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CORNERSTONE

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Returning Mined Land to Productivity Through Reclamation

Jason Hayes
Associate Director, American Coal Council

Working Alongside the Great Barrier Reef

The Colowyo Mine: A Case Study for Successful Mine Reclamation

Mining Site Restoration by Spontaneous Processes in the Czech Republic

WORLD COAL ASSOCIATION

30TH ANNIVERSARY \ 1985-2015

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Learning From Positive Outcomes on Land Reclamation

Holly Krutka
Executive Editor, *Cornerstone*

As this issue of *Cornerstone* goes to press, world leaders are meeting in Paris, France, for the COP21 negotiations under the United Nations Framework Convention on Climate Change. Momentum for the meetings has long been building, and future issues of *Cornerstone* will cover the outcomes, as they pertain to the coal industry and the broader energy community. As we have done in the past, we will continue to focus on policy approaches and technologies—including high-efficiency, low-emissions (HELE) coal-fired power plants and carbon capture, utilization, and storage—which enable coal utilization in a carbon-constrained world.

While the significance of reducing emissions is not easily overstated, the environmental footprint of energy production and utilization is far from limited to greenhouse gases. For example, working with local communities and governments to ensure mined land is successfully reclaimed is a process that may not garner the same amount of attention as climate change mitigation, but to those living near mines it can cut at the heart of sustainable energy. Thus, in this issue of *Cornerstone*, we are highlighting lessons learned and international best practices in reclamation projects—principally from opencast mines. For countries currently growing their coal production, the decades of experience gained in reclamation efforts around the world could help leapfrog standard learning cycle time requirements to enhance reclamation practices.

Reclamation often begins while coal is being actively mined elsewhere at the same site. Such an approach minimizes the footprint of an opencast mine at any given time. Prior to the first excavation shovel, successful reclamation requires soliciting input from local stakeholders and ecology experts. Identifying any plant or animal species at risk, planning for drainage, and defining the optimal end use for the land are key first steps that are site specific. For example, as highlighted in this issue, while the western U.S. may use reclaimed land for livestock grazing, in the Czech Republic, which has recently announced that it is increasing limits on lignite production, nature preserves are a good fit. In cases such as the Czech Republic, spontaneous reclamation—allowing nature to do the work—has demonstrated ecological value.

Positive reclamation projects require an understanding of the local ecology and the risks posed by mining and other associated activities. Protection of the sage grouse in the western U.S. is an important success story of how mining companies have worked with local governments and environmental experts to minimize impact. As this issue of *Cornerstone* was being prepared, the U.S. Fish and Wildlife Service announced that the sage grouse would not be added to the endangered species list—a positive result for the bird and also the stakeholder groups that have been working to operate mines without affecting it unduly.

As global leaders negotiate on climate change mitigation, there may well be lessons on collaboration and commitment to the environment that can be gleamed by considering decades-long reclamation efforts. On behalf of the editorial team, I hope you enjoy this issue of *Cornerstone*.

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Returning Mined Land to

By Jason Hayes
Associate Director, American Coal Council
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"Key objectives in reclamation activities are to reduce potential damage and prevent negative impacts to the natural environment in and near mined areas..."

Nearly 8.2 billion tonnes of coal were produced globally in 2014.[1] Although a great deal of activity occurs around the extraction of coal, a limited amount of land is disturbed during mining compared to total landmass. For example, Natural Resources Canada has estimated that less than 0.01% of Canada's total landmass was used in metal and mineral mining in over 100 years.[2] Similarly, Haigh estimated that mining affected 0.16% of the U.S. landmass from 1940 to 1971.[3] However, even if mining affects a relatively small amount of land, its impact can be significant and the extractive industries have an ethical and often legal obligation to return land to productivity.

Productivity Through Reclamation

Each coal mine has a limited life span due to the finite nature of the resource being extracted. Eventually the resource is exhausted, or the point is reached at which it is no longer profitable to extract for any number of reasons, such as increasing mine depth, increasing strip ratios, changing regulations, or market pressures.

When extractive activities cease, restoration processes must be completed, although they normally begin far sooner. In fact, reclamation processes typically begin while active mining is still occurring in another area of a mine. Thus, mining and restoration can be completed continuously and progressively throughout the life of a mine.

