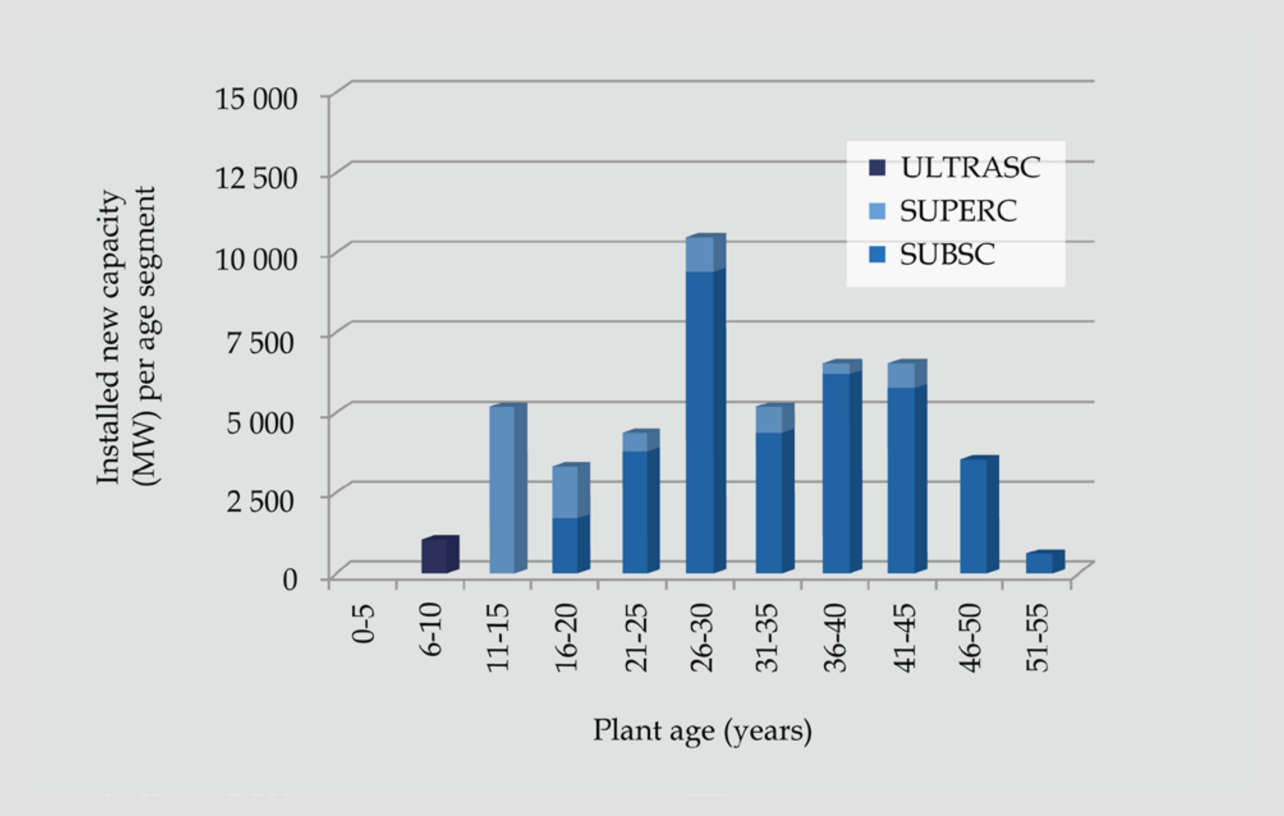
43 California's Clean Energy Future (2011). Once Through Cooling Phase-Out.

European Union

Overview of Subcritical Stock and Trends

Comprehensive breakdowns of the ages and efficiency of all the coal-fired plants in the European Union were not available. However, this data was identified for the three EU nations with the largest shares of subcritical generation in the EU: Germany (34%), Poland (21%), and incompletely for the United Kingdom (13%).

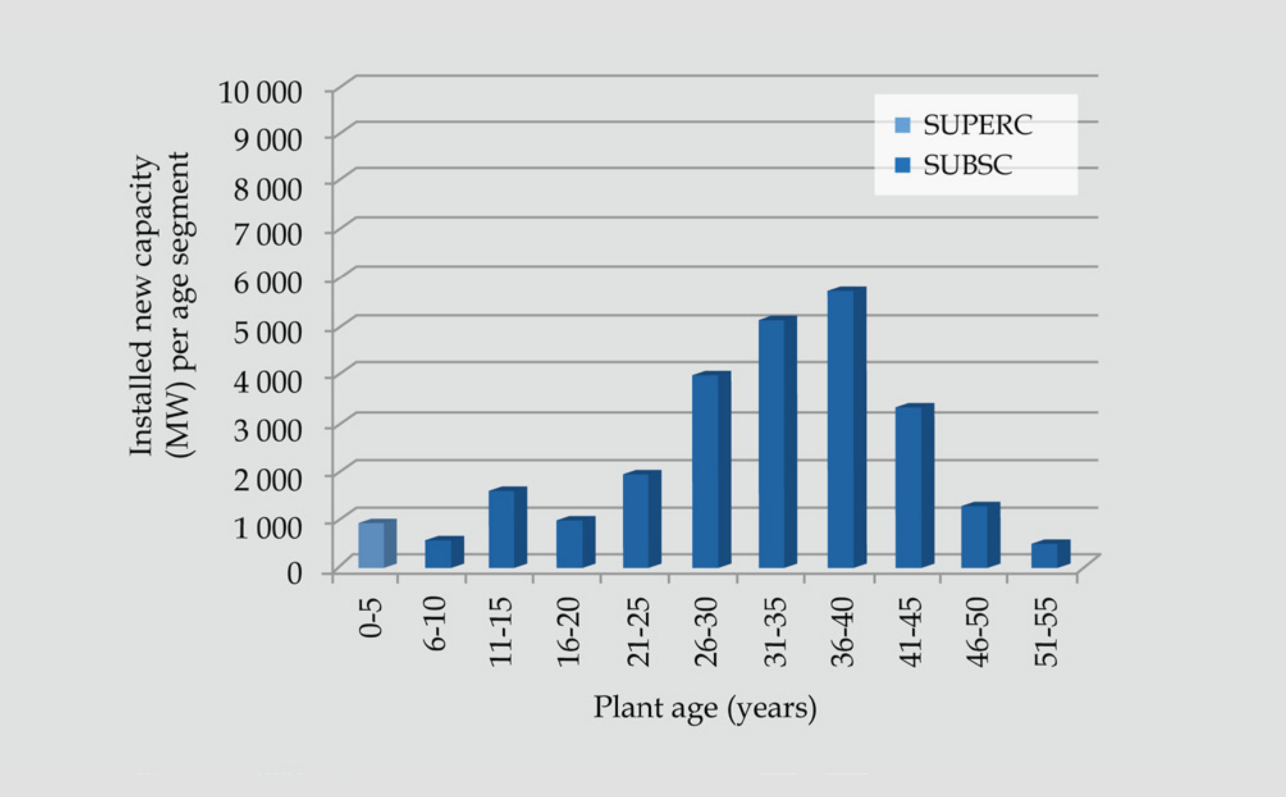
Figure 16: Germany Coal-Fired Generation by Age and Boiler Technology



Source: IEA (2012).

German coal-fired generation totals 51GW. Supercritical or ultra-supercritical technologies now account for 19% of total generation. These technologies have been constructed in Germany since the 1970s, and exclusively so since Germany signed the Kyoto Protocol in 1998.

Figure 17: Poland Coal-Fired Generation by Age and Boiler Technology



Source: IEA (2012).

Poland's 32GW coal fleet, by contrast, only began constructing supercritical plants after it entered the EU in 2004, and this technology only accounts for 3% of its total generation.

The United Kingdom has 12 coal-fired power plants with a total capacity of 20GW, and this consists exclusively of subcritical generation.[44] In total, the EU has 150GW of coal-fired capacity, of which 65% is subcritical.[45]

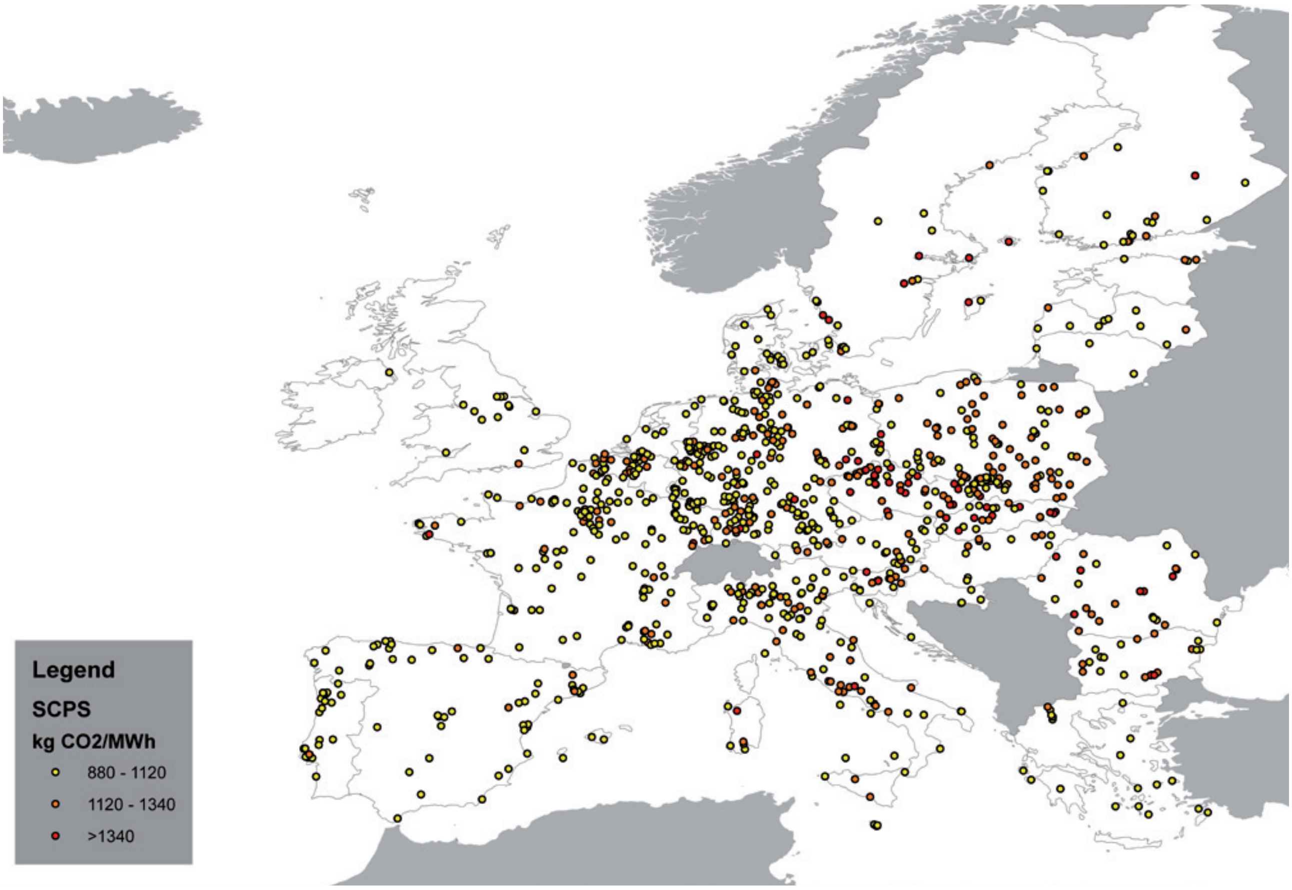
Footnotes:

[44] IEA (2013). Tracking Clean Energy Progress 2013. Paris, France, OECD/IEA.

[45] IEA (2013). World Energy Outlook 2013. Paris, France, OECD/IEA.

Station Efficiency and Forthcoming GHG Policies

Figure 18: SCPS in the European Union by Carbon Intensity



The carbon intensity of SCPSs is highest in the eastern EU. A key part of the EU's flagship Climate and Energy Package is the EU ETS. The EU ETS has been in operation alongside other national policies since 2006. However, because of the low price of carbon credits and cost of alternative fuels, coal-fired generation has recently increased in Germany, for example.

Over allocation of carbon credits is recognised and initiatives are underway to address this by reducing the total number of emission credits available annually starting in 2021.[46] Although it remains to be seen how effective this policy will be, it has the potential to impact coal-fired generators more significantly. That said, carbon prices capable of closing or even displacing older coal-fired generators are likely to be unrealistic in the short to medium term (3 to 7 years). Analysis by the IEA suggests that a carbon price equivalent to 110 USD/tonne is necessary to close an existing coal-fired generator and replace it with a new CCGT station in Germany. While a carbon price equivalent to 60 USD/tonne leads to the despatch of existing CCGT stations ahead of coal-fired stations.[47]

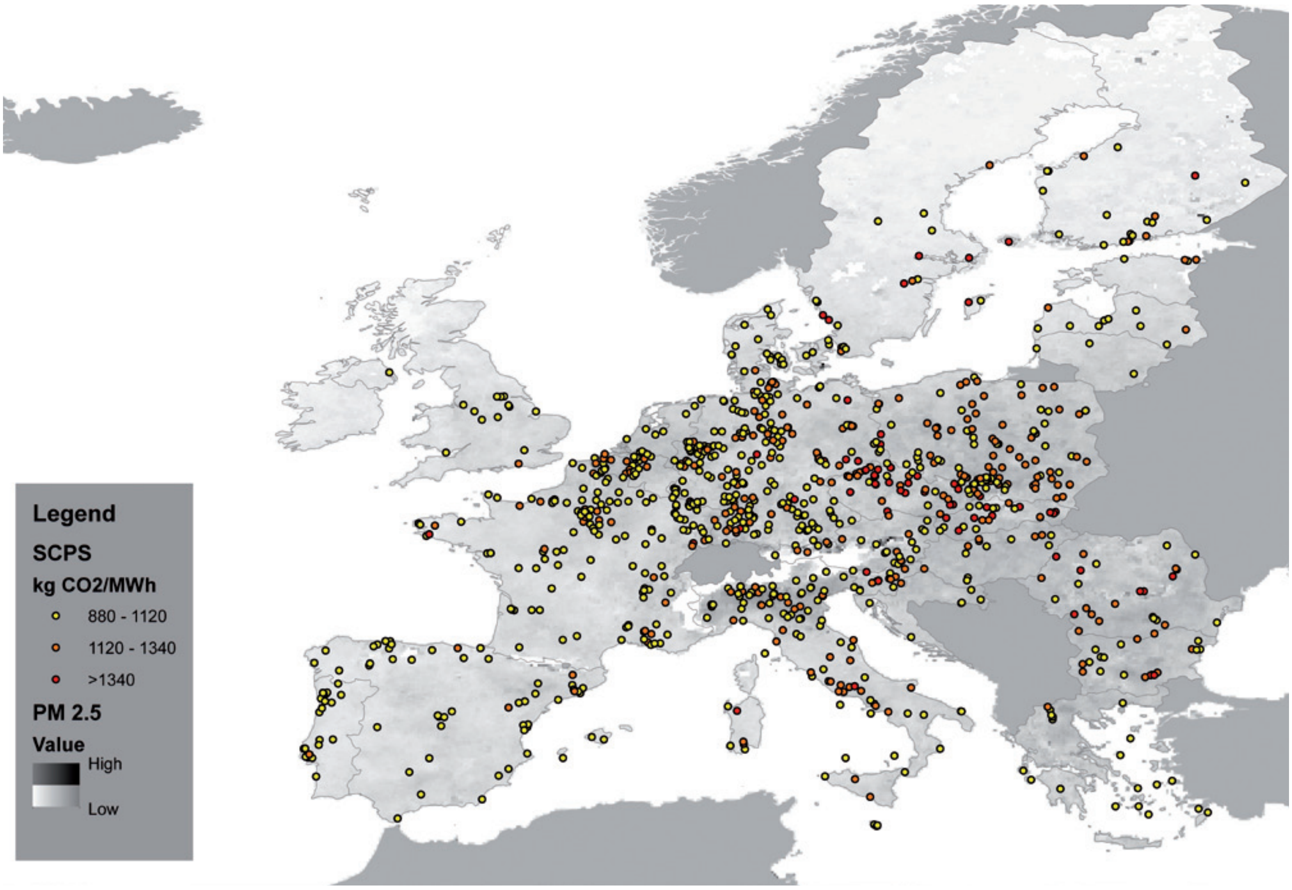
Footnotes:

[46] GLOBE International (2014). The GLOBE Climate Legislation Study: A Review of Climate Change Legislation in 66 Countries.

[47] IEA (2014). Energy, Climate Change and Environment.

PM 2.5 Pollution and Forthcoming Non-GHG Emission Policies

Figure 19: SCPS by Carbon Intensity with PM 2.5 Pollution in the European Union



There are two pieces of EU legislation on air pollutants that will have an impact on coal-fired generation capacity. The first is the Large Combustion Plant Directive (LCPD), which requires stations to install flue gas desulphurisation units or close by the end of 2015.[48] Thus far it has closed 35GW of European capacity.[49] All remaining stations without flue gas desulphurisation units must close by 2016.

