THE CASE FOR COAL

THE POWER OF HIGH EFFICIENCY COAL

REDUCING EMISSIONS WHILE DELIVERING ECONOMIC DEVELOPMENT AND RELIABLE ENERGY

WORLD COAL ASSOCIATION

KEY POINTS

- There are 1.1 TW of coal capacity under construction or in development in non-OECD regions. Analysis indicates that there is around:

  – 200 gigawatt under construction
  – 900 gigawatt in development.

- Of the 900 gigawatt in development in non-OECD regions, analysis suggests that around 500 gigawatt are planned to use high-efficiency, low emission (HELE) technologies.

- Analysis suggests that by 2040 subcritical coal-fired power generation capacity could comprise 43% of incremental coal-generation capacity. From the perspective of global action on climate change there is a clear need to shift incremental coal-generation capacity further away from subcritical and towards HELE technologies.

- The conversion of the remaining 400 gigawatt of capacity in development to HELE technologies would cost around $31 billion and save 6 billion tonnes of CO_2 from 2015 through to 2040.

- There is a significant opportunity to influence the type of technology that developers select. But with limited financing options available from development banks developers may accept lower efficiency and poorer emissions rates due to the upfront capital cost differences between subcritical and HELE technologies.

- By 2040, the tonnes of CO_2 saved will amount to 1.1 billion per year.

- The conversion of both 400 gigawatt of subcritical and 300 GW of supercritical capacity to ultra-supercritical capacity would cost around $81 billion and save 13 billion tonnes of CO_2 from 2015 through to 2040.

- Given that coal is expected to remain the most affordable option to meet increasing power demand (on an $/MWh basis), no other low-emission generation technology can provide the same terawatt-hour of generation for the same investment.

- In 2035, under our Base Case assumptions for non-OECD Asia, ultra-supercritical is between 30% and 45% cheaper than Combined Cycle Gas Turbines, and between 25% and 30% cheaper than large-scale solar PV (on a levelised cost of electricity basis).

- Furthermore, given the higher capital costs of renewable technologies and their lower load factors, in most regions, conversion to HELE technologies represents the lowest CO_2 abatement alternative (on a $/tonne basis).

- In 2035, under our Base Case assumptions for non-OECD Asia, the avoided cost of CO_2 through ultra-supercritical is between $40/tonne and $75/tonne lower than Combined Cycle Gas Turbines, and between $10/tonne and $35/tonne lower than large-scale solar PV.

Disclaimer: The analytical basis and assumptions for this outlook are based on long-term macroeconomic and energy secondary analysis from reports including the IEA World Energy Investment Outlook 2014 and IEA Projected Costs of Generating Electricity – 2015 Edition. Further information on data sources is available on the World Coal Association website.

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REDUCING EMISSIONS WHILE DELIVERING ECONOMIC DEVELOPMENT AND RELIABLE ENERGY

The International Energy Agency (IEA) forecasts that coal will continue to play an important role in power generation over the long-term. Indeed, the IEA projects that the share of coal in power generation will rise from 32% to 50% in Southeast Asia – a region the agency's Executive Director has referred to as the centre of the global energy arena.

Emerging economies require coal for more than just safe, reliable and affordable energy. Coal is also set to play a critical role in achieving the UN 2030 Sustainable Development Goals (SDGs). Over the coming decades, urbanisation and industrialisation will increase as SDGs are realised. Cities will see their populations rise as more and more people are attracted to the economic opportunities, modern amenities and access to education they provide. Economic and demographic changes will lead to the increased use of highly energy-intensive materials, such as steel, cement, glass and aluminium. These materials are necessary for the construction and development of transport, energy, housing and water management infrastructure critical for an advanced economy. Coal is a major part of this outcome. For instance, around 770 kg of coal is required to produce 1 tonne of crude steel.

These trends explain why many countries submitted Intended Nationally Determined Contributions (INDCs) which demonstrated a role for advanced coal technologies. High efficiency, low emission (HELE) technologies with rates of efficiency of around 40% are available "off-the-shelf". Currently, they are being installed and used in many countries where they have proved to provide efficiency gains and are financially viable. Raising the average global efficiency of coal plants from 33% to 40% with the off-the-shelf technology that is available today would save 2 gigatonnes of CO_2 emissions. This is equivalent of running the Kyoto Protocol three times over.

As the Paris Agreement is formalised and NDCs are standardised, it is a fair to assume that other countries will look to HELE coal technologies as part of their emissions reductions plans. Recognising this, the World Coal Association (WCA) commissioned external analysis to demonstrate how HELE technology can play a constructive role as governments seek to limit greenhouse gas (GHG) emissions.