The costs associated with these restoration activities can be substantial: One estimate suggests US$1.5 million per mine, although varied mine sizes, regulatory regimes, or the presence of legacy reclamation costs could result in wide fluctuations in cost.[4]

Today in many parts of the world, reclamation and restoration plans must be prepared prior to mining. An improved understanding of the potential impacts of industrial activities, societal attitudes toward mining, increasingly stringent regulatory regimes, and dynamic market conditions now typically require companies to state clearly how their operating area will be restored before mining can begin.

There are various approaches to reclamation, and collaborative efforts between industry and government can help to improve mine management and reclamation processes. Thus, best practices and select case studies are worth exploring to highlight examples of successful mine closure and remediation.

THE PROCESS OF RECLAMATION

Reclamation can be roughly defined as the replacement of soil materials—often to approximate original contour—and revegetation of mined areas or areas adjacent to mines that have been affected by mining activities. An alternative definition, offered by the International Energy Agency's Clean Coal Centre, is "the process of repairing any negative effects of mining activities on the environment".[4]

Reclamation activities sometimes can also employ passive means of ecosystem restoration—wherein a less intensive

The image on the left is of crops growing on land reclaimed from a Shenhua Group mine in Inner Mongolia, China.

A former opencast coal mine in Montana, U.S. now hosts grazing land. (AP Photo/Billings Gazette, Larry Mayer)

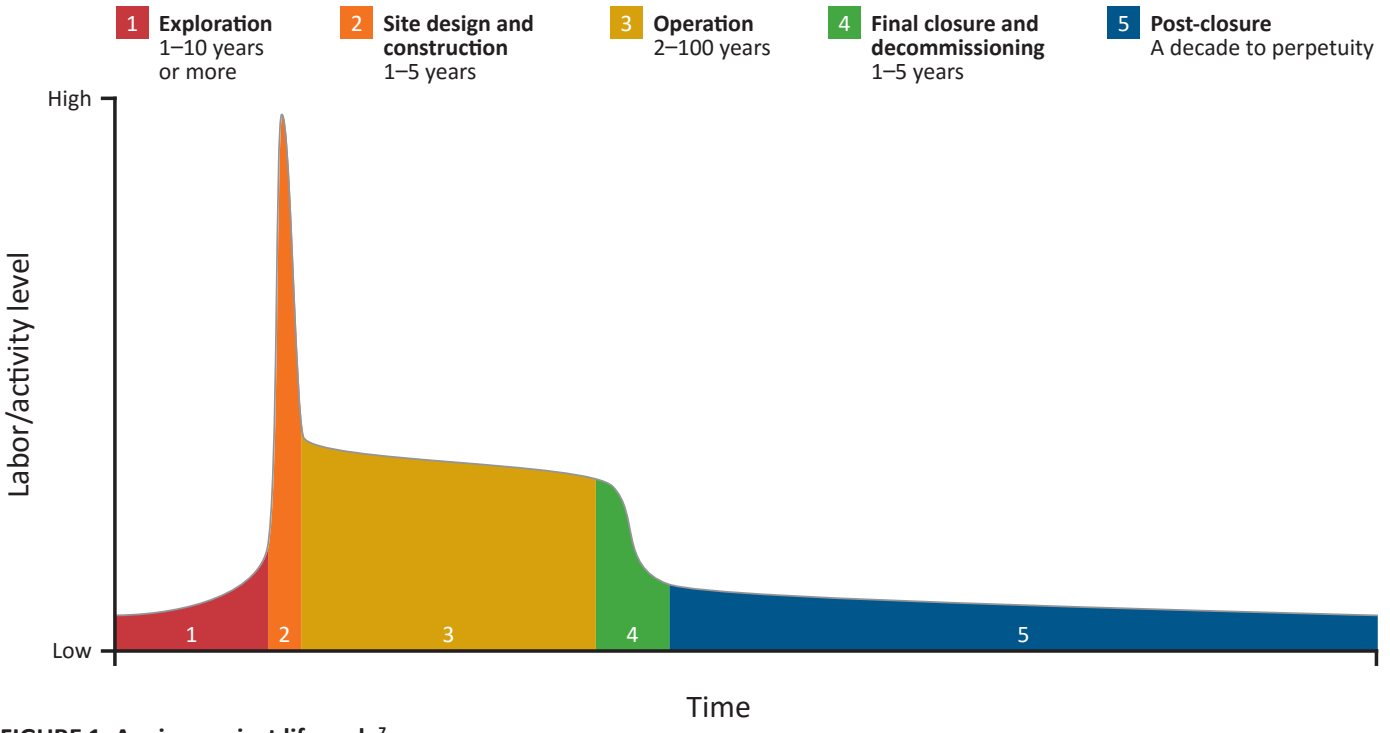

FIGURE 1. A mine project life cycle[7]