The second is the Industrial Emissions Directive (IED), which places a limit on power station NOx emissions. The intention of the IED was for all coal-fired stations to either install selective catalytic reduction (SCR) technologies or to operate limited hours and close by the end of 2023.[50] 110 of 140GW of eligible European coal-fired capacity are already IED-compliant. The remaining 30GW face the choice of retrofitting stations or closure by 2023. To date, one major coal-fired station, Emile Huchet in France, and several smaller ageing coal-fired stations have confirmed that they will close.[51]

Footnotes:

[48] European Commission. from http://ec.europa.eu/environment/industry/stationary/lcp/implementation.htm.

[49] Sandbag (July 2014). "Europe's failure to tackle coal: Risks for the EU low-carbon transition."

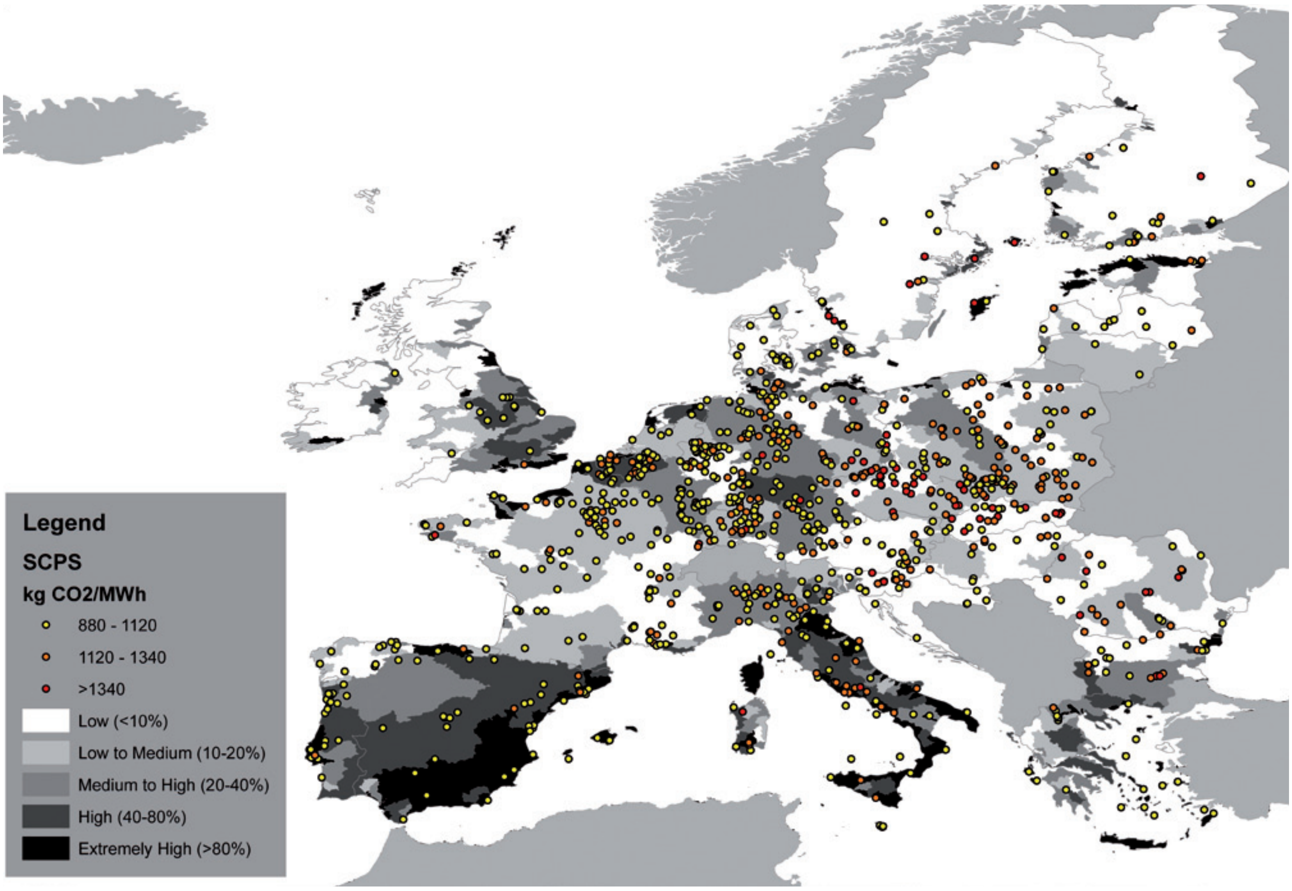
[50] European Commission. from http://ec.europa.eu/environment/industry/stationary/lcp/implementation.htm.

[51] Sandbag (July 2014). "Europe's failure to tackle coal: Risks for the EU low-carbon transition."

Two factors make the impact of the IED on coal-fired stations uncertain. The first is that the majority (30GW) of undecided stations are in the UK and Poland, where capacity mechanisms are being implemented. These arguably make it more profitable to keep coal-fired stations operating. The second is the development of emission abatement technologies that are approximately 20% cheaper than the €180m/MW SCR technology. This technology is not as effective as SCR, but meets the IED NOx standard. There is discussion in the EU to tighten compliance thresholds - increasing the cost of compliance – and potentially forcing the closure of more SCPSs.[52]

Water Stress and Forthcoming Water Policies

Figure 20: SCPS by Carbon Intensity with Water Stress in the European Union



Overall, EU water abstraction is within sustainable limits. However, because of mismatches between population and available water resources, some regions experience high or extremely high water stress. Spain, which has built over 700 desalination plants, is a good example of this.[53]

Footnotes:

[52] Ibid.

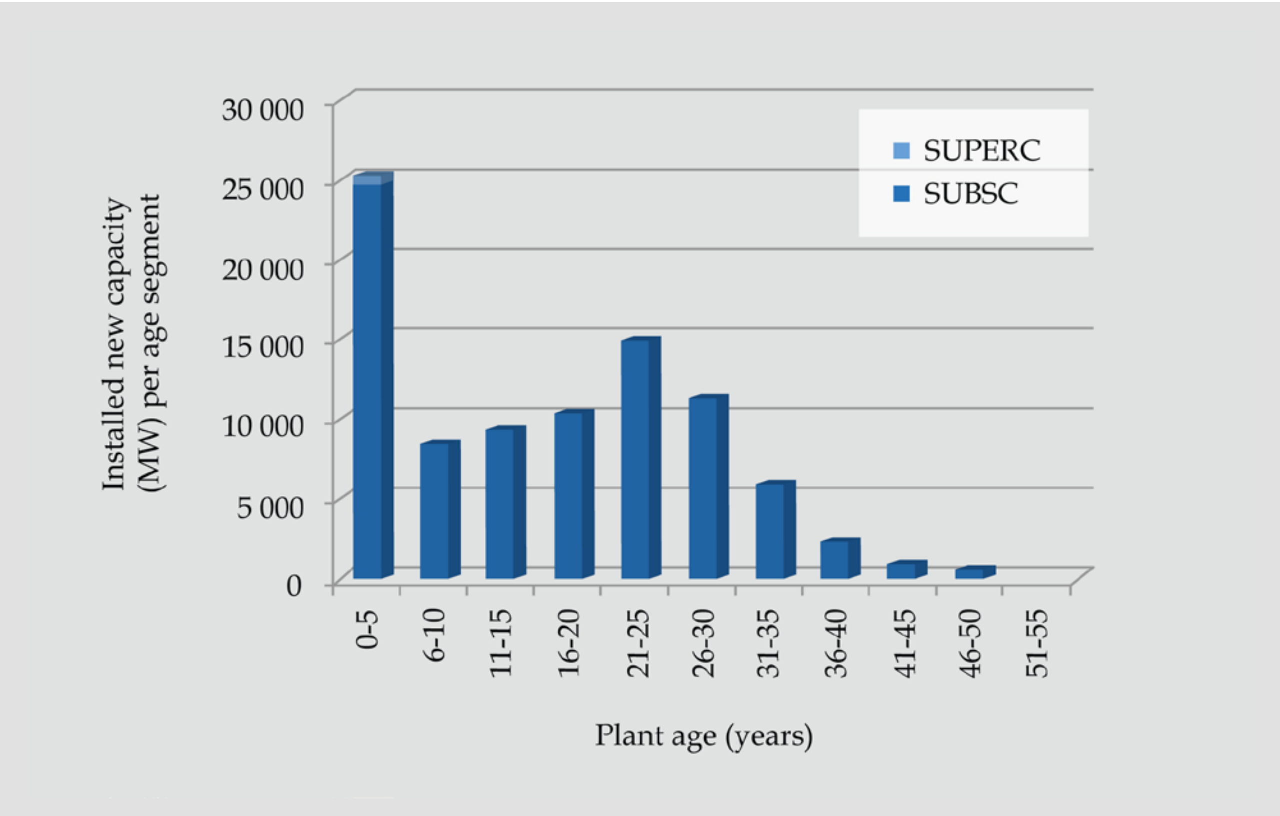
[53] Sandbag (July 2014). "Europe's failure to tackle coal: Risks for the EU low-carbon transition."

Climate change poses challenges to thermal power generation within the EU, where thermal generation accounts for 44% of water abstraction. Stream flow in water-stressed southern Europe has decreased and is expected to continue decreasing.[54] While there are no forthcoming water-related policies that would negatively impact the EU's SCPS fleet, changes in climate certainly will create challenges for the allocation of water resources. Recent recognition of gaps in EU policy around water allocation during drought conditions suggests that water abstraction policies may change.[55]

India

Overview of Subcritical Stock and Trends

Figure 21: India Coal-Fired Generation by Age and Boiler Technology



Source: IEA (2012).

Footnotes:

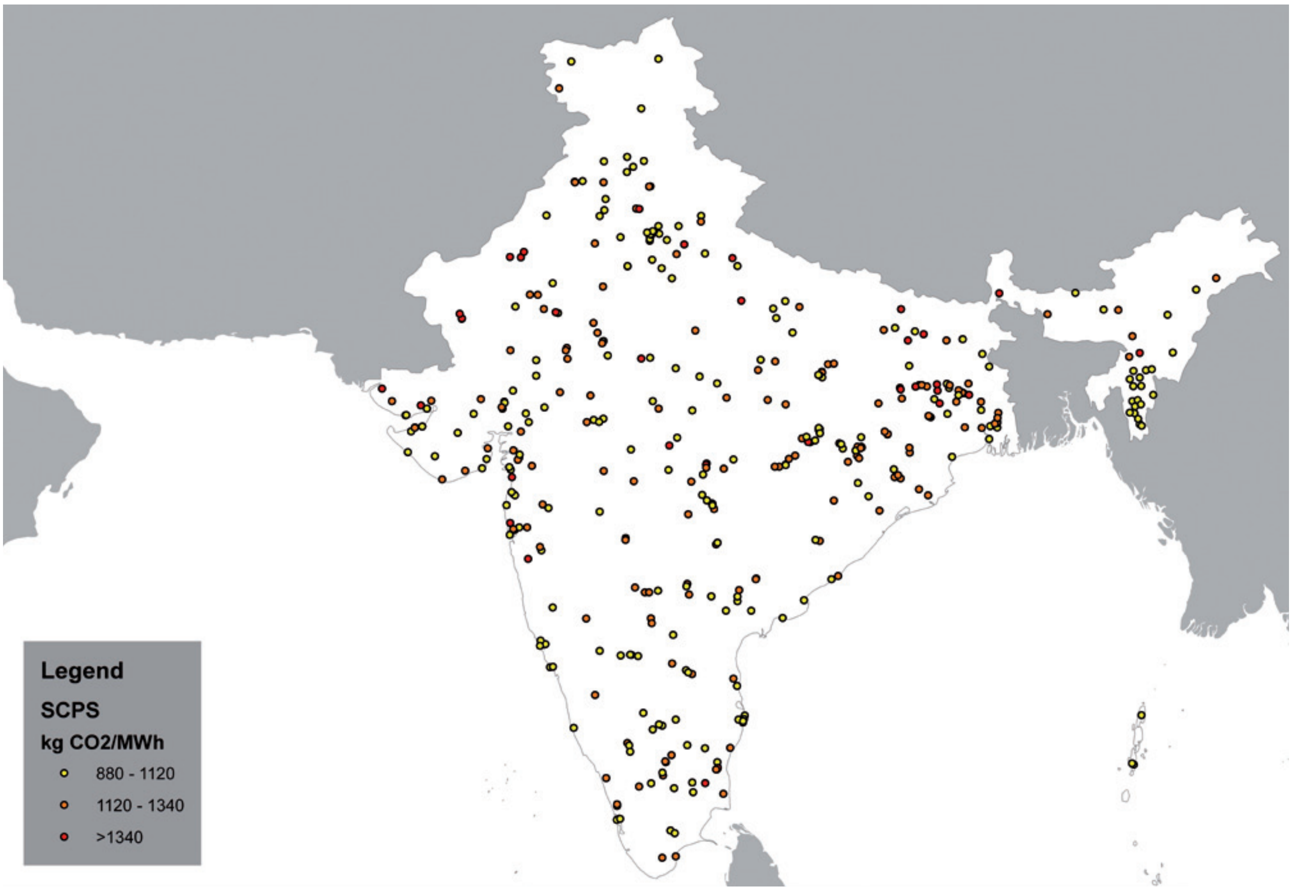
[54] Ibid.

[55] ACTeon Environment Research and Consultancy (2012). "Gap Analysis of the Water Scarcity and Droughts Policy in the EU."

Station Efficiency and Forthcoming GHG Policies

India has 101 GW of coal-fired capacity, almost all of which is subcritical (c. 99%).[56] Due to the smaller size of Indian generators, it is relatively inefficient capacity. India has recently accelerated the construction of coal-fired power generation through initiatives such as the Ultra Mega Power Plants programme, which seeks to streamline the permitting process and construction of new capacity with private capital. However, domestic coal supply issues remain a critical concern with the potential to strand considerable assets.[57]

Figure 22: SCPS in India by Carbon Intensity



The National Action Plan on Climate Change (NAPCC) is India's flagship climate change legislation. Its goal is to reduce the emissions intensity of generation by 20-25% by 2020 based on 2005 levels. The Government of India has established several missions for achieving this goal, including expanding solar generation, large-scale coal-fired generation, and energy efficiency.[58]

Footnotes:

[56] IEA (2012). CCS Retrofit: Analysis of the Globally Installed Coal-Fired Power Station Fleet. Paris, France, OECD/IEA.

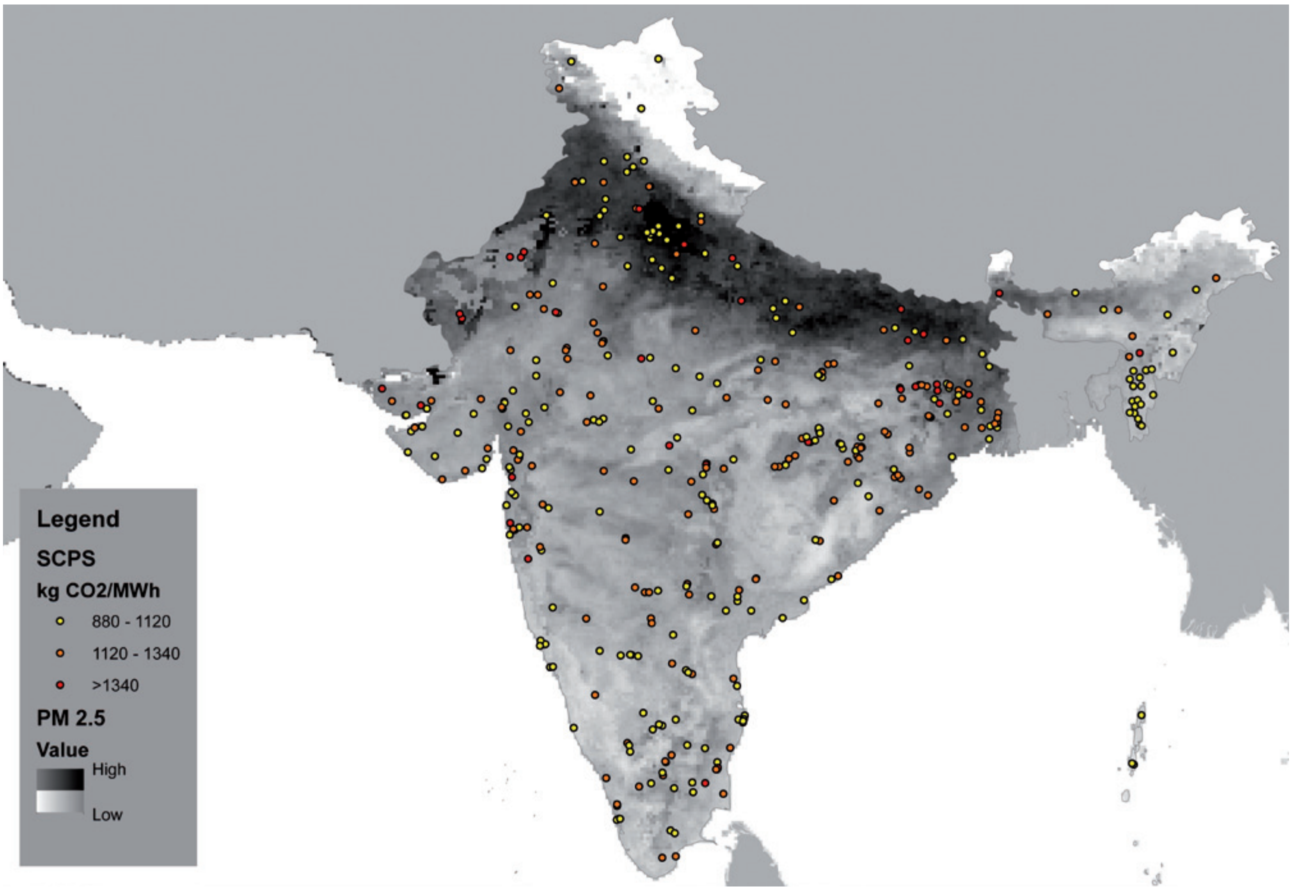
[57] Yang, A. and Y. Cui (2012). Global coal risk assessment: Data analysis and market research, World Resources Institute.