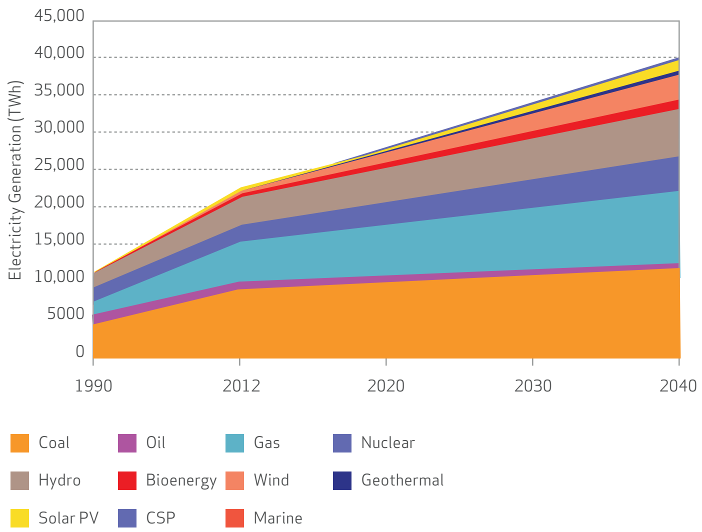
This paper provides a high-level summary of the outcomes of this analysis.

Note: unless otherwise indicated all data and figures are taken from analysis conducted for WCA. Unless otherwise specified, all figures are in US $.

Projections of new coal-fired generation capacity

Under its New Policies Scenario (NPS)[1], the IEA projects that global installed coal-fired generation capacity will reach 2.6TW by 2040, representing about 12,000 TWh of electricity generation. Most of the new coal-fired generation is expected in developing countries, with Non-OECD Asia[2] representing just over 75% of the coal installed capacity and generation by 2040. Of this, China and India account for around 840 GW, with Indonesia and Vietnam accounting for around a further 96 GW.

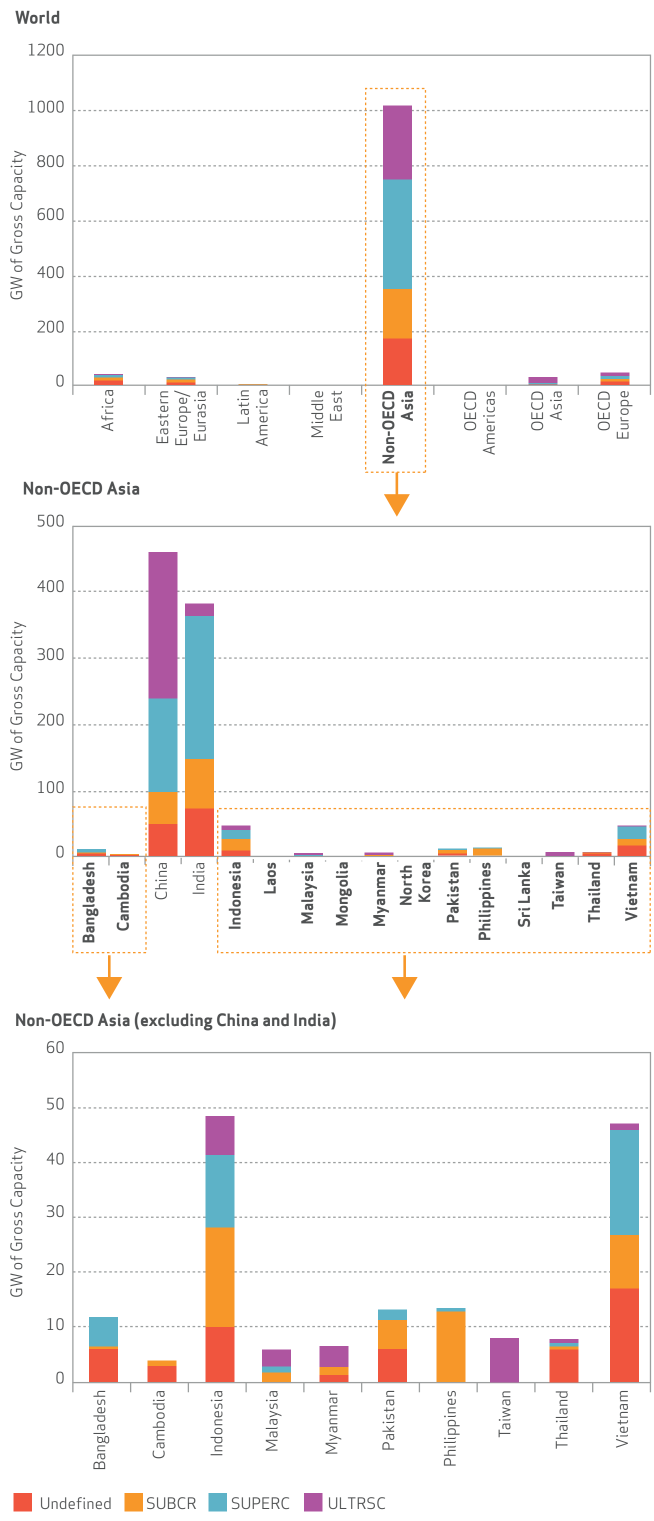
Figure 1: Global Electricity Generation Mix