management approach is taken and, for example, flora and fauna are allowed to self-colonize after soil replacement and stabilization are completed.[5] However, the vast majority of contemporary reclamation and restoration efforts are based on technical reclamation, which exceeds simply repairing the affected property. Technical reclamation activities often aim to proactively manage a mined area for specific natural or recreational value, or other human uses, which can include infrastructure needs such as airports, schools, or shopping centers. Reclamation activities can also target agricultural or silvicultural (i.e., forestry) objectives. Plans to return mined areas to a more natural state, focusing on soil, vegetative, wildlife, and/or water management values, can also play a large role in guiding reclamation activities.

Both underground and opencast mines require reclamation, but the approaches are different. Reclamation activities for underground mines will typically require less aboveground activity, but can necessitate extensive management to avoid drainage and flooding issues after mine closure. This management can involve techniques such as filling of excavated areas with mine spoil or fly ash and diverting or controlling the flow of groundwater to keep it from entering existing mine structures. Doing so avoids the risk of rising water becoming contaminated by dissolved metals and other substances and potentially being discharged into rivers and streams. Notably, higher levels of calcite or carbonates in the rock, however, may neutralize acidic mine water, allowing metals to stay immobile.[6]

Reclamation of opencast mines typically involves replacement of overburden that was removed or repositioned to access buried coal layers. When excavated areas are built up, re-landscaping or recontouring is completed along with drainage control measures. Recontouring will be guided by mine plan objectives (i.e., the intended end use for the land). Where natural processes are sought, recontouring will typically attempt to return landforms to the mine site's approximate original contour, or to mimic natural contours. Where other human uses are planned for, the land will often be leveled or shaped in a manner that improves access or aids in future infrastructure development.

ENSURING BEST PRACTICES ON RECLAMATION

The time frame extending from exploration to post-reclamation and closure requires decades (see Figure 1). In many cases, reclamation processes—which can include the mine closure and decommissioning stage, as well as the post-closure stage—can require as long as, or even longer than, the combined previous stages of exploration, site construction, and mining.

Even with mining plans in place, mining can substantially affect local or regional environments. Proper reclamation of mine sites, however, can avoid many risks, including unstable spoil piles, acid drainage and water quality issues, and potential cave-ins.

Best practice reclamation activities are designed to limit or avoid these impacts to the greatest degree possible. Although

fully listing the legislative, regulatory, or best practices standards governing global mine reclamation is outside the scope of this article, a few prominent examples are worth highlighting. For example, general requirements for the approval of mining permits could resemble the conservation practice standards published by the Natural Resources Conservation Service (NRCS), U.S. Department of Agriculture (USDA). NRCS describes a threefold purpose for land reclamation:

1. Prevent negative impacts to soil, water, and air resources in and near mined areas
2. Restore the quality of soils to their pre-mining level
3. Maintain or improve landscape visual and functional quality[8]

Australia's Department of Industry Tourism and Resources gives similar guidance for land reclamation, but also encourages consultation, reporting, and monitoring with stakeholders during mine plan development and mining activities. Companies are also urged to rehabilitate progressively through the full life cycle of the mine and, where possible, to manage and rehabilitate historical disturbances.[9] Expanded regulatory oversight combined with a trend toward a lesser number of larger, mechanized mining operations that are governed by binding mining plans are decreasing concerns about unregulated or unmonitored activities.

RIGHTING THE PAST

Employing best practices during contemporary mine reclamation helps to avoid the challenges associated with mines that were not properly reclaimed in the past. The varied nature of reporting measures and regulatory regimes governing mine management worldwide are compounded by the fact that many private or unregulated mines have been created, especially in developing nations where regulatory oversight may not yet be as thorough. Thus, it is difficult—if not impossible—to get a full count of the number of abandoned coal mines worldwide.

The legacy of abandoned mines, however, is being addressed in many areas. For example, since the passage of the 1977 Surface Mining Control and Reclamation Act (SMCRA) in the U.S., direct fees have been collected by government agencies from existing coal mining companies. Various states and Native American tribes have used over US$4.06 billion of those funds to reclaim almost "240,000 acres of hazardous high-priority coal-related problems".[10] As described by the UK Environment Agency (2008),[6] similar programs are being carried out across the UK and internationally.