[58] Government of India (2008). National Action Plan on Climate Change. P. M. s. C. o. C. Change.

The energy efficiency scheme is the Perform, Achieve, and Trade (PAT) Mechanism. This is an energy efficiency credit-trading scheme. Stations are given targets and if they outperform their targets, they can sell surplus credits. If they fail to meet their targets, they then have to buy credits from the market. The mechanism began operating in 2012 and its first binding compliance period ends in March 2015. Case studies have shown that ageing and underperforming coal-fired generators have been the most heavily impacted by PAT.[59] This is partially because the design of PAT disadvantages less efficient companies.

PM 2.5 Pollution and Forthcoming Non-GHG Emission Policies

Figure 23: SCPS by Carbon Intensity with PM 2.5 Pollution in India



India's air quality was recently ranked the 174th out of 178 countries.[60] It has also received an increasingly bad press, including a recent study that air pollution alone may be cutting Indian crop yields in half.[61] While there are no imminent regulatory risks to the SCPS fleet, India is taking crucial steps to establishing a regulatory regime that could create such risks.

Footnotes:

[59] Rao, R., R. Dusa and T. Kumar (May 2014). "Perform Achieve Trade (PAT) Mechanism, Its achievability and Impact on Industrial Energy Efficiency."

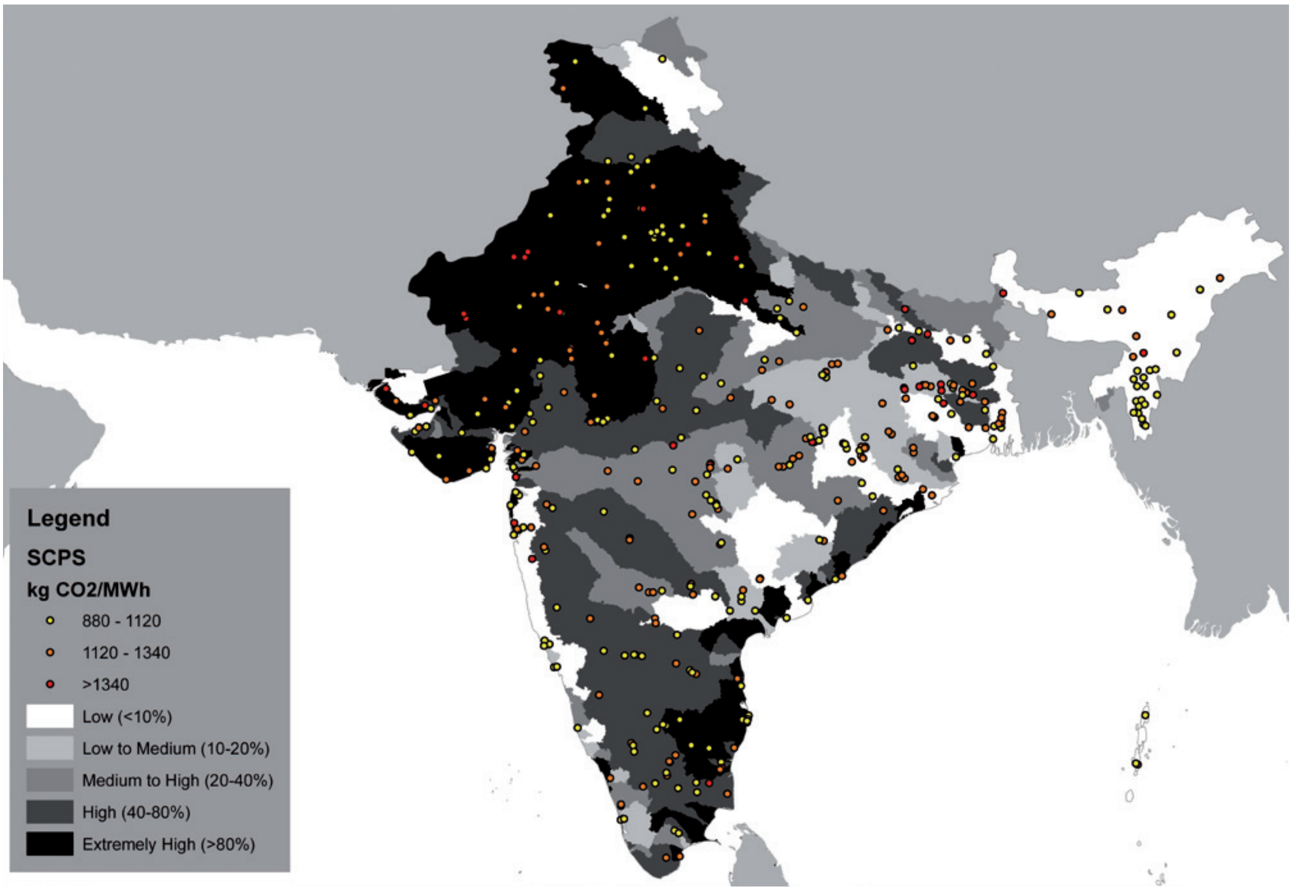
[60] Yale University (2014). Yale University Environmental Performance Index.

[61] Burney, J. and V. Ramanathan (2014). "Recent climate and air pollution impacts on Indian agriculture." Proceedings of the National Academy of Sciences 3(46).

First, in 2014 the Government of India (GOI) announced that it would establish a national air quality index within five years. This will require the continuous monitoring of emissions in 66 major cities, which is not currently done. Second, in 2011-12, the GOI initiated a pilot of continuous emission monitoring systems and PM emission credit trading schemes in three states, Gujarat, Maharashtra and Tamil Nadu. The purpose of this pilot is to inform national environmental policy.[62] Though no timeline could be identified for the development of a broader policy, it is likely that such a policy could exist before the end of the decade. This is due to two factors. First, if the GOI does develop the national air quality index as promised, reliable air quality data for 66 major cities will be available within five years. Second, the GOI has three years of experience operating a similar credit-trading scheme at a national scale, the PAT mechanism. The future implementation of policies restricting the emission of PM is likely to heavily impact the Indian SCPS fleet.

Water Stress and Forthcoming Water Policies

Figure 24: SCPS by Carbon Intensity with Water Stress in India



Footnotes:

[62] Center for International Development (July 2014). Continuous Emission Monitoring: A Paradigm Shift in Regulatory Practice. Harvard University, Evidence for Policy Design.

Water scarcity represents two main risks to generators. The first is operational risk – if stations are closed entirely or run at partial capacity due to a lack of water availability.[63] Coal-water risks have already caused nationwide blackouts in India and water shortages that restrict plants from operating at full capacity have been shown to quickly erode Indian plant profitability.[64] These problems are expected to intensify with the further development of new coal-fired generation capacity.

The second risk is regulatory. The Government of India has recognised the need to address water scarcity. Though specific policies have not been prescribed and implemented, the 2012 National Water Policy recognises the need for water use in power generation, but also recognises the need for water pricing and balancing the multiple uses of watersheds.[65] It is unknown when these policies may be implemented. However, their implementation is likely to impact generators in water stressed regions, the northwest and south, the most.

Footnotes:

[63] Kumar, A. (2010). Same Problem, New Execution Risks, HSBC Global Research.

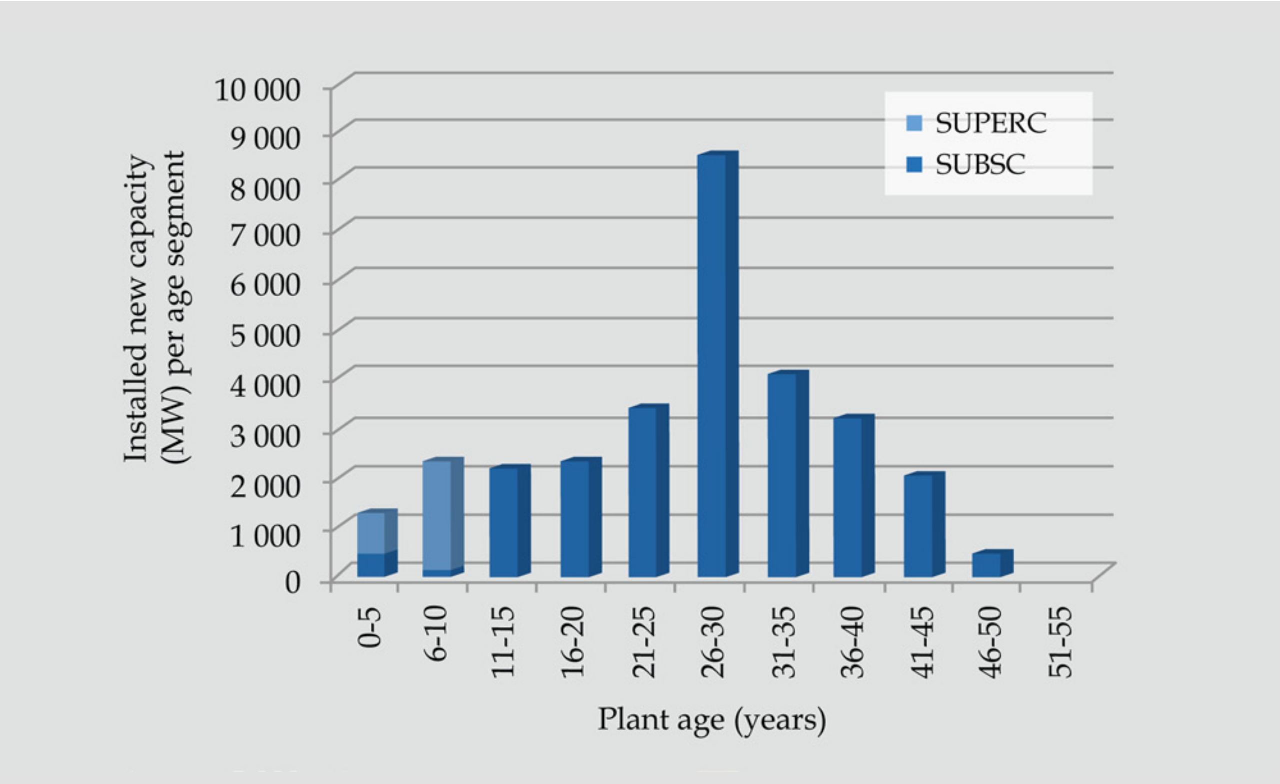
[64] IEA (2012). Water for Energy: Is Energy Becoming a Thirstier Resource? Excerpt from the World Energy Outlook 2012. Paris, France, OECD/IEA.

[65] Government of India (2012). National Water Policy 2012. M. o. W. Resources.

Australia

Overview of Subcritical Stock and Trends

Figure 25: Australia Coal-Fired Generation by Age and Boiler Technology

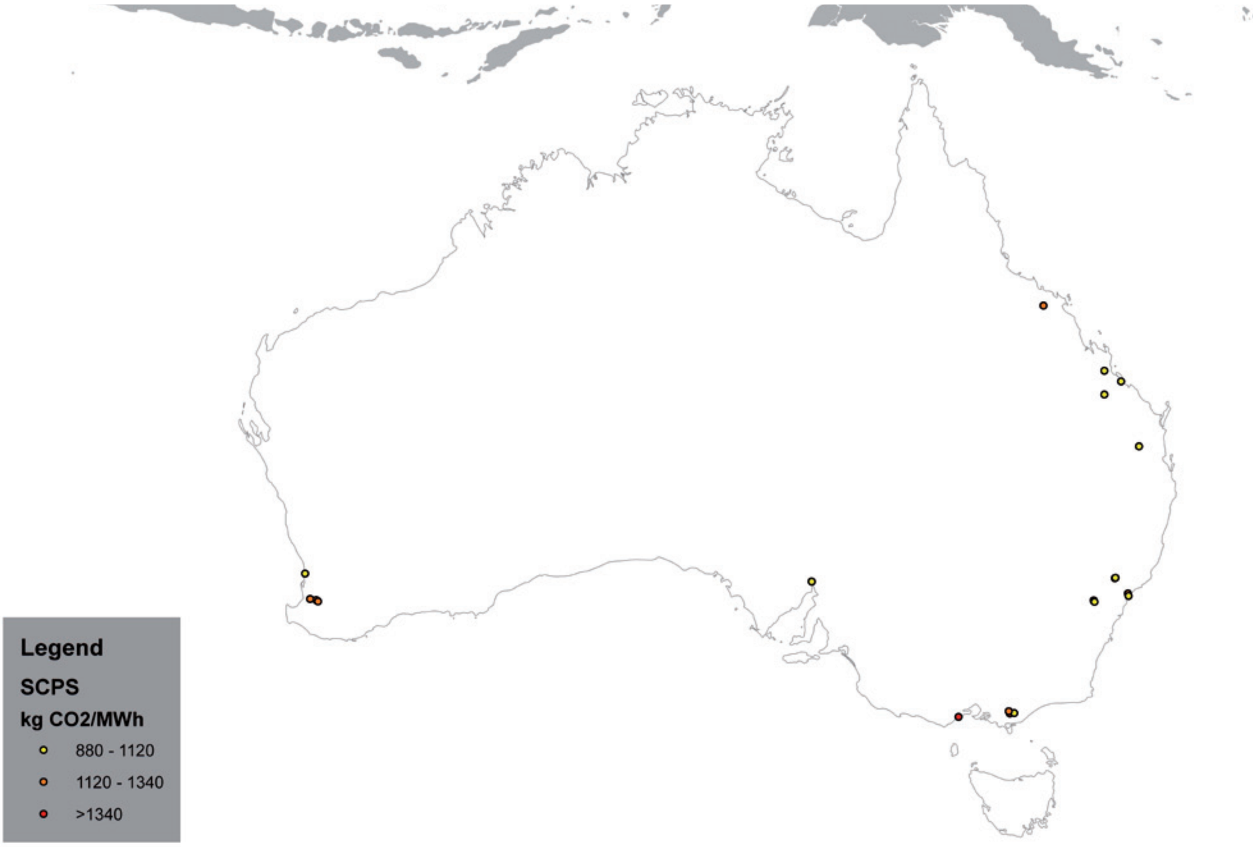


Source: IEA (2012).

Australia's total coal-fired generation capacity is 29GW and 89% of its fleet is subcritical. Supercritical plants are a recent addition to its fleet and now comprise the main share of new builds.

Station Efficiency and Forthcoming GHG Policies

Figure 26: SCPS in Australia by Carbon Intensity



Australia's flagship climate policy, the Clean Energy Act of 2011, was repealed in 2014. This included the repeal of the 20.9 USD/tonne carbon tax. Its replacement will be the Emissions Reduction Fund (ERF).[66] The fund will operate reverse auctions with which the Commonwealth will purchase 'lowest cost' emission reductions from industry.[67] The emission reductions from the ERF are expected to be significantly less than under the Clean Energy Act,[68] and therefore the impact of the ERF on subcritical generators is expected to be less severe.