Source: World Coal Association analysis, 2015

This is an unsurprising development when the relative costs of different power generation technologies are compared. In addition to reliability, coal is projected to be the cheapest option to meet electricity demand growth for many Asian economies[3].

Figure 2: Coal-fired capacity under construction or in development



Source: World Coal Association analysis, 2015

[1] *Analysis based on IEA data (WEO 2014, Annex A)*
[2] *China, Pakistan, Bangladesh*
[3] *On the basis of capital cost, cost of capital and fuel price assumptions used in analysis*

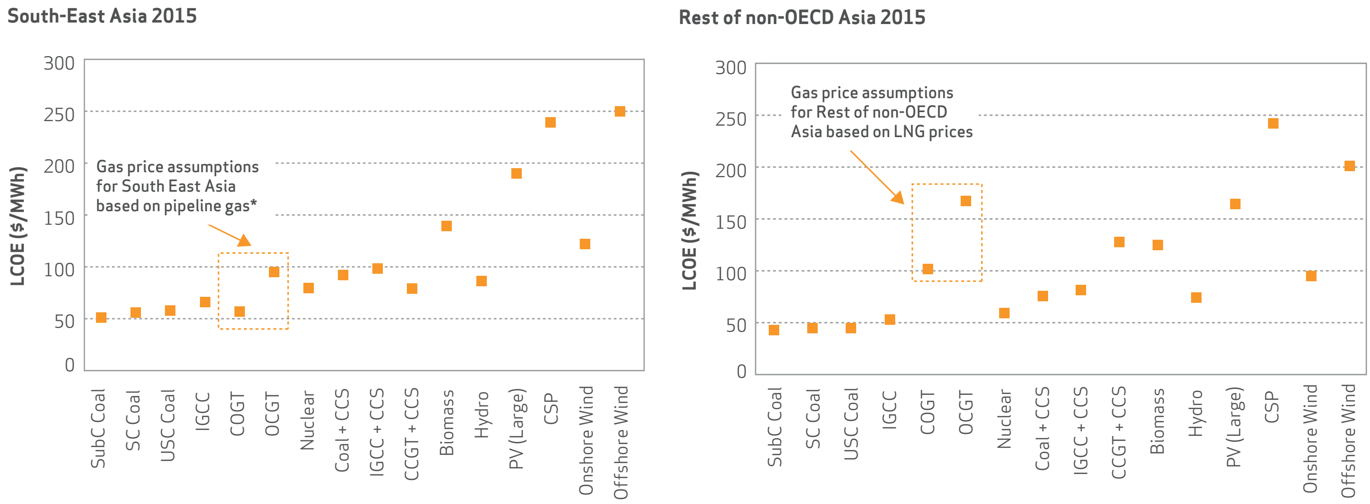
Demonstrating this, Figure 3 plots the levelised cost of electricity (LCOE) per megawatt hour (MWh) across generation technologies in 2015.

The graphic highlights that coal costs less than other technologies – including gas – in ASEAN countries plus India, Bangladesh, Sri Lanka and Pakistan (grouped as South East Asia in the graphs below). The LCOE cost for the HELE technologies – supercritical coal (SC), ultra-supercritical coal (USC) and integrated gasification combined cycle (IGCC) – ranges from 55 to 60 $/MWh. In comparison, the LCOE cost of Open Cycle Gas Turbine (OCGT) is almost double.

It should also be taken into consideration that for many of these countries coal is more readily available than gas, which requires the development of pipeline infrastructure for its delivery.