RECLAMATION COLLABORATION

Collaborative efforts between mining companies and conservation organizations can promote successful mine reclamation as these organizations can lend expertise in developing best practices for wildlife, water, plant, and/or soil management. Demonstrating a transparent working relationship with conservation groups and other stakeholders can also help regulatory agencies when reviewing permit applications. If these agencies observe widespread support for mine plans and objectives and are convinced the area will be properly reclaimed and managed in the post-mining stages, permit approvals can likely be obtained much more easily.

One example of a collaborative effort is the U.S.-based Appalachian Wildlife Foundation's Mine Land Stewardship Initiative (MLSI), which enables industry to pair with conservation organizations to move ahead in a challenging regulatory environment. The MLSI is working to design voluntary reclamation standards that "elevate the overall ecological performance of the coal industry"[11] and help to enhance

1. Conservation and restoration of ecosystem services
2. Conservation and restoration of wildlife habitat
3. Protection of water quality
4. Recreational opportunities for mining communities
5. Scientific and technical knowledge needed to protect and restore wildlife and aquatic habitats on mine lands[11,12]

Efforts like the MLSI are a positive and proactive approach to reduce confusion and litigation, increase stakeholder involvement and buy-in, improve transparency, and ensure the highest standard of reclamation is carried out.

Ditches slow runoff and encourage groundwater recharge at Coal-Mac Mining's Phoenix #2 mine.

BONDING AND FINANCIAL ASSURANCE

Even with proactive management efforts like the MLSI, reclamation can be an expensive endeavor. As the mine will not continue producing saleable material, no additional income will be brought in after operations cease. Therefore, most regulatory agencies require some form of a financial safety net, or bonding, to ensure sufficient funds are available for reclamation even if a bankruptcy occurs. In this manner, company insolvency or an abandoned mine will not impose mine closure and reclamation costs on taxpayers.

While having adequate funds for reclamation is clearly important, public policy must recognize that environmental protection, reclamation in this case, must be balanced with financial realities to avoid stifling economic activity and to allow mining companies to operate profitably. The International Council on Mining and Metals (ICMM) has reported that expectations from an increasingly risk-averse public and government have been forcing assurance costs higher.[13] The ICMM described how, in 1998, a mining company based in Australia had "identified more than 1,056 financial assurance instruments in place in four countries, which represents a contingent liability of greater than AUD$20 million. By 2004 the comparative amount had risen to AUD$60 million."[13] ICMM expressed concern that setting aside growing levels of operating funds in bonds restricts investment and operational flexibility. In fact, increasingly conservative expectations of certainty relating to environmental protection could place such strict financial and administrative pressures on mining companies that mining projects could be cancelled as uneconomic.

When this photo was taken in 2004, the Phoenix #2 mine had been backfilled. Final grading and seeding had yet to be completed on the top lift. Rock side drains were constructed at the perimeter to prevent erosion.

Phoenix #2 mine demonstrating new growth approaching year five (2009)

CASE STUDY

Numerous mines around the world are demonstrating successful reclamation projects, several of which are profiled in other articles in this issue of *Cornerstone*. One such project is Coal-Mac Mining's Phoenix #2 surface mine in West Virginia, U.S. The Phoenix #2 mine was the recipient of the U.S. Office of Surface Mining's 2010 Excellence in Reforestation Award for almost a decade's worth of reclamation efforts and implementation of the Appalachian Regional Reforestation Initiative's (ARRI) Forest Reclamation Approach (FRA).[14]

ARRI is a working group comprised of citizen representatives, industry, academia, and government, and was formed to encourage planting of productive trees on reclaimed coal mine lands and abandoned mine lands.[15] FRA is a means by which mining companies and forest managers can improve forest productivity, wildlife habitat, floral diversity, and water management on reclaimed mine lands. The FRA is made up of five steps:

1. Create a suitable rooting medium for good tree growth that is no less than four feet deep and comprised of topsoil, weathered sandstone, and/or the best available material.
2. Loosely grade the topsoil or topsoil substitutes established in step one to create a non-compacted growth medium.
3. Use ground covers that are compatible with growing trees.
4. Plant two types of trees: (a) early succession species for wildlife and soil stability and (b) commercially valuable crop trees
5. Use proper tree planting techniques

Phoenix #2 mine is a 560-acre (227-ha) operation, originally permitted in January 2001 under the approximate original contour (AOC)-plus backfill guidelines. Under these guidelines, final backfill elevations were established to mimic the natural terrain of West Virginia, avoid soil compaction, and enhance post-mine land use.

As year six approaches (2010), the Phoenix #2 mine area is returning to a productive, natural state.