Footnotes:

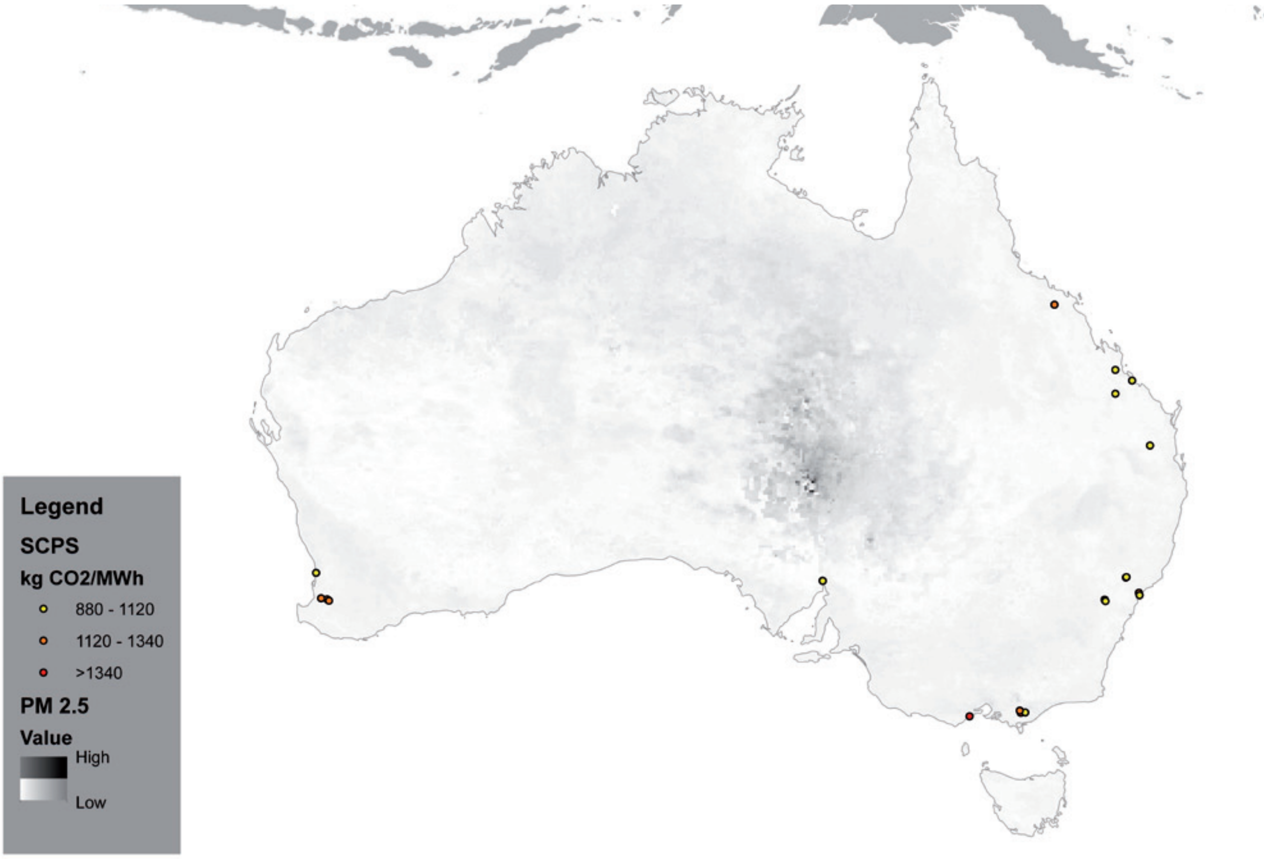
[66] GLOBE International (2014). The GLOBE Climate Legislation Study: A Review of Climate Change Legislation in 66 Countries.

[67] Australian Government (2014). Emissions Reduction Fund. D. o. t. Environment.

[68] UNEP (2014). The Emissions Gap Report 2014.

PM 2.5 Pollution and Forthcoming Non-GHG Emission Policies

Figure 27: SCPS by Carbon Intensity with PM 2.5 Pollution in Australia



Australia's current regulatory framework for pollutants from power stations is the National Environmental Protection Measure for Ambient Air Quality (Air NEPM). The 1998 Air NEPM sets ambient air standards for major pollutants, such as PM, NOx and SOx. It fails to require state and territorial governments to enforce these standards by regulating polluting activities.[69] In 2011, the Air NEPM was recognised as inadequate[70] and ministers have agreed to work towards a new policy by 1 July, 2016.[71] If a national plan is established and its implementation is similar to regulations in the US and EU, ageing and inefficient generators may face a decision of whether to close or make large capital investments towards the end of their technical lifespans.

Footnotes:

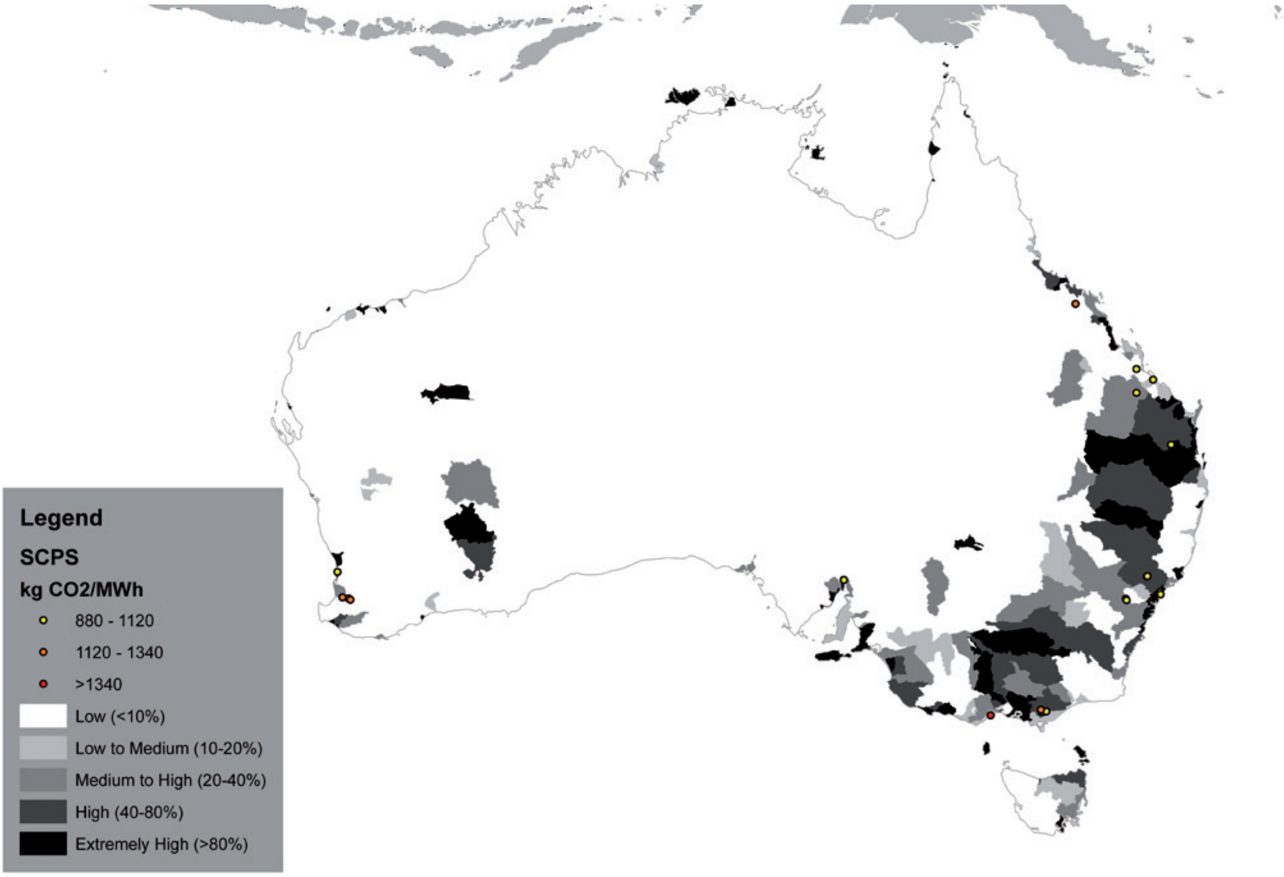
[69] Australian Government (2003). National Environment Protection (Ambient Air Quality) Measure. A. G. s. Department.

[70] Australian Government (2011). National Environment Protection (Ambient Air Quality) Measure Review. N. E. P. Council.

[71] The Hon. Greg Hunt MP (29 April, 2014). Agreed Statement - Environment Ministers meeting. M. f. t. Environment.

Water Stress and Forthcoming Water Policies

Figure 28: SCPS by Carbon Intensity with Water Stress in Australia



Water withdrawal caps have been in place since 1997 for Australia's most water stressed basin, the Murray-Darling basin (MDB). The most recent regulatory change was the 2007 Water Act, which established water pricing and basin management for the MDB. No other major changes in policy that would impact subcritical generators were identified.

However, evidence from January 2014 suggests that climate change poses direct water-related risks to Australian coal-fired power generation. During a heat wave in the Australian summer last year, electricity demand increased in tandem with water temperatures. Loy Yang power station's generating ability was greatly reduced because it could not cool itself effectively. This caused the spot price to increase tenfold in Victoria.[72]

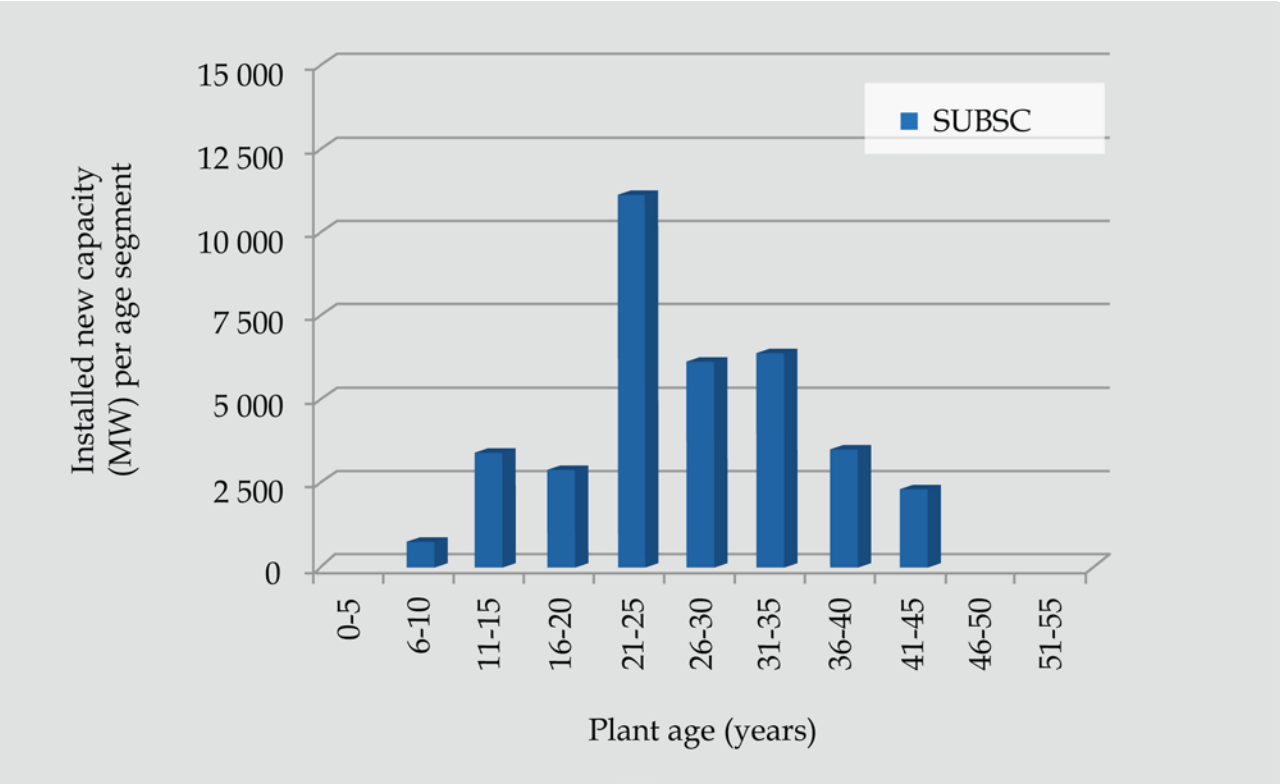
Footnotes:

[72] Knell, S. (2014). "Thermal Stress Promises Higher Electricity Costs." IHS.

South Africa

Overview of Subcritical Stock and Trends

Figure 29: South African coal-fired capacity by age and boiler type

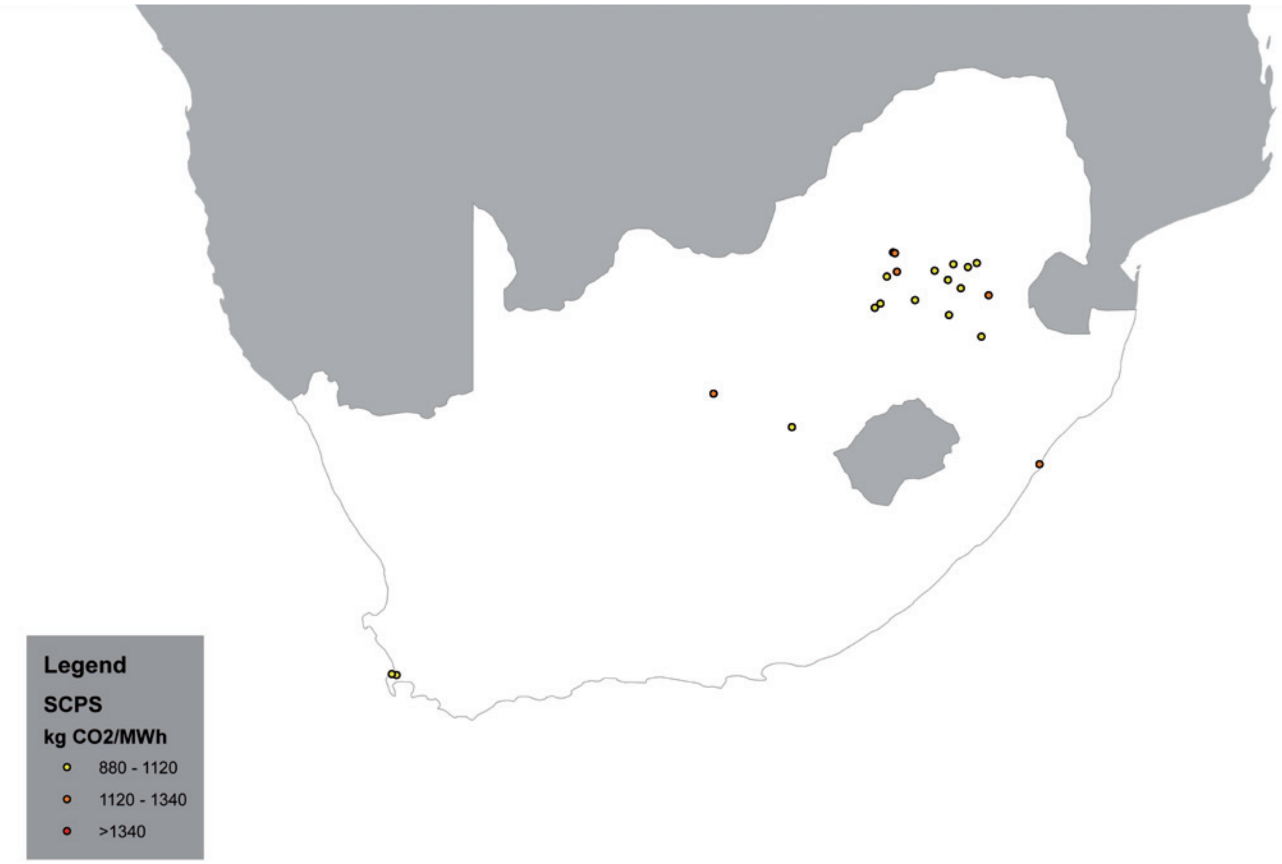


Source: IEA (2012).

Energy is South Africa is dominated by the state monopoly Eskom and is provided almost exclusively by coal-fired generators. South Africa's entire coal fleet consists of SCPS, however supercritical technology is now being introduced into the country, with two 4.8GW plants known as Medupi and Kusile now under construction.

Station Efficiency and Forthcoming GHG Policies

Figure 30: SCPS in South Africa by Carbon Intensity



About 90% of South Africa's domestic energy output is coal-fired.[73] Due to chronic maintenance backlogs and underinvestment and delay in new capacity, South Africa has been subject to regular rolling power cuts dating back to 2008. In 2006, the Government of South Africa acknowledged its intent to diversify power generation through the National Integrated Resource Plan. While not binding, this lays out its intent to diversify South African generation to include more nuclear, wind, and solar power.[74] This led to the 2009 Renewable Energy Feed-In Tariffs (REFIT) programme.[75] The initial intent of this programme was to add 10 TWh of renewable generation annually from 2013-20. Due to various financial and regulatory uncertainties, this was replaced with the Renewable Energy Independent Power Producers Procurement Programme (dubbed REBID). Under REBID, 3,725 MW of renewable capacity have been approved and bids for a further 3,200 MW of renewable capacity have been announced as of 2013.[76]

Footnotes:

[73] Knell, S. (2014). "Thermal Stress Promises Higher Electricity Costs." IHS.

[74] GLOBE International (2014). The GLOBE Climate Legislation Study: A Review of Climate Change Legislation in 66 Countries.

[75] Ibid.

[76] Greenpeace (2013). "Powering the Future: Renewable Energy Roll-out in South Africa."