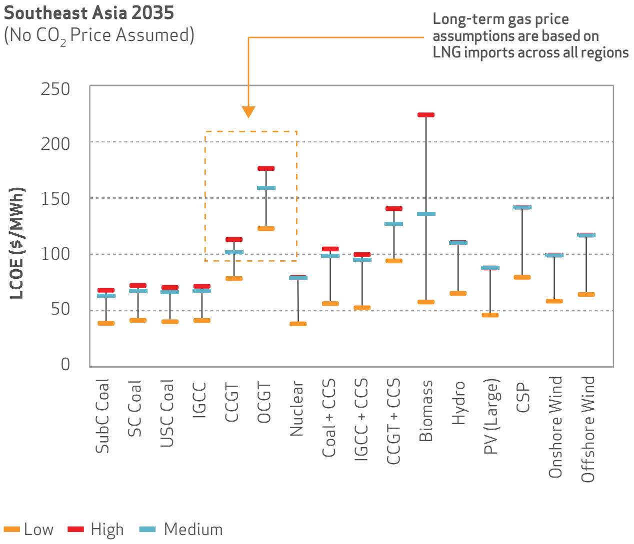
The comparative cost advantages of coal generation is even clearer in China, which is the main economy represented in the 'Rest of non-OECD Asia' graphs below. The various HELE technologies have an LCOE of around $50/ MWh, a third of the price of open cycle gas turbines.

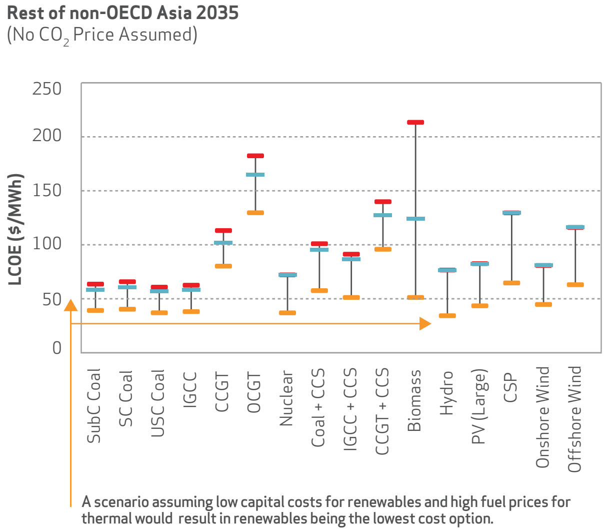
Figure 3: Lifetime Cost of Electricity per MWh across Generation Technologies in 2015



Source: World Coal Association analysis, 2015

Figure 4: Lifetime Cost of Electricity per MWh across Generation Technologies in 2035





Source: World Coal Association analysis, 2015

As demonstrated in Figure 4, analysis suggests that coal-fired generation is likely to remain the affordable option to meet electricity demand in developing and emerging economies over the next two decades. The 'high' case in Figure 4 (red line) represents the impact of high fuel price sensitivity, while the low case (blue line) illustrates the impact of low capital costs. Given that the high case focuses on fuel prices this is not applicable to the renewable technologies.

While it may be assumed the capital costs of renewables will increase their competitiveness against thermal generation over time, low load factors are also likely to limit their competiveness on a $/MWh basis. As recent events highlight, gas is subject to significant fuel price uncertainty.

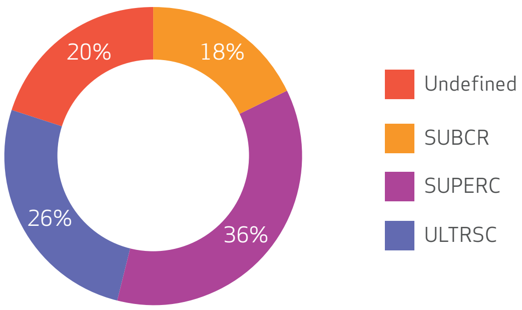
Under the price assumptions, however, gas will remain a higher cost alternative than coal.

The benefits of substituting subcritical coal with HELE coal-fired power generation

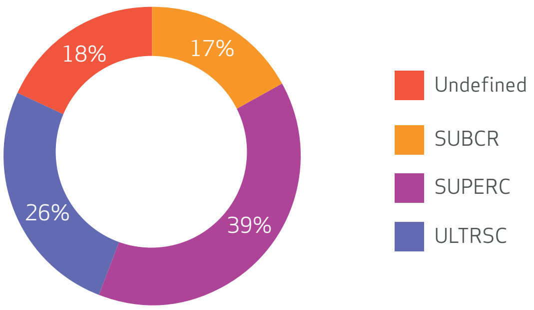
While there are clear environmental benefits to deploying HELE technologies, around 18% of coal-fired capacity currently under construction or under development will use subcritical technology. In Africa, this figure increases to 28% of capacity in the project pipeline. Moreover, for many proposed projects the technology choice has not been finalised. This represents a significant opportunity to influence the type of technology that developers select. Analysis suggests that by 2040 subcritical coal-fired power generation capacity could comprise 43% of incremental coal-generation capacity. From the perspective of global action on climate change there is a clear need to shift incremental coal-generation capacity further away from subcritical, towards HELE technologies.