CONCLUSIONS

Finite resources entail a finite mining life cycle. As coal reserves in a mine are removed or become uneconomical to continue mining, reclamation activities will replace removed soil and/or substrate materials and revegetate the mine in an effort to (1) return it to as close to natural state as possible or (2) redesign landforms to allow improved human access to, or use of, an area.

Key objectives in reclamation activities are to reduce potential damage and prevent negative impacts to the natural environment in and near mined areas, to restore the viability and growing potential of soils to their pre-mining level, and to maintain or improve landscape visual and functional quality.

Reviewing effective examples of mine reclamation from around the globe, such as those profiled in this issue, allows the extractive industry to develop a suite of best practices for successfully reclaiming mined areas. These properly reclaimed mines can provide essential lessons on technology, policy, and collaboration and serve as the gold standard for mine reclamation efforts.

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Working Alongside the Great Barrier Reef

By Michael Roche
Chief Executive, Queensland Resources Council

Coal is a cornerstone of Queensland's economy and is responsible for more than half the value of the state's merchandise exports of AU$47 billion in 2014. Despite challenging market conditions, coal exports also reached a new record of 216 million tonnes in 2014—an amount that is on track to be exceeded in 2015.

Directly and indirectly in 2014–15, the coal mining industry generated almost AU$32 billion in economic activity—equivalent to 11% of Queensland's Gross State Product, while supporting 183,000 jobs, or around 8% of its workforce. It also contributed AU$1.6 billion to the Queensland budget in royalties.

The 60,000-km^2 Bowen Basin in central Queensland is the jewel in the state's resource crown, containing much of its known Permian coal resources, including virtually all of the known mineable prime metallurgical coal.

Including other exports such as beef, sugar, timber, metals, and fertilizer, northern Queensland exports goods worth AU$40 billion each year. This amount excludes the emerging coal-seam gas to LNG industry, which shipped its first consignment from Gladstone in December 2014.

Queensland's exporting industries have a long history and must continue to work responsibly alongside one of Australia's, and the world's, most important natural sites: the Great Barrier Reef (GBR). The GBR takes up an area of about 350,000 km^2, and is the world's most extensive coral reef ecosystem boasting one of the most complex and biodiverse natural ecosystems on earth.[1] In addition to the natural beauty, the GBR contributes economically to Queensland—about AU$5.4 billion to the state's economy each year—based on the two million people that visit the site annually, although tourism is limited to a relatively small area (about 7% of the reef).[2]

Coal export facility operating near the Great Barrier Reef.

The exporting industries, including the coal industry, can and will continue their legacy of working responsibly alongside the GBR.

"Queensland's exporting industries have a long history and must continue to work responsibly alongside one of Australia's, and the world's, most important natural sites: the Great Barrier Reef…"

A BRIEF HISTORY OF QUEENSLAND'S COAL EXPORTS AND THE GBR

Forty years ago, the Australian government placed 348,000 km^2 of the Coral Sea into the GBR Marine Park and created the Great Barrier Reef Marine Park Authority to manage the area. It simultaneously recognized the essential role of 11 trading ports along 2300 km of coastline adjacent to the marine park, including two coal export ports: Gladstone and Hay Point.

The GBR's inscription on the World Heritage Register in 1981 for its "outstanding universal value" included the port precincts, which gave UNESCO an interest in both the marine park administered by the Australian government and the ports mostly owned and operated by the Queensland state government. Although World Heritage Sites are internationally recognized for their value to humanity, the management and protection of such sites remains the responsibility of the

Tourism around the Great Barrier Reef is a significant contributor to Queensland's economy.

nation in which the sites occur. Australia and Queensland have long recognized that the GBR could be protected simultaneously with a vibrant export industry.

Thus, even after GBR was named a World Heritage Site careful expansion of exports occurred. In 1984, Abbot Point terminal became Queensland's third coal export facility adjacent to the GBR and the additional capacity helped expand coal exports.

The coal export facilities have confirmed Queensland's position as the world's largest seaborne exporter of metallurgical coals, which is an essential ingredient for producing blast furnace steel. From Gladstone, which services the southern end of the Bowen Basin, to Abbot Point in the north, is a distance of some 650 km. The contact with GBR is limited as that is less than one third of the distance the Queensland coastline adjoins the GBR Marine Park. In the south of the state, high-volatile thermal coals from the Clarence-Moreton and Surat basins are exported through the Port of Brisbane. To the west of the Bowen Basin lies the undeveloped Galilee Basin, boasting high-quality thermal coal resources estimated in the tens of billions of tonnes.