In 2012 the Minister of Finance announced plans for a carbon tax. While initially planned for implementation in 2015, it has now been rescheduled for implementation in 2016. When implemented, a tax of 11.78 USD/tonne CO2e will be levied above tax-free thresholds for industries. The tax-free threshold for the power sector is 60% of total emissions, and this exemption will decrease by 10% per year.[77] While there is considerable government push for a carbon tax in South Africa, there are opponents to its implementation, such as the South African Chamber of Commerce and Industry. Furthermore, the eventual implementation of a policy will likely be tempered by the monopolistic nature of the South African power sector, as evidenced by the selection of a carbon tax over an emission trading scheme.[78]

Nonetheless, the IEA suggests that while coal will remain the primary source of energy in South Africa, this position will be begin to be challenged due to renewables policies and the falling costs of competitors. For instance, because of the near exhaustion of coalfields in Mpumalanga and the co-location of much of Eskom's power generation facilities, there are upward pressures on coal-fired power production costs. By 2025, the levelised cost of imported hydropower is expected to become lower than domestic coal-fired power, and the levelised costs of wind and solar are also expected to fall significantly. These technological advances will be augmented by the introduction and escalation of carbon taxation.[79]

Footnotes:

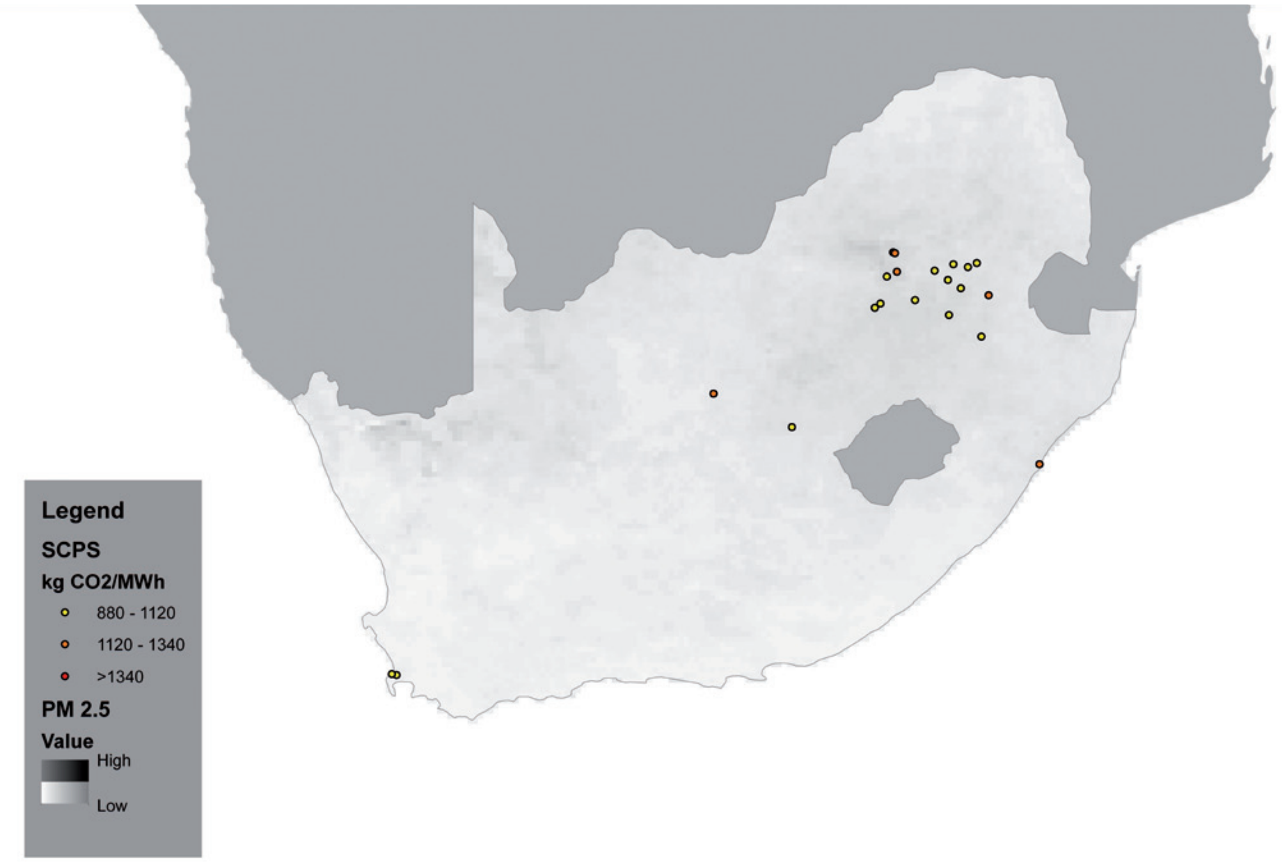
[77] GLOBE International (2014). The GLOBE Climate Legislation Study: A Review of Climate Change Legislation in 66 Countries.

[78] Nakhooda, S. (June 2014). Carbon taxes in South Africa: The political and technical challenges of pricing carbon, Overseas Development Institute.

[79] IEA (2014). World Energy Outlook 2014. Paris, France, OECD/IEA.

PM 2.5 Pollution and Forthcoming Non-GHG Emission Policies

Figure 31: SCPSs by Carbon Intensity with PM 2.5 Pollution in South Africa



South Africa set new PM, SO2, and NO2 emission standards for power stations through the National Environmental Management Air Quality Act of 2004,[80] which have increased the costs of new coal-fired plants.[81] These standards were meant to be binding in 2010; however, the compliance date was extended to April 2015.[82] Eskom had applied to have the regulations postponed and to allow its coal-fired generators to slowly reduce their emissions under a separate emissions reduction plan. However, a decision reached in late 2014 denied that request. Because of this ruling ESKOM now faces a choice of either shutting half of its baseload capacity by April 2015 or installing emissions controls at a cost of up to 200 billion Rand (USD18 billion).[83]

Footnotes:

[80] Government of South Africa (2014). South Africa Emission Standards.

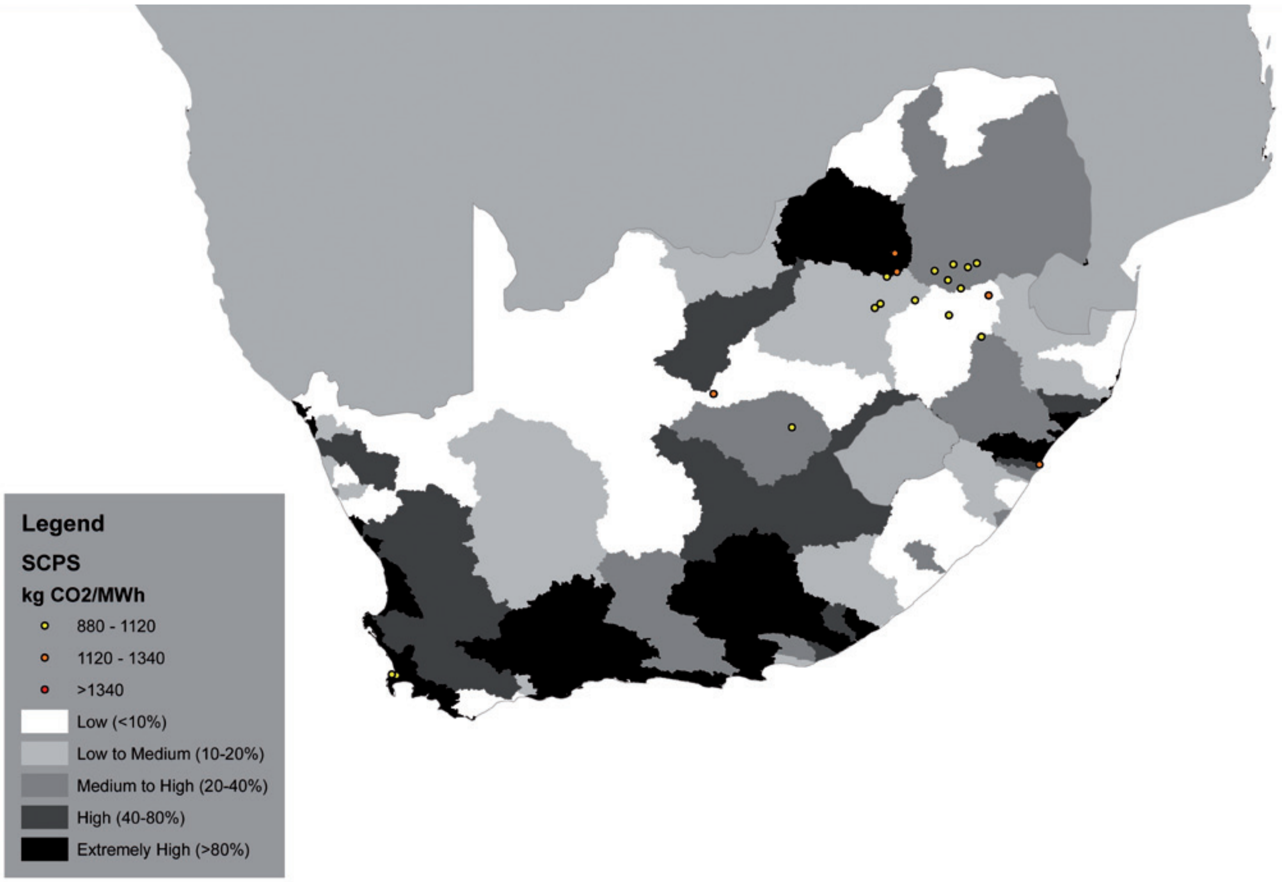
[81] Myllyvirta, L. (2014). Health impacts and social costs of Eskom's proposed non-compliance with South Africa's air emission standards, Greenpeace International.

[82] Gilder, A. and M. Mamkeli (2014). Postponement of air quality compliance timeframes for large emitters.

[83] Matthews, C. (6 November 2014). "Air Quality: last-gasp attempt." from http://www.financialmail.co.za/fmfox/2014/11/06/air-quality-last-gasp-attempt.

Water Stress and Forthcoming Water Policies

Figure 32: SCPS by Carbon Intensity with Water Stress in South Africa



No forthcoming water abstraction policies with the potential to impact SCPSs were identified. Power generation accounts for only 2% of South Africa's water use. However, there are significant water risks in South Africa within coal-fired generation. This is evidenced by Eskom's recently-built power station, Medupi, which is now the world's largest dry-cooled coal-fired power plant. Both Eskom and the Government of South Africa received significant criticism from the World Bank for a complete lack of consideration of the Waterburg region's communal water needs. By 2030, demand for water is expected to outstrip supply by 17%. This suggests increases in water-related conflict and significant risks relating to Eskom's social licence to operate.[84]

Footnotes:

[84] Groenwald, Y. (2012). "Coal's Hidden Cost to South Africa."

Indonesia

Overview of Subcritical Stock and Trends

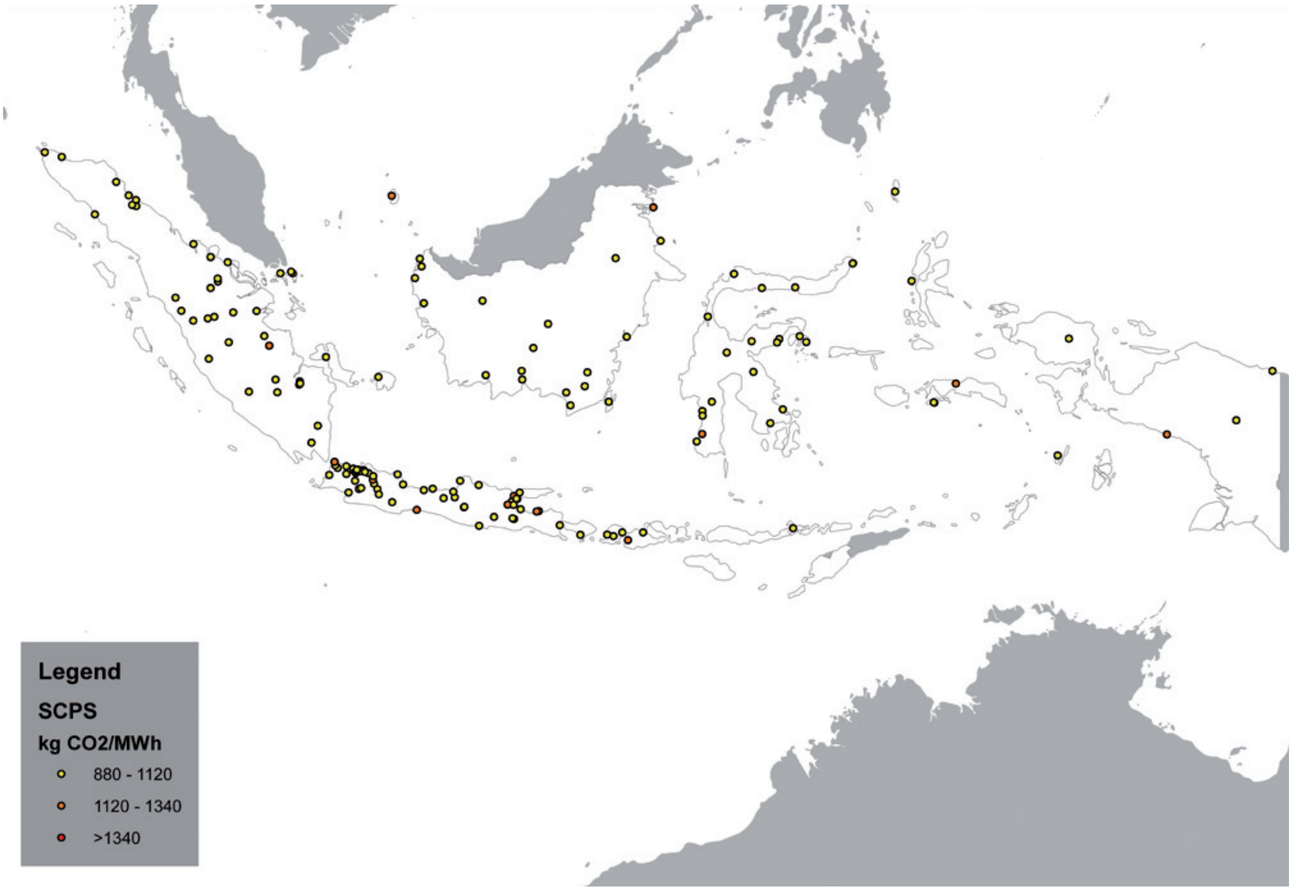
Table 8: Indonesian SCPS Carbon-Intensity Breakdown

	Number of SCPSs	Percent of SCPSs with 880-1,120kg CO2/MWh	Percent of SCPSs with 1,120-1,340kg CO2/ MWh	Percent of SCPSs with >1,340kg CO2/ MWh
Indonesia	337	91.99%%	6.82%	0.89%

Over the past three decades Indonesia has increased its coal use 5,900%: faster than any other country. Even so, Indonesian citizens are still considered to suffer energy poverty, consuming 630KWh/capita/yr: or about one-fifth the global average. Total electricity consumption in Indonesia is expected to double by 2022 (CEPE October 2014). Comprehensive data on the age and efficiency of the total Indonesian coal fleet was unavailable. However, the Carbon Monitoring for Action (CARMA) data does allow us to breakdown Indonesia's SCPS fleet according to its carbon efficiency and this is displayed in Table 8. The high weighting of 'efficient' SCPS suggests that the Indonesian SCPS fleet is comparatively young. Large new projects such as the 2GW plant in Batang, central Java will utilise ultra-supercritical technology.