Figure 5: Capacity growth of coal-fired power generation

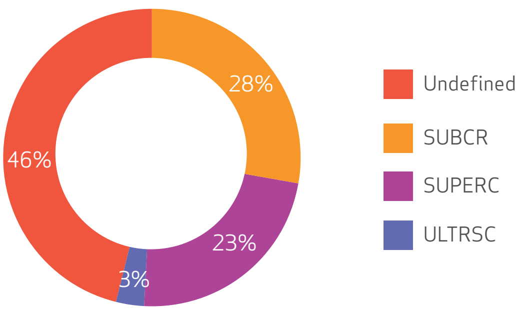
Global
Under Construction and Planned
Coal-Fired Capacity (1.2TW)



Non-OECD Asia
Under Construction and Planned
Coal-Fired Capacity (1 TW)



Africa
Under Construction and Planned
Coal-Fired Capacity (44 GW)



Source: World Coal Association analysis, 2015

With limited financing options available from development banks developers may accept lower efficiency and poorer emissions rates due to capital cost differences between subcritical and HELE technologies.

For instance, Table 1 below shows that a new 1,000MW subcritical coal generation plant in South East Asia currently costs around $1 billion, while an equivalent ultra-supercritical plant costs around $1.5 billion.

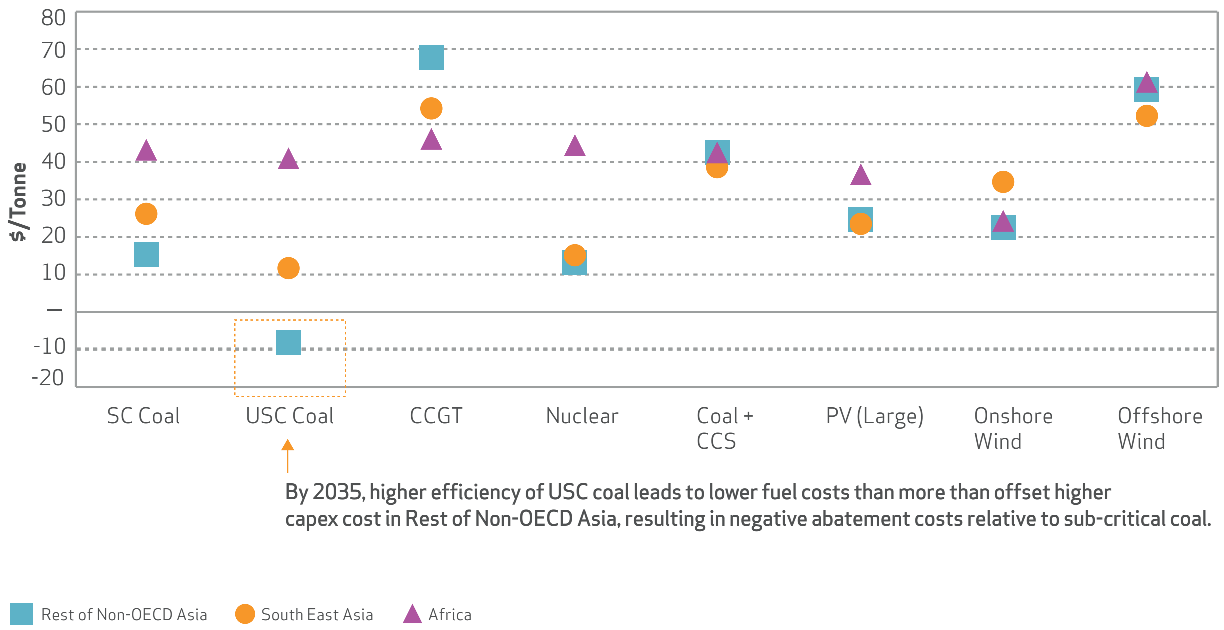
Table 1: Relative Performance of Coal-Fired Generation Technologies in South East Asia

Technology	**Capital cost**	**Net thermal efficiency**	**Emission rate**	**Capital cost 1GW plant**	**Annual emissions (@85% load factor)**
	2014 $Mil/MW	*(%)*	*tCO_2/ MWh*	*2014 $Mil*	*Million t CO_2*
Subcritical	1.05	32%	1.04	1,047	7.73
Supercritical	1.26	36%	0.88	1,256	6.54
Ultra supercritical	1.47	39%	0.81	1,465	6.06

Source: World Coal Association analysis, 2015

Despite this higher initial capital outlay, investment in supercritical coal is a cost-effective way to reduce CO2 emissions across the developing world.

Figure 6: Avoided Cost of CO_2 in Sample non-OECD Regions (Subcritical Coal Plant used as Baseline)



Source: World Coal Association analysis, 2015

Figure 6 plots the LCOE analysis and relative emissions rates of different types of power generation technologies across non-OECD regions, calculating the cost of avoiding a tonne of CO_2 emissions through the replacement of sub-critical coal with different technology options.

As shown in Figure 6, analysis indicates that replacing sub-critical with supercritical coal technology saves CO_2 at a cost of around $25/ tonne in Southeast Asia, $15/ tonne in the rest of non-OECD Asia, and just over $40/ tonne in Africa. Moreover, under the Base Case assumptions, the cost of CO_2 abatement through the deployment of ultra-supercritical technology in Southeast Asia and the rest of non-OECD Asia is lower than any other alternative (from around -$10/tonne to around $10/tonne), due to the reduction in fuel prices achieved through the technology's higher energy efficiency. In other words, the higher initial cost of building an ultra-supercritical plant in non-OECD Asia, for instance in China, is more than offset by the reduced cost of fuel over the facilities life span.

Examining this further, Table 2 highlights the impact of two scenarios relative to the Business-as-Usual (BAU) assumption of continued investment in subcritical capacity.

Table 2: Investment in HELE technologies can reduce global emissions by up to 13 billion tons of CO_2

	Mix per current pipeline	Shift to Super-critical	Shift to Ultra Super-critical
Scenario Description	Total installed coal capacity by 2040 based on WEO projections with linear extrapolation between current pipeline of projects as reported by the Platts WEPD (percentage of Sub-Critical capacity through 2040 based on current pipeline)	Shift capacity from sub-critical to super-critical except plant than are under contruction or planned sub-critical plant capacity lower than 300MW	Shift all capacity from super-critical in the previous scenario to ultra super-critical
Capacity Mix (GW Capacity)	USC 240 SC 394 SubC 483	USC 240 SC 801 SubC 76	USC 952 SC 96 SubC 76
NPV Capital Costs ($ Billion) (from 2015 through 2040)	$588 Billion	$619 Billion	$670 Billion
		$82 billion of additional financing required to shift to ultra super-critical	
CO_2 Emissions (tCO_2) (from 2015 through 2040)	115 Billion	109 Billion	102 Billion
		Additional funding can reduce carbon emissions by 13 billion tons	

Notes:
1) Total GW of coal capacity additions based on WEO projections under the New Policies Scenario to 2040
2) Subcritical capacity in this analysis includes pipeline coal capacity with undefined technology plus a projected share of WEO total projected coal-generation capacity in proportion to the mix of Sub-Critical, Super-Critical and Ultra Super-Critical based on coal capacity currently under construction or in development as reported by the Platts WEPD
3) Costs include only capital costs

Source: World Coal Association analysis, 2015

In the first scenario, the possible new 'switchable' subcritical coal-fired generation capacity (that is not already under construction and which is greater than 300MW) is assumed to be replaced with supercritical coal-fired generation capacity in the period through to 2040. This leaves some 76GW of coal capacity remaining subcritical but more than doubles the amount of possible supercritical coal capacity. As a consequence, the upfront capital costs, expressed in net present value terms, increases from $588bn to $619bn. However, at the expense of this additional $31bn, CO2 emissions are reduced by 6bn tonnes.

In the second scenario, ultra-supercritical coal-fired generation capacity is deployed instead of subcritical capacity and supercritical capacity that is not already under construction. This has a larger upfront capital cost - some $82bn more than in the BAU scenario - but reduces CO2 emissions by 13bn tonnes.

The greater benefits of HELE coal-fired generation relative to renewables

Without financial support, development of subcritical coal capacity is likely to continue. However, with an extra $82bn of financial support, the question might be asked: "Isn't it better to use this financial support to fund technology with zero emissions?"