Station Efficiency and Forthcoming GHG Policies

Figure 33: SCPS in Indonesia by Carbon Intensity



Presidential Decree 21 is Indonesia's flagship climate legislation. Implemented in 2011, it covers 70 programmes in forestry and peat land, agriculture, energy and transportation, industry and waste management. Together, it represents a pledge to reduce Indonesia's GHG emission 26-41% by 2020 as compared with a business as usual scenario. It is recognised that the majority of these reductions will come from land use change-oriented policies, but Indonesia is also seeking to tap its vast renewable capacity. Ministerial Regulation 15/2010 seeks to increase Indonesia's renewable generation capacity by 10,000 MW. By the end of 2014, nearly 4,000 MW will be in operation. In addition, in 2009, the Ministry of Finance initiated a discussion about carbon taxation with a green paper.[85] However, since then carbon taxation has largely not been discussed.[86]

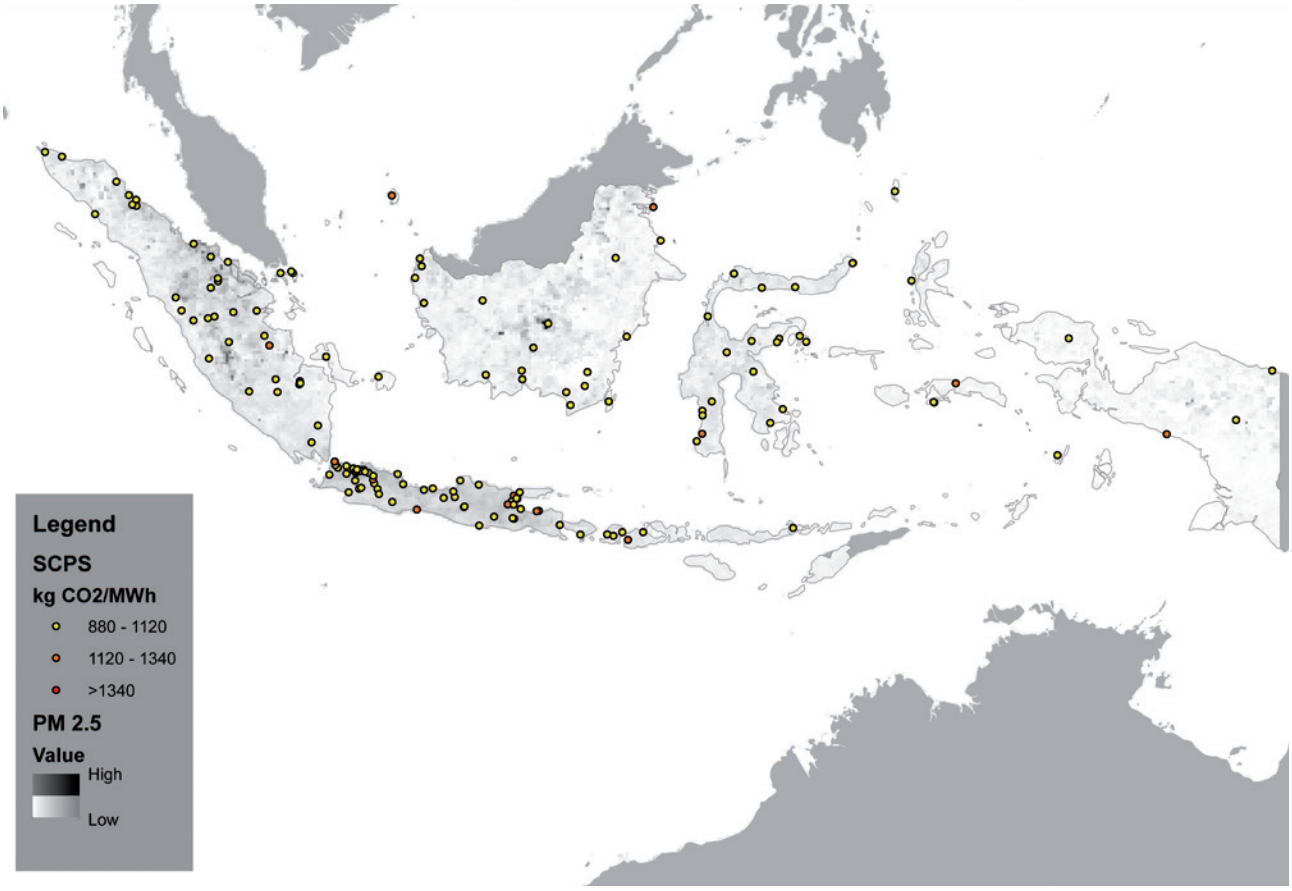
Footnotes:

[85] Republic of Indonesia (2009). Economic and Fiscal Policy Strategies for Climate Change Mitigation in Indonesia, Executive Summary. M. o. Finance.

[86] Maulidia, M. (April 29th 2014) "Carbib Tax for Indonesia: Time to Act Now." The Jakarta Post.

PM 2.5 Pollution and Forthcoming Non-GHG Emission Policies

Figure 34: SCPS by Carbon Intensity with PM 2.5 Pollution in Indonesia



Indonesia's air quality is rated 112th out of 178 counties. However, their urban air quality, particularly in Jakarta is among the world's worst and air quality overall is degrading.[87] Indonesia currently has national-level ambient air quality and industrial emission standards, which are administered by the Ministry of the Environment (MoE). Provincial governments can impose more stringent standards than those administered by the MoE.[88]

While no forthcoming policies with the potential to financially impact the Indonesian SCPS within the next few years were identified, it is reasonable to expect emission standards to tighten. This is due to actions being taken within the MoE. From 2007 to 2011, Indonesia developed robust emission monitoring systems for 26 metropolitan areas and cities across Indonesia and now publishes city pollution levels to encourage cities to continuously improve their competitiveness in air quality management. While emissions from transport are currently receiving the most regulatory attention,[89] policies to establish market-based mechanisms to control air pollution from power stations are also being investigated.[90]

Footnotes:

[87] Yale University (2014). Yale University Environmental Performance Index.

[88] Clean Air Initiative for Asian Cities Center (October 2010). Indonesia: Air Quality Profile.

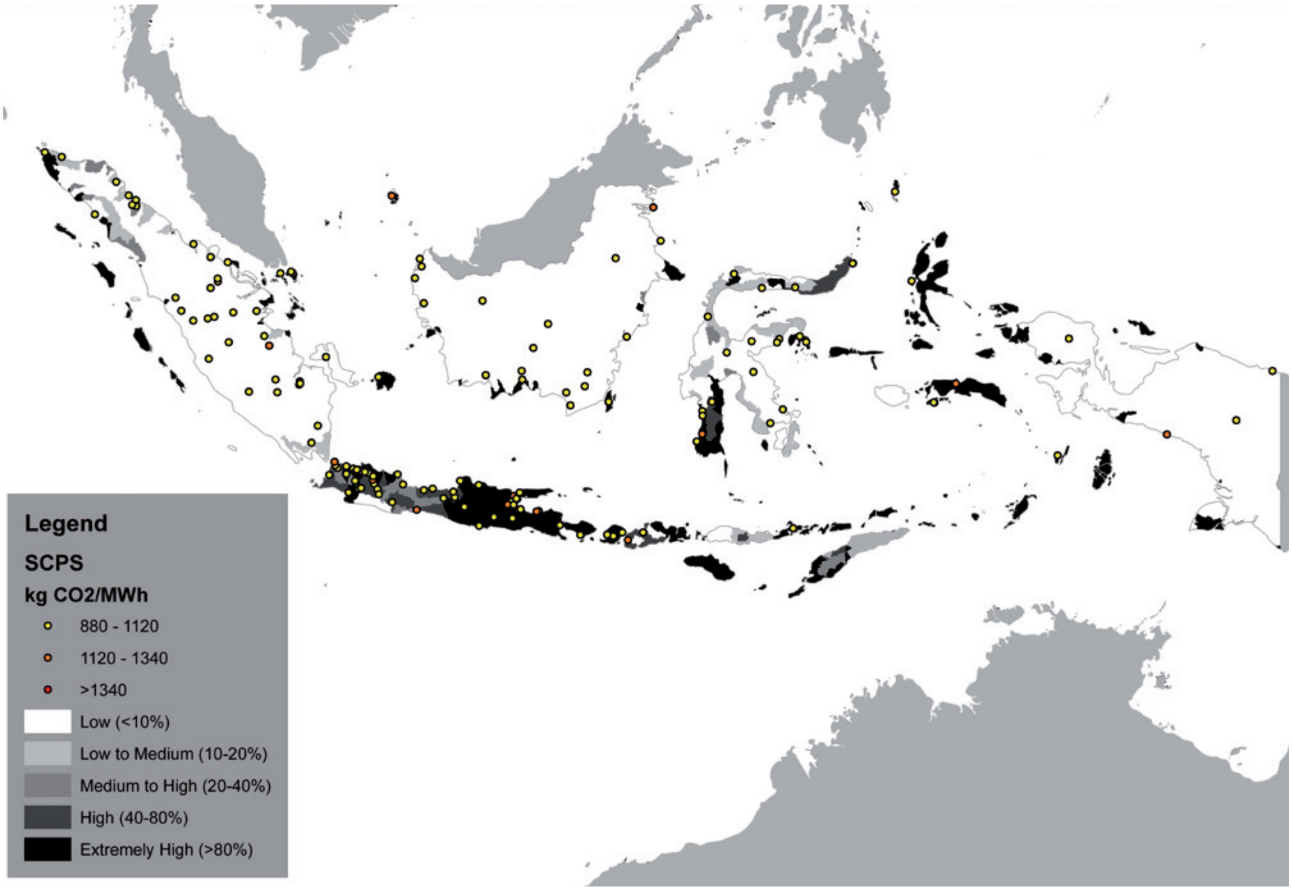
[89] Ministry of Environment (2011). Urban Air Quality Evaluation in Indonesia 2011, Blue Sky Program.

[90] Reliantoro, S. (2008). The Proposed Emission Standard, Environmental Monitoring & Compliance of Power Generation Plant in Indonesia. Presentation to the APEC Energy Working Group.

The greater availability of air quality information will likely lead to increased demand from citizens for cleaner air, making stricter emission regulations in Indonesia only a matter of time. Whether these regulations come in the form of nationwide market-based systems or tightening of existing regulations by provincial governments remains to be seen, but regardless will have an impact on Indonesia's SCPS fleet.

Water Stress and Forthcoming Water Policies

Figure 35: SCPS by Carbon Intensity with Water Stress in Indonesia



Although no forthcoming policy changes pertaining to water abstraction that would impact subcritical generators in Indonesia were identified, development, urbanisation, and climate change will increasingly stress Indonesia's water resources. This will, in turn, pose challenges to fresh water use by thermal power generators.

Climate change has already increased the incidence of droughts in Indonesia from one in four years to one in three and claimed 20 small islands due to rising sea level. By 2030, up to 2,000 Indonesian islands may be eroded or submerged by rising sea levels attributable to climate change.[91] This will increase what is already an extremely high water stress situation by forcing even higher population densities.

Footnotes:

[91] Asian Cities Climate Change Resilience Network (n.d.). Indonesia.

Summary Tables of Selected National Coal-Fired Power Plant Portfolios

Table 9: National Coal-fired Power Station Fleet Age and Performance

				Share of Total Coal Power Stations that are...				
	Total Capacity (GW)	Average Age (years)	Average Age of Subcritical (years)	Subcritical	Older than 15 years	Subcritical AND Older than 15 years	Older than 35 years	Subcritical AND Older than 35 years
World	1,617	21	23	75%	56%	47%	23%	18%
China	669	9	11	75%	19%	19%	1%	1%
United States	336	39	40	73%	95%	66%	51%	30%
European Union	150	37	-	65%	-	-	-	-
Germany	*51*	*34*	*37*	*79%*	*87%*	*76%*	*37%*	*35%*
Poland	*32*	*34*	*36*	*97%*	*88%*	*88%*	*41%*	*41%*
UK	*20*	*44*	*44*	*100%*	*100%*	*100%*	*100%*	*100%*
India	101	16	16	99%	51%	51%	4%	4%
Australia	29	30	33	89%	82%	82%	19%	19%
South Africa	38	30	30	100%	88%	88%	15%	15%

Source: IEA (2012)

Table 10: New (gross) Installations of Coal-fired Power Plants (GW)

	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2011-2035
China	197.1	135.7	76.3	72.4	73.9	555.4
India	74.5	30.6	22.8	52.8	70.5	251.2
United States	16.7	42.6	25.2	41.3	32.9	158.7
EUG4	12.4	1.4	14.7	3.7	2.7	34.9
EU17	*11.7*	*3.7*	*2.5*	*2.3*	*1.3*	*21.6*
Australia & New Zealand	*1.6*	*2.5*	*2.6*	*2.5*	*6.3*	*15.5*
South Africa	*4.8*	*8.0*	*6.9*	*10.0*	*11.4*	*41.1*

EUG4 consists of; France, Germany, Italy, and the United Kingdom
Source: IEA (2012)

Table 11: Total Projected Coal-fired Power Plant Retirements (GW)

	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2011-2035	Net Increase including Table 10, 2011-2035
China	9.9	10.7	15.6	17.6	14.3	67.9	487.5
India	1.5	3.2	3.5	6.2	12.2	26.6	224.8
United States	8.3	23.6	23.5	59.0	67.9	182.4	-23.7
EUG4	5.2	28.6	21.8	8.4	16.1	80.1	-45.2
EU17	*5.2*	*9.8*	*16.0*	*17.0*	*14.8*	*62.9*	*-41.3*
Australia & New Zealand	*0.6*	*2.2*	*3.4*	*4.1*	*9.6*	*19.9*	*-4.4*
South Africa	*0.4*	*3.0*	*3.5*	*6.4*	*6.1*	*19.4*	*21.7*

Source: IEA (2012)

5. Analysis of SCPS Exposure

In the following section we analyse the world's 100 largest SCPS portfolios by total generation - together these account for 66.2% of global subcritical generation. However, there are important caveats to this data. Although the most up-to-date CARMA, Enipedia, and CoalSwarm data available was used in order to develop the company-level SCPS information used here, it is inevitable that some SCPSs have changed hands since the last updates. Therefore, although on the whole we expect the data to be largely representative of actual company portfolios, the situations of some individual firms may be significantly different from those reported here. We invite firms who believe the data below to be inaccurate to disclose this information publicly so we can revise the data accordingly.

Our company portfolio data suggests that, at least for the largest companies, company sensitivity to environmental and regulatory risks essentially mirror respective national analyses. This is due to the fact that power companies do not typically operate across multiple regulatory jurisdictions. However, in large countries regional differences can also produce material variation in firm-level exposure to the risks considered here.

Largest Company SCPS Portfolios

Table 12: Breakdown of the SCPS Portfolios by Country and Region

	Total number of companies with SCPS assets	Number of companies in the largest 100 company SCPS portfolios†	Percentage of companies in the largest 100 company SCPS portfolios that are government-owned
World	4,128	100	59%
China	368	19	95%‡
United States	391	29	10%
EU	899	12	58%
India	391	15	87%
Australia	19	4	50%
South Africa	9	1	100%
Indonesia	223	2	100%

†Largest 100 SCPS portfolios defined in terms of total MWh.

‡The non-government owned company is CLP based in Hong Kong.

Globally, Chinese and US companies dominate in terms of size, with 7 out of the 10 largest SCPS portfolios being Chinese, and 6 of the largest 20 American. Government-owned companies[92] account for 59 of the world's 100 largest company SCPS portfolios, and over two-thirds of their generation. Among the remaining 41 non-government owned company portfolios, the United States (26), EU (5), and India (3) have the greatest number, whereas China[93], Indonesia, and South Africa have none. Where governments have a significant stake in SCPS portfolios, it is generally thought that they would be less likely to introduce policies that would directly strand their own assets. However, this view is being contradicted by recent policy tightening in both China and India.

Footnotes:

[92] Government-owned companies are defined as those for which a controlling interest in the company (>50%) is held by the state.

[93] With the exception of CLP from Hong Kong.