The problem with increasing funding for the deployment of renewable generation is that its low load factor means that per dollar of investment, it substitutes for much fewer MWh of subcritical generation than is the case with HELE coal-fired generation. Therefore, in practice, HELE coal-fired generation mitigates more CO_2 emissions than renewables per dollar of investment.

To put this in context, the IEA projects a growth of approximately 10,000 TWh of electricity demand in non-OECD Asia between 2020 and 2040. The analysis in Table 3 compares the upfront capital investment required for the different generation scenarios which could be used to meet this demand growth.

In the first instance, this could be met at an investment cost of $699bn with subcritical coal-fired generation capacity resulting in 9.5bn tonnes of CO_2 per annum.

However, with an extra $233bn of funding, ultra-supercritical coal-fired capacity could replace all the subcritical capacity, produce the same 10,000TWh but emit 2.5bn tonnes less CO_2 each year.

Table 3: Compared to renewables, HELE technologies can reduce more emissions for the same upfront investment

Investment Option	Generation Mix for 10,000 TWh (%)		Required Capacity (GW)		Total CAPEX[1] ($Billion)	% Increase in CAPEX to Baseline	Annual Emission (Bn. tCO_2)
	Coal	Renewable	Coal	Renewable			
Sub-Critical Coal Only	**100**	**0**	**1,343**	**0**	**699**	**Baseline**	**9.5**
Ultra Super-critical Coal Only	100	0	1,343	0	932	33	**7.0**
Sub-critical Coal and Onshore Wind	95	5	1,269	241	932	33	9.0
Sub-critical Coal and Solar PV	96	4	1,284	264	932	33	9.1
Onshore Wind Only	0	100	0	4,391	4,944	607	0
Solar PV Only	0	100	0	6,008	6,002	759	0

$233 Billion of additional funding required

For the same additional financing, ultra super-critical coal technology generates the least amountof emissions

Low load factor renewable technologies means significantly higher required capacity - and therefore higher CAPEX - to generate the same TWh of electricity

Notes:
1) Based on IEA's WEO 2014 New Policy Scenarios capital cost estimates for China in 2035 with construction costs spread equally over the construction period

Source: World Coal Association analysis, 2015

In contrast, with the same additional funding, onshore wind or large scale solar PV cannot displace subcritical coal-fired capacity to the same extent, while also delivering the 10,000TWh. As a result, the residual TWh demand not met by renewable sources may be met by subcritical generation capacity and, as a subsequent result, onshore wind or large scale solar PV does not reduce emissions by the same amount as ultra-supercritical coal capacity.

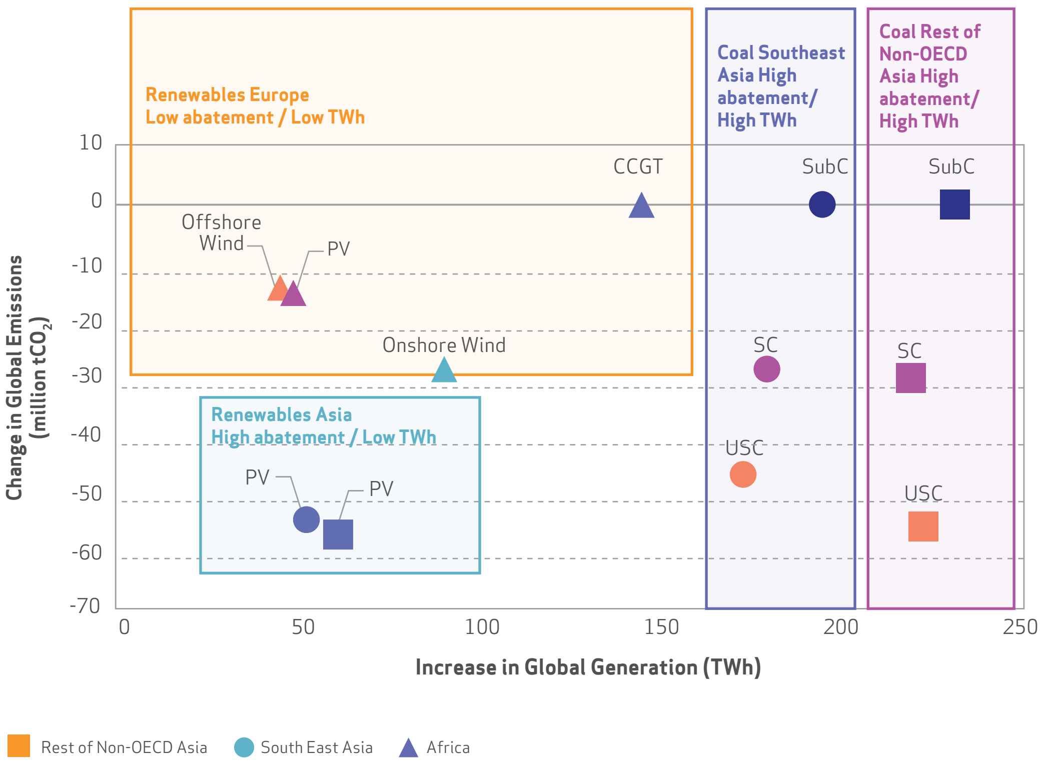
This means that, while satisfying consumers' demand for electricity and meeting financial constraints, ultra-supercritical coal capacity may be a more logical choice than renewable technologies (given the underlying cost and technical assumptions in this analysis).