Table 13: Largest 100 SCPS Portfolios, Ranked by Total Generation

Rank	Portfolio/Company	Country	State owned	Listed	Number of SCPSs	Total SCPS MWh
1	China Huaneng Group	China	YES	YES	66	320,928,260
2	Huadian Group	China	YES	YES	69	284,448,220
3	China Guodian Group	China	YES	YES	65	267,433,170
4	China Datang Corp	China	YES	YES	52	211,691,720
5	NTPC	India	YES	YES	24	202,008,689
6	Eskom	South Africa	YES	YES	11	186,960,300
7	Shenhua Group	China	YES	YES	36	144,993,390
8	China Power Investment Corp	China	YES	NO	41	129,003,080
9	AES Corporation	United States	NO	YES	12	107,196,652
10	China Resources Power Holdings	China	YES	YES	29	97,645,759
11	Southern Company	United States	NO	YES	15	94,839,824
12	Duke Energy	United States	NO	YES	15	93,956,682
13	NRG Energy	United States	NO	YES	17	92,966,708
14	American Electric Power Co	United States	NO	YES	9	87,596,600
15	RWE	Germany	NO	YES	13	79,964,585
16	North China Grid Co Ltd	China	YES	NO	29	72,872,466
17	E.ON	Germany	NO	YES	25	65,771,927
18	Berkshire Hathaway Energy	United States	NO	NO	10	61,267,972
19	AGL Energy	Australia	NO	YES	4	60,329,581
20	State Grid Power Corp	China	YES	NO	28	58,341,956
21	Edison International	United States	NO	YES	14	56,911,497
22	Ameren	United States	NO	YES	10	55,407,367
23	Tennessee Valley Auth	United States	YES	NO	7	54,234,600
24	Vattenfall	Sweden	YES	NO	13	53,716,430
25	PPL Generation LLC	United States	NO	YES	10	51,399,861
26	Xcel Energy	United States	NO	YES	11	49,584,827

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Rank	Portfolio/Company	Country	State owned	Listed	Number of SCPSs	Total SCPS MWh
27	Guangdong Yudean Group	China	YES	NO	17	48,841,980
28	Firstenergy Generation Corp	United States	NO	YES	7	46,827,700
29	Taiwan Power Co	Taiwan	YES	NO	10	42,689,090
30	Saudi Electricity Co	Saudi Arabia	YES	YES	78	41,446,725
31	CLP Group	China	NO	YES	6	40,979,981
32	Korea Midland Power (komipo)	South Korea	YES	YES	3	40,076,100
33	Elektrik Uretim AS	Turkey	YES	YES	23	39,600,929
34	Maharashtra State Power Gen Co	India	YES	NO	7	37,556,000
35	Public Power Corp (dei)	Greece	YES	NO	21	37,273,661
36	Ameren	United States	NO	YES	5	36,378,645
37	Polska Grupa Energetyczna	Poland	YES	YES	2	36,020,000
38	Dominion Energy Inc	United States	NO	YES	8	35,249,444
39	Korea East-west Power Co	South Korea	YES	YES	3	35,068,900
40	ENEL Spa	Italy	YES	YES	22	34,277,325
41	Israel Electric Corp	Israel	YES	NO	2	31,995,000
42	PLN	Indonesia	YES	NO	92	31,432,217
43	Korea Southern Power (kospo)	South Korea	YES	YES	2	31,095,500
44	Tata Group	India	NO	YES	7	30,718,558
45	GDF Suez	France	NO	YES	10	30,125,526
46	Comision Federal De Elec	Mexico	YES	NO	58	30,041,312
47	Korea Western Power (kowepo)	South Korea	YES	YES	2	29,677,340
48	EDF	France	YES	YES	8	29,610,720
49	Cez As	Czech Republic	YES	YES	13	29,522,734
50	State Power Central Co	China	YES	NO	6	28,836,060
51	Entergy	United States	NO	YES	3	28,260,700
52	Guizhou Electric Power Co	China	YES	NO	9	27,641,800

Rank	Portfolio/Company	Country	State owned	Listed	Number of SCPSs	Total SCPS MWh
53	Beijing Energy Invest Holding	China	YES	NO	4	27,519,000
54	Shenergy Company Ltd	China	YES	YES	3	27,240,107
55	Citic Pacific Ltd	China	YES	YES	6	26,846,285
56	Korea Southeast Power Co	South Korea	YES	YES	3	26,712,900
57	Rao Ues Russia	Russia	YES	NO	23	25,275,890
58	Great Plains Energy	United States	NO	YES	5	25,004,472
59	Energy Future Holdings	United States	NO	NO	2	24,780,700
60	Elektroprivreda Srbije (eps)	Serbia	YES	NO	5	24,560,768
61	Vedanta Resources Plc	India	NO	YES	5	23,753,132
62	Gujarat Urja Vikas Nigam Ltd	India	YES	NO	8	23,366,839
63	Andhra Pradesh Power Gen Corp	India	YES	NO	5	23,309,290
64	Basin Electric Power Coop	United States	NO	NO	3	22,810,600
65	Kazakhmys Plc	Kazakhstan	NO	NO	4	22,748,920
66	Transalta Utilities Corp	Canada	NO	YES	2	22,522,300
67	Adani Power	India	NO	YES	2	22,036,568
68	Drax Power Ltd	United Kingdom	NO	YES	1	21,870,000
69	Progress Energy	United States	NO	YES	4	21,782,600
70	Salt River Project	United States	YES	NO	2	21,716,000
71	Uttar Pradesh Rajya Vidyut	India	YES	NO	5	21,017,800
72	Santee Cooper	United States	YES	NO	2	20,483,400
73	Dynegy Holdings	United States	NO	YES	4	19,761,600
74	Zes Elek Patnow-adamow-konin	Poland	NO	NO	5	19,057,090
75	West Bengal Power Dev Corp	India	YES	NO	5	18,568,000
76	Stanwell Corp Ltd	Australia	YES	NO	2	18,399,600
77	Tamil Nadu Electricity Board	India	YES	NO	5	18,136,518
78	CMS Energy	United States	NO	YES	7	17,749,878

Rank	Portfolio/Company	Country	State owned	Listed	Number of SCPSs	Total SCPS MWh
79	Westar Energy Inc	United States	NO	YES	3	17,637,600
80	Origin Energy	Australia	NO	YES	1	17,482,000
81	Punjab State Electricity Board	India	YES	NO	3	17,197,000
82	Ogk-2	Russia	NO	NO	4	17,067,700
83	East China Electric Power Corp	China	YES	NO	8	17,035,085
84	Rajasthan Rv Utpadan Nigam	India	YES	NO	4	16,837,000
85	Neyveli Lignite Corp Ltd	India	YES	YES	2	16,725,380
86	Pt Indonesia Power - Suralaya	Indonesia	YES	NO	1	16,644,000
87	Fpc Huayang Zhangzhou Power	China	YES	NO	1	15,453,000
88	Termoelectrica	Romania	YES	NO	17	15,257,687
89	DTEK	Ukraine	YES	NO	2	15,148,900
90	Oklahoma Gas & Electric	United States	NO	YES	2	15,064,400
91	J-power	Japan	NO	YES	4	14,642,370
92	Delta Electricity	Australia	YES	NO	2	14,633,400
93	Associated Electric Coop Inc	United States	NO	NO	3	14,626,761
94	Mp Power Generating Co Ltd	India	YES	NO	3	14,472,000
95	We Energies	United States	NO	YES	3	14,290,400
96	Xishan Coal And Electricity	China	YES	YES	3	13,660,800
97	Electricity Generating Authority of Thailand	Thailand	YES	NO	4	13,631,406
98	Intermountain Power Agcy	United States	NO	NO	1	13,556,000
99	Puget Sound Energy Inc	United States	NO	NO	1	13,155,000
100	Damodar Valley Corp	India	YES	NO	5	13,048,590

Table 14: Carbon Intensity, Air Pollution, and Water Stress of the Largest 100 SCPS Portfolios

Rank by total SCPS MWh	Portfolio/Company	Number of SCPSs	SCPS portfolio mean carbon intensity (CO2 kg/ MWh)	SCPS portfolio mean 100km radius PM 2.5 levels	SCPS portfolio mean Water Stress	Percentage of SCPS portfolio located in areas with air pollution exceeding the WHO PM 2.5 limit	Percentage of SCPS portfolio in extremely high water stress catchments	Percentage of SCPS portfolio with air pollution exceeding the WHO PM 2.5 limit AND with extremely high water stress
1	China Huaneng Group	66	1,051	44	50.01%	77.27%	31.82%	27.27%
2	Huadian Group	69	1,029	50	51.26%	82.61%	34.78%	27.54%
3	China Guodian Group	65	1,016	43	48.62%	89.23%	29.23%	26.15%
4	China Datang Corp	52	1,049	46	64.24%	88.46%	48.08%	46.15%
5	NTPC	24	973	41	37.35%	95.83%	25.00%	20.83%
6	Eskom	11	1,026	8	23.40%	0.00%	0.00%	0.00%
7	Shenhua Group	36	960	38	61.84%	86.11%	36.11%	27.78%
8	China Power Investment Corp	41	1,046	51	53.33%	87.80%	43.90%	39.02%
9	AES Corporation	12	993	8	7.48%	0.00%	0.00%	0.00%
10	China Resources Power Holdings	29	1,028	66	49.57%	100.00%	31.03%	31.03%
11	Southern Company	15	1,016	6	15.00%	0.00%	0.00%	0.00%
12	Duke Energy	15	987	8	19.89%	0.00%	0.00%	0.00%
13	NRG Energy	17	1,034	7	32.51%	0.00%	17.65%	0.00%
14	American Electric Power Co	9	999	8	8.22%	0.00%	0.00%	0.00%
15	RWE	13	996	14	19.60%	0.00%	7.69%	0.00%
16	North China Grid Co Ltd	29	1,154	66	87.97%	96.55%	79.31%	79.31%
17	E.ON	25	971	12	28.51%	0.00%	12.00%	0.00%
18	Berkshire Hathaway Energy	10	1,067	7	32.24%	0.00%	20.00%	0.00%
19	AGL Energy	4	1,064	2	54.73%	0.00%	0.00%	0.00%
20	State Grid Power Corp	28	1,136	61	35.18%	96.43%	14.29%	10.71%
21	Edison International	14	1,013	12	29.12%	14.29%	7.14%	0.00%
22	Ameren	10	1,061	8	14.60%	0.00%	0.00%	0.00%

Rank by total SCPS MWh	Portfolio/Company	Number of SCPSs	SCPS portfolio mean carbon intensity (CO2 kg/MWh)	SCPS portfolio mean 100km radius PM 2.5 levels	SCPS portfolio mean Water Stress	Percentage of SCPS portfolio located in areas with air pollution exceeding the WHO PM 2.5 limit	Percentage of SCPS portfolio in extremely high water stress catchments	Percentage of SCPS portfolio with air pollution exceeding the WHO PM 2.5 limit AND with extremely high water stress
23	Tennessee Valley Auth	7	1,013	8	5.64%	0.00%	0.00%	0.00%
24	Vattenfall	13	1,038	14	22.24%	0.00%	0.00%	0.00%
25	PPL Generation LLC	10	1,014	8	17.32%	0.00%	10.00%	0.00%
26	Xcel Energy	11	1,050	6	66.47%	0.00%	45.45%	0.00%
27	Guangdong Yudean Group	17	1,049	33	11.50%	94.12%	0.00%	0.00%
28	Firstenergy Generation Corp	7	998	9	12.93%	0.00%	0.00%	0.00%
29	Taiwan Power Co	10	939	14	0.00%	0.00%	0.00%	0.00%
30	Saudi Electricity Co	78	1,035	41	86.32%	93.59%	82.05%	82.05%
31	CLP Group	6	1,039	27	27.82%	83.33%	16.67%	16.67%
32	Korea Midland Power (komipo)	3	936	23	19.73%	100.00%	0.00%	0.00%
33	Elektrik Uretim AS	23	1,085	16	30.08%	4.35%	0.00%	0.00%
34	Maharashtra State Power Gen Co	7	1,243	28	41.71%	100.00%	0.00%	0.00%
35	Public Power Corp (dei)	21	1,070	14	60.87%	0.00%	52.38%	0.00%
36	Ameren	5	1,058	8	0.70%	0.00%	0.00%	0.00%
37	Polska Grupa Energetyczna	2	1,141	16	12.83%	0.00%	0.00%	0.00%
38	Dominion Energy Inc	8	994	8	17.93%	0.00%	0.00%	0.00%
39	Korea East-west Power Co	3	999	20	36.41%	33.33%	33.33%	0.00%
40	ENEL Spa	22	1,059	13	50.35%	22.73%	31.82%	0.00%
41	Israel Electric Corp	2	897	24	50.00%	100.00%	50.00%	50.00%
42	PLN	92	1,017	7	33.34%	0.00%	26.09%	0.00%
43	Korea Southern Power (kospo)	2	1,008	16	84.43%	0.00%	50.00%	0.00%
44	Tata Group	7	934	39	46.48%	100.00%	42.86%	42.86%

Rank by total SCPS MWh	Portfolio/Company	Number of SCPSs	SCPS portfolio mean carbon intensity (CO2 kg/ MWh)	SCPS portfolio mean 100km radius PM 2.5 levels	SCPS portfolio mean Water Stress	Percentage of SCPS portfolio located in areas with air pollution exceeding the WHO PM 2.5 limit	Percentage of SCPS portfolio in extremely high water stress catchments	Percentage of SCPS portfolio with air pollution exceeding the WHO PM 2.5 limit AND with extremely high water stress
45	GDF Suez	10	1,279	9	29.73%	0.00%	0.00%	0.00%
46	Comision Federal De Elec	58	1,027	7	53.99%	0.00%	39.66%	0.00%
47	Korea Western Power (kowepo)	2	1,044	23	50.00%	100.00%	50.00%	50.00%
48	EDF	8	948	10	28.28%	0.00%	0.00%	0.00%
49	Cez As	13	1,220	14	11.49%	0.00%	0.00%	0.00%
50	State Power Central Co	6	1,067	75	64.95%	100.00%	50.00%	50.00%
51	Entergy	3	1,060	7	15.39%	0.00%	0.00%	0.00%
52	Guizhou Electric Power Co	9	1,149	43	9.45%	100.00%	0.00%	0.00%
53	Beijing Energy Invest Holding	4	939	48	100.00%	100.00%	100.00%	100.00%
54	Shenergy Company Ltd	3	949	60	44.92%	100.00%	0.00%	0.00%
55	Citic Pacific Ltd	6	996	52	56.26%	100.00%	33.33%	33.33%
56	Korea Southeast Power Co	3	1,105	16	40.99%	0.00%	33.33%	0.00%
57	Rao Ues Russia	23	1,222	7	16.19%	0.00%	4.35%	0.00%
58	Great Plains Energy	5	1,038	8	5.12%	0.00%	0.00%	0.00%
59	Energy Future Holdings	2	1,130	5	28.77%	0.00%	0.00%	0.00%
60	Elektroprivreda Srbije (eps)	5	1,121	17	4.74%	0.00%	0.00%	0.00%
61	Vedanta Resources Plc	5	1,047	28	50.49%	100.00%	40.00%	40.00%
62	Gujarat Urja Vikas Nigam Ltd	8	1,114	30	68.56%	100.00%	37.50%	37.50%
63	Andhra Pradesh Power Gen Corp	5	998	23	33.83%	80.00%	0.00%	0.00%
64	Basin Electric Power Coop	3	1,127	6	36.96%	0.00%	33.33%	0.00%
65	Kazakhmys Plc	4	1,277	8	72.08%	0.00%	75.00%	0.00%
66	Transalta Utilities Corp	2	906	6	19.35%	0.00%	0.00%	0.00%

Rank by total SCPS MWh	Portfolio/Company	Number of SCPSs	SCPS portfolio mean carbon intensity (CO2 kg/ MWh)	SCPS portfolio mean 100km radius PM 2.5 levels	SCPS portfolio mean Water Stress	Percentage of SCPS portfolio located in areas with air pollution exceeding the WHO PM 2.5 limit	Percentage of SCPS portfolio in extremely high water stress catchments	Percentage of SCPS portfolio with air pollution exceeding the WHO PM 2.5 limit AND with extremely high water stress
67	Adani Power	2	893	27	50.23%	100.00%	50.00%	50.00%
68	Drax Power Ltd	1	937	8	27.80%	0.00%	0.00%	0.00%
69	Progress Energy	4	1,023	8	19.51%	0.00%	0.00%	0.00%
70	Salt River Project	2	1,016	5	32.22%	0.00%	0.00%	0.00%
71	Uttar Pradesh Rajya Vidyut	5	1,114	47	59.58%	100.00%	40.00%	40.00%
72	Santee Cooper	2	985	6	14.00%	0.00%	0.00%	0.00%
73	Dynegy Holdings	4	1,080	8	21.27%	0.00%	0.00%	0.00%
74	Zes Elek Patnow-adamow-konin	5	1,118	17	23.18%	0.00%	0.00%	0.00%
75	West Bengal Power Dev Corp	5	1,269	43	14.15%	100.00%	0.00%	0.00%
76	Stanwell Corp Ltd	2	1,085	2	38.22%	0.00%	0.00%	0.00%
77	Tamil Nadu Electricity Board	5	1,073	21	63.72%	60.00%	40.00%	20.00%
78	CMS Energy	7	1,019	7	38.95%	0.00%	0.00%	0.00%
79	Westar Energy Inc	3	1,155	8	5.40%	0.00%	0.00%	0.00%
80	Origin Energy	1	1,130	2	100.00%	0.00%	100.00%	0.00%
81	Punjab State Electricity Board	3	1,090	53	92.22%	100.00%	66.67%	66.67%
82	Ogk-2 (second Generation Co)	4	1,253	10	11.00%	0.00%	0.00%	0.00%
83	East China Electric Power Corp	8	1,186	59	76.79%	100.00%	50.00%	50.00%
84	Rajasthan Rv Utpadan Nigam	4	1,075	42	98.72%	100.00%	100.00%	100.00%
85	Neyveli Lignite Corp Ltd	2	1,447	32	91.51%	100.00%	100.00%	100.00%
86	Pt Indonesia Power - Suralaya	1	1,170	13	68.76%	0.00%	0.00%	0.00%
87	Fpc Huayang Zhangzhou Power	1	932	22	10.75%	100.00%	0.00%	0.00%
88	Termoelectrica	17	1,226	16	11.22%	0.00%	0.00%	0.00%

Rank by total SCPS MWh	Portfolio/Company	Number of SCPSs	SCPS portfolio mean carbon intensity (CO2 kg/ MWh)	SCPS portfolio mean 100km radius PM 2.5 levels	SCPS portfolio mean Water Stress	Percentage of SCPS portfolio located in areas with air pollution exceeding the WHO PM 2.5 limit	Percentage of SCPS portfolio in extremely high water stress catchments	Percentage of SCPS portfolio with air pollution exceeding the WHO PM 2.5 limit AND with extremely high water stress
89	DTEK	2	1,083	13	6.24%	0.00%	0.00%	0.00%
90	Oklahoma Gas & Electric	2	1,091	6	0.98%	0.00%	0.00%	0.00%
91	J-power	4	988	12	66.81%	0.00%	50.00%	0.00%
92	Delta Electricity	2	1,026	2	65.49%	0.00%	50.00%	0.00%
93	Associated Electric Coop Inc	3	1,050	8	0.82%	0.00%	0.00%	0.00%
94	Mp Power Generating Co Ltd	3	1,342	24	30.76%	100.00%	0.00%	0.00%
95	We Energies	3	1,121	8	47.56%	0.00%	33.33%	0.00%
96	Xishan Coal And Electricity	3	1,140	48	100.00%	100.00%	100.00%	100.00%
97	Electricity Generating Authority of Thailand	4	1,240	18	9.77%	25.00%	0.00%	0.00%
98	Intermountain Power Agcy	1	921	5	100.00%	0.00%	100.00%	0.00%
99	Puget Sound Energy Inc	1	1,120	4	14.46%	0.00%	0.00%	0.00%
100	Damodar Valley Corp	5	1,178	41	13.08%	100.00%	0.00%	0.00%

Note: SCPS portfolio mean carbon intensity is weighted by each power plant's MWh of generation. 'SCPSs located in areas with air pollution exceeding the WHO PM 2.5 limit' consist of SCPSs which have average observed PM 2.5 levels within 100km which exceed the WHO limit. Extremely High Water Stress is defined as BWS>80%.

SCPS Portfolio Carbon Intensity

Although Indian firms (5) dominate the tables for poor carbon efficiency, former Soviet (6) and Chinese portfolios (5) are also notable for their poor carbon performance.

Table 15: The 20 Least Carbon-Efficient Company Portfolios among the Largest 100 SCPS Portfolios

Rank	Portfolio/Company	Country	State owned	Listed	Number of SCPSs	Total SCPS MWh	SCPS portfolio mean carbon intensity (kg CO2/MWh)†
85	Neyveli Lignite Corp Ltd	India	YES	YES	2	16,725,380	1,447
94	Mp Power Generating Co Ltd	India	YES	NO	3	14,472,000	1,342
45	GDF Suez	France	NO	YES	10	30,125,526	1,279
65	Kazakhmys Plc	Kazakhstan	NO	NO	4	22,748,920	1,277
75	West Bengal Power Dev Corp	India	YES	NO	5	18,568,000	1,269
82	Ogk-2 (second Generation Co)	Russia	NO	NO	4	17,067,700	1,253
34	Maharashtra State Power Gen Co	India	YES	NO	7	37,556,000	1,243
97	Electricity Generating Authority of Thailand	Thailand	YES	NO	4	13,631,406	1,240
88	Termoelectrica	Romania	YES	NO	17	15,257,687	1,226
57	Rao Ues Russia	Russia	YES	NO	23	25,275,890	1,222
49	Cez As	Czech Republic	YES	YES	13	29,522,734	1,220
83	East China Electric Power Corp	China	YES	NO	8	17,035,085	1,186
100	Damodar Valley Corp	India	YES	NO	5	13,048,590	1,178
86	Pt Indonesia Power - Suralaya	Indonesia	YES	NO	1	16,644,000	1,170
79	Westar Energy Inc	United States	NO	YES	3	17,637,600	1,155
16	North China Grid Co Ltd	China	YES	NO	29	72,872,466	1,154
52	Guizhou Electric Power Co	China	YES	NO	9	27,641,800	1,149
37	Polska Grupa Energetyczna	Poland	YES	YES	2	36,020,000	1,141
96	Xishan Coal And Electricity	China	YES	YES	3	13,660,800	1,140
20	State Grid Power Corp	China	YES	NO	28	58,341,956	1,136

†SCPS fleet mean carbon intensity is weighted by power plant MWh of generation.

SCPS Portfolio Ambient PM2.5 Air Pollution

In an analogous fashion to the national analyses, in this section we take the average PM 2.5 measurements observed within a 100km radius of each SCPS, and average these figures across each of the SCPSs within each of the largest 100 portfolios. Reflecting the national analyses, the Chinese and Indian company portfolios have the worst PM 2.5 air pollution, with respectively, 15 and 5 firms in this largest 20.

Table 16: The 20 Company Portfolios with the Worst Ambient PM2.5 Air Pollution among the Largest 100 SCPS Portfolios

Rank	Portfolio/Company	Country	State owned	Listed	Number of SCPSs	Total SCPS MWh	SCPS portfolio mean 100km radius PM 2.5 levels
50	State Power Central Co	China	YES	NO	6	28,836,060	75
16	North China Grid Co Ltd	China	YES	NO	29	72,872,466	66
10	China Resources Power Holdings	China	YES	YES	29	97,645,759	66
20	State Grid Power Corp	China	YES	NO	28	58,341,956	61
54	Shenergy Company Ltd	China	YES	YES	3	27,240,107	60
83	East China Electric Power Corp	China	YES	NO	8	17,035,085	59
81	Punjab State Electricity Board	India	YES	NO	3	17,197,000	53
55	Citic Pacific Ltd	China	YES	YES	6	26,846,285	52
8	China Power Investment Corp	China	YES	NO	41	129,003,080	51
2	Huadian Group	China	YES	YES	69	284,448,220	50
53	Beijing Energy Invest Holding	China	YES	NO	4	27,519,000	48
96	Xishan Coal And Electricity	China	YES	YES	3	13,660,800	48
71	Uttar Pradesh Rajya Vidyut	India	YES	NO	5	21,017,800	47
4	China Datang Corp	China	YES	YES	52	211,691,720	46
1	China Huaneng Group	China	YES	YES	66	320,928,260	44
75	West Bengal Power Dev Corp	India	YES	NO	5	18,568,000	43
3	China Guodian Group	China	YES	YES	65	267,433,170	43
52	Guizhou Electric Power Co	China	YES	NO	9	27,641,800	43
84	Rajasthan Rv Utpadan Nigam	India	YES	NO	4	16,837,000	42
100	Damodar Valley Corp	India	YES	NO	5	13,048,590	41

Company SCPS Portfolios Water Stress

As in the national analyses, water stress is defined in this section as the annual proportion of water withdrawn to the total available flow ('Baseline Water Stress' from Aqueduct[94]). The 'SCPS Fleet Mean Water Stress' column in Table 17 below refers to the average water stress experienced across the SCPSs in each company fleet. It is calculated by taking the unweighted average of the water stress levels in each of the catchments where the applicable SCPSs are located. China (6) and India (5) have the greatest number of company portfolios that are under the most acute water stress.

Table 17: The 20 Company Portfolios with the Highest Water Stress among the Largest 100 SCPS Portfolios

Rank	Portfolio/Company	Country	State owned	Listed	Number of SCPSs	Total SCPS MWh	SCPS portfolio mean water stress
53	Beijing Energy Invest Holding	China	YES	NO	4	27,519,000	100.00%
80	Origin Energy	Australia	NO	YES	1	17,482,000	100.00%
96	Xishan Coal And Electricity	China	YES	YES	3	13,660,800	100.00%
98	Intermountain Power Agcy	United States	NO	NO	1	13,556,000	100.00%
84	Rajasthan Rv Utpadan Nigam	India	YES	NO	4	16,837,000	98.72%
81	Punjab State Electricity Board	India	YES	NO	3	17,197,000	92.22%
85	Neyveli Lignite Corp Ltd	India	YES	YES	2	16,725,380	91.51%
16	North China Grid Co Ltd	China	YES	NO	29	72,872,466	87.97%
30	Saudi Electricity Co	Saudi Arabia	YES	YES	78	41,446,725	86.32%
43	Korea Southern Power (kospo)	South Korea	YES	YES	2	31,095,500	84.43%
83	East China Electric Power Corp	China	YES	NO	8	17,035,085	76.79%
65	Kazakhmys Plc	Kazakhstan	NO	NO	4	22,748,920	72.08%
86	Pt Indonesia Power - Suralaya	Indonesia	YES	NO	1	16,644,000	68.76%
62	Gujarat Urja Vikas Nigam Ltd	India	YES	NO	8	23,366,839	68.56%
91	J-power	Japan	NO	YES	4	14,642,370	66.81%
26	Xcel Energy	United States	NO	YES	11	49,584,827	66.47%
92	Delta Electricity	Australia	YES	NO	2	14,633,400	65.49%
50	State Power Central Co	China	YES	NO	6	28,836,060	64.95%
4	China Datang Corp	China	YES	YES	52	211,691,720	64.24%
77	Tamil Nadu Electricity Board	India	YES	NO	5	18,136,518	63.72%

Footnotes:

[94] See the Appendix for a detailed breakdown of Baseline Water Stress levels.

6. Conclusion

China: SCPS Fleet on the Wrong Side of the Kuznets Curve

The outlook for the Chinese SCPS fleet is poor. The GHG, non-GHG, and water regulatory regimes around coal-fired power generation in China are tightening. While it is likely that the impact on generation will be nationwide, SCPSs in the heavily polluted and water-scarce northeastern region will be most heavily impacted. Given the young age of Chinese SCPSs and enormous size of the SCPS stock in northeastern China, this may well create a significant number of stranded SCPS assets through forced closure and impairment of profitability.

In addition to regulatory risk, physical water scarcity is a serious risk to a significant portion of the SCPS fleet, with nearly 37% of the fleet located in watersheds with high water stress and 33% of the fleet in watersheds with both high water stress and mean 100km Radius PM 2.5 pollution above WHO levels. Because of the severity of this pollution, both water availability and air quality should be considered a significant direct risk to the profitability of plants and indirectly via reputation. Potential reputational risks will increase over the short term in northwestern provinces as a result of tightening regulatory regimes that will push coal-fired generation westward, away from population centres and water resources. Previous analysis suggests that this shift will cause severe supply capacity problems beginning in 2015.[95]

US and EU: Existing and Impending Regulations Close Ageing Generators

The US and EU SCPS fleets face similar and seemingly final challenges. Both fleets are ageing, significant amounts of subcritical generation capacity have recently been closed by regulation, and future regulations promise further closures.

In the US, non-GHG policies will force the closure of at least 16% of SCPS capacity in 2015. Proposed regulations on maximum allowable GHG emissions will essentially preclude the construction of coal-fired power plants without carbon capture and storage. Furthermore, proposed state-based GHG emission reductions promise to put further pressure on existing SCPSs. Early analysis of this proposed regulation suggests that $28 billion in industry value will eventually be stranded, though immediate plant closures are expected to be minimal.

In the EU, little regulatory pressure is expected from the EU ETS. However, Europe's non-GHG emission policies have and will continue to close significant amounts of coal-fired generation. 35GW of capacity have been closed by the Large Combustion Plant Directive, an amount that may still increase by the end of 2015. This scheme will transition to the Industrial Emissions Directive, which has the potential to close up to 40GW of Europe's remaining 150GW of coal-fired capacity by 2023.

Footnotes:

[95] Greenpeace (August 2012). Thirsty Coal: A Water Crisis Exacerbated by China's New Mega Coal Power Bases..

India: Water Already a Serious Risk Factor

The Indian SCPS fleet faces serious water-related risks that are threatened to worsen, with currently 33% of generators located in areas of extremely high water stress. Since 2010, water scarcity has forced significant plant suspensions, which greatly impact plant profitability and lead to rolling blackouts. While companies such as India's NTPC, state that they secure water guarantees from state governments for the lifetime of plants before construction, this can create direct competition with irrigation for agriculture. This competition has already resulted in political tensions and social unrest, and should be considered a serious reputational risk.

Nearly one in three Indian SCPSs are located in areas of water stress and also have mean 100km Radius PM 2.5 levels which exceed the WHO limit. Although no forthcoming direct regulatory policies that would require the installation of emission scrubbers, electrostatic precipitators, or FGD units were identified, the possibility of market-based mechanisms to control NOx and SO2 pollution should be considered a serious future risk to the Indian SCPS fleet.

Beyond this risk, there are two additional regulatory risks to the Indian SCPS fleet. The first is the Perform, Achieve, Trade (PAT) mechanism, an energy efficiency trading scheme that is designed to financially disadvantage less efficient plants. Because this mechanism affects subcritical plants more severely than newer supercritical plants, this policy decreases the profitability of the least efficient and oldest portions of India's SCPS fleet. The second regulatory risk is India's 2012 National Water Policy; however, the Government of India has not specified mechanisms, tools, or charges related to this policy. Thus, there exists great uncertainty for SCPSs in water-stressed areas in terms of profitability and licenses to operate.

Implications for Investors, Companies, and NGOs

This report has disentangled general environmental and regulatory risks associated with the ownership of subcritical coal-fired generation assets into specific carbon, air pollution, and water stress threats. There is a strong case for financial institutions to utilise the information contained in this report to evaluate the risk of companies that hold subcritical assets and, where appropriate to then screen, engage, or divest. As part of further analysis and engagement with companies exposed to at risk subcritical assets, investors and civil society could encourage companies to: i) publicly confirm their exposure and the proportion of their total generation portfolio that is subcritical, ii) disclose what proportion of this is most at risk, for example, the bottom quartile in terms of carbon intensity, air pollution, and water stress, iii) disclose how much of their capex pipeline is subcritical and how this might change portfolio risk exposure, and iv) describe the strategies employed at an asset-level and across a portfolio to minimise carbon intensity and manage deleterious contributions to local air pollution and water stress.

Table 18: Summary of Possible Responses

Relevant SCPS Stakeholders	Possible Responses
Fixed-Income Investors	Reassess required yields Divest if necessary
Ratings Agencies	Reassess company ratings
Equity Investors	Reassess required returns Demand that management reduce environmental and regulatory risks Divest if necessary
Bank Loan Assessment	Reassess lending rates Resell risky loans
Environmental Groups	Target environmentally irresponsible nations and companies for improvement

Research Extensions

This report has analysed the global stock of the world's most carbon inefficient and heavily polluting power stations. Refinement of this data, such as by developing a timeline for projected global SCPS capacity, or incorporating additional individual plant-level information on plant age, boiler type, installed pollution abatement technologies, coal-fuel specifications, cooling methods, and the percentages of total generation which consists of SCPS would allow for more fine-grained analyses of national fleets and company portfolios. Future research might also cast a critical eye on the relationship between SCPS and other coal pollutants, such as NOx, SOx and mercury. Another possible extension would be to assess the upstream constraints of further coal generation expansion by overlaying SCPSs against proximate coal mines and coal delivery infrastructure capacity.

Appendix

Power Plant Data Notes

Individual power plant information is taken from the most recent version (v3) of the Carbon Monitoring for Action (CARMA) database. This data is merged with plant-level data from Enipedia and new plant data from CoalSwarm's Global Coal Plant Tracker. For CoalSwarm data only plants classified as currently operational are considered. Although CARMA was last systematically updated in 2009, Enipedia is continuously updated on an individual power plant basis. The merger between these datasets produced a dataset which effectively defined the locations of all the world's power plants, the ownership of these plants, the annual megawatt hours of electricity produced at each plant, and the carbon intensity of each plant's electricity production. Because subcritical coal power plants are the most carbon intensive form of energy production, we can infer which power plants are SCPS based solely on their carbon intensity. In this report we use the IEA's definition of SCPSs, which are power plants with carbon-intensity of ≥880kg CO_2/MWh.

The CARMA data has a number of caveats which are thoroughly enumerated on its website (carma.org), but there are two points which are particularly relevant to this paper. The first is that CARMA estimates electricity generation and CO_2 emissions using statistical models that have been fitted from detailed US plant data. Roughly 87% of the SCPS data used in this report is based off of these fitted values. CARMA reports that fitted CO_2 emissions values are within 20% of the true value 60% of the time, and that electricity generation is within 20% of the true value 40% of the time. The remaining 13% of SCPS data comes from actual reported values, and consists of 26% of total SCPS generation. Second, CARMA geographical location data varies in its degree of precision. For almost all power plants the state/province location is known, for 80% of power plants at least the city location is known, for 40% county/district data is known, and for 16% of power stations a unique postal code is assigned. Comparisons of approximate and precise coordinates suggest that the average spatial error is about 7 km.

Particulate Matter (PM) 2.5 Data Notes

For analysis of air quality risks associated with SCPSs, a measure of PM 2.5 is used. This data is taken from the analysis of Boys, Martin et al. (2014), and consists of annual ground-level PM 2.5 averages between 2010-12 derived from satellite observation. Particulate matter levels are naturally high above deserts due to windborne dust, and both this natural and anthropogenic sources of PM 2.5 show up in the Boys, Martin et al. (2014) data. This phenomenon appears to account for the high levels of PM 2.5 visible across the Sahara Desert and the Arabian Peninsula in spite of the low-levels of industrial activity in these locations. However, both of these regions are outside the study areas of this report.

Water Stress Data Notes

The measure for water stress used in this report is Baseline Water Stress (BWS) from Aqueduct created by the World Resources Institute (WRI). BWS is defined as total annual water withdrawals (municipal, industrial, and agricultural) expressed as a percent of the total annual available flow within a given watershed. Higher values indicate greater competition for water among users. Extremely high water stress areas are defined by WRI as watersheds with >80% withdrawal to available flow ratios, 80-40% as high water stress, 40-20% as high to medium, 20-10% as medium to low, and <10% as low. Mean water stress is calculated by taking the unweighted average of the water stress levels in each of the catchments where the applicable SCPSs are located.

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