Investment in HELE technologies in Non-OECD Asia can achieve higher generation and higher CO_2 reduction than the same investment in OECD Europe

Additional investment in HELE coal-fired generation is not just preferable to investment in renewables in Non-OECD Asia. It is also preferable to investment in renewables in Western Europe.

This is shown in Figure 7 which illustrates the impact of spending $10bn across different generation options in South Asia (mainly India) and OECD Europe. In contrast to the preceding analysis, it considers not just capital investment costs but LCOEs, as well as emission rates across technologies.

Figure 7: The generation and reduction benefits of a $10 billion HELE investment in non-OECD Asia



Notes:
1) Based on 2015 LCOEs
2) Given that a $10 Billion investment may not be able to replace all the TWh generated by the 'baseline' technology, any TWh shortfall is assumed to be generated at the emission rate of the baseline technology

Source: World Coal Association analysis, 2015

In Western Europe, the $10bn expenditure in offshore/onshore wind or solar PV is considered to displace output from a combined cycle gas-fired turbine (CCGT). A CCGT is selected as the baseline technology due to the availability of gas and additional environmental regulations that discourage construction of new coal plants in the region. Emissions are reduced by up to 30mn tonnes of CO_2 per annum. This is shown by the renewable technologies in the black-bordered rectangle in the figure.

In contrast, the same investment in South Asia in Solar PV has the potential to reduce emissions by up to 55mn tonnes CO_2 per annum, in part because it is considered to be displacing subcritical coal capacity as opposed to CCGTs. However, the incremental generation from the solar PV is only some 50TWh which can only replace around 25% of the equivalent output from subcritical capacity for the same expenditure. However, ultra-supercritical capacity, with the same fixed expenditure of $10bn, is able to both match the TWh output of the subcritical capacity and, as a result, deliver nearly the same emission reductions as the investment in solar PV. This is much more than the emission reductions achieved in Western Europe for the same expenditure.

Platform for Accelerating Coal Efficiency

HELE coal-fired power generation has a vital role in promoting energy access and economic development, whilst reducing emissions from the use of coal.

Recognising this, the WCA published a concept paper on establishing a global Platform for Accelerating Coal Efficiency (PACE).

PACE provides a vision that for countries choosing to use coal, the most efficient power plant technology possible is deployed. The overriding objective is to raise the global average efficiency of coal-fired power plants and so minimise CO_2 emissions which will otherwise be emitted while maintaining legitimate economic development and poverty alleviation efforts.

It is the WCA's position that there should be coordinated global action to support developing and emerging economies already choosing to use coal to do so with the lowest possible emissions profile.

Key messages from the PACE proposal include –

- Over the next 20 years, continuing industrialisation and urbanisation will result in a continued demand for coal. Additionally, with 1.3 billion people globally without access to electricity, it is clear all sources of energy will be needed to meet this demand, including coal.
- Technologies such as HELE coal plants and carbon capture, use and storage (CCUS), can make a significant contribution to reducing global CO_2 emissions as part of the energy mix. Moreover, deploying HELE technology is a key first step along a pathway to near-zero emissions from coal with CCUS.
- Moving the current average global efficiency rate of coal-fired power plants from 33% to 40% by deploying more advanced off-the-shelf technology could cut two gigatonnes of CO_2 emissions now, while allowing affordable energy for economic development and poverty reduction.

World Coal Association

The World Coal Association is a global industry association formed of major international coal producers and stakeholders. The WCA works to demonstrate and gain acceptance for the fundamental role coal plays in achieving a sustainable and lower carbon energy future. Membership is open to companies and not-for-profit organisations with a stake in the future of coal from anywhere in the world, with member companies represented at Chief Executive or Chairman level.

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