A RECORD OF RESPONSIBLE EXPORTING

Queensland's industries, including the coal industry, have been successfully exporting goods from eastern shores for decades and have a long history of balancing environmental protection—especially along the precious GBR—with a vibrant export-based economy able to respond to international commodity demand.

The ability to balance protection of the GBR and a healthy export industry is founded on the fact that Australia is a world leader in shipping management. The country's innovation has been recognized by the International Maritime Organisation's adoption of a mandatory reporting system which was developed in Australia specifically to protect the GBR Marine Park. This world-class system covers the park and extends into the Coral Sea. REEFVTS (Vessel Tracking Service) operates around the clock, supported by automated position reporting, ship identification, and other advanced support tools. Compulsory marine pilot areas—where specifically licensed pilotage is required—also apply in sections of the reef. Despite a substantial increase in ship movements since 1996, groundings have been reduced from one per year to just a single incident in the 10 years since REEFVTS was introduced.

Despite a record of excellence and improving protection of the GBR, there have been challenges, which led to UNESCO's World Heritage Committee (WHC) considering whether to list the GBR as "in danger", which would have dramatically restricted the state's ability to grow its exports. Fortunately, on 1 July 2015, in a unanimous decision the WHC opted not to place the GBR on its "in danger" sites list and instead to accept a resolution to support Australia's Reef 2050 Long Term Sustainability Plan (Reef 2050 Plan).[3] This outcome was welcomed by the Australian and Queensland governments.[4]

"Queensland's industries, including the coal industry, have been successfully exporting goods from eastern shores for decades..."

THE POTENTIAL FOR GROWTH

In 2011 a Deloitte study commissioned by the QRC revealed plans for Queensland resources projects worth AU$142 billion over the following decade, much of which would be destined for exports. There was never a possibility that all proposed projects would move forward, but AU$70 billion was ultimately committed to the development of an export LNG industry at Gladstone, underpinned by the discovery of more than 42,000 petajoules of methane in the Surat and Bowen Basin coal seams.

Also responding to an unprecedented surge in demand for minerals and energy from Asia, Queensland coal miners announced greenfield, brownfield, and export supply chain enhancements, including port expansions. The prospect of opening the Galilee Basin created huge international interest, especially from Indian companies focused on securing long-term supplies of high-quality thermal coal.

The interest from the Indian companies was not surprising. Around 300 million people in India do not have any access to electricity. Many of those that have access are unable to rely on its availability, partly due to a lack of coal to fuel their power plants. The aim of Indian developers, such as Adani and GVK Resources, is to source high-quality Galilee Basin coal. In India, this coal can be used to reduce emissions and provide quality of life improvements that can be taken for granted in the developed world.

The proposed development of the Galilee Basin, coupled with forecast coal and gas production expansions, galvanized Australian environmental activists into convening what was described as an "anti-coal convergence" in late 2011. In March 2012, a funding strategy document formulated at the gathering was leaked to the media and signaled the start of a campaign to have the GBR declared "in danger" by UNESCO, thus preventing the expansion.

AN UNFOUNDED CAMPAIGN TO HALT PROGRESS

The funding strategy document created around the GBR case, called "Stopping the Australian Coal Export Boom"[5,6], continues to serve as the play book for activists. "We urgently need to build the anti-coal movement and mobilise off the back of the community backlash to coal-seam gas. If we fail to act decisively over the next two years, it will be too late to have any chance of stopping almost all of the key infrastructure projects and most of the mega-mines," it begins.

The strategy identifies the potential of the GBR to be used as political leverage against the expansion of the coal and gas industries in Queensland and, specifically, the opening up of the state's fourth major coal province—the Galilee Basin. The activists noted Queensland's major coal ports are "…next to the World Heritage-listed Great Barrier Reef Marine Park and there are strong opportunities for alliance building with scientists and industries that will be negatively impacted (fishing, tourism, etc.)".

The campaign scored its first victory when a UNESCO Reactive Monitoring Mission visited Queensland in 2012, assigned to investigate unfounded claims that Australia had given the green light to oil and gas production in the marine park and the dredging of channels through it. It also became evident as inquiries continued that UNESCO had not been made fully aware of the environmental approvals process required for major developments in Queensland.

This campaign made several unsubstantiated claims, such as one from Greenpeace that coal exports alone would reach almost one billion tonnes by 2020, transported annually in more than 10,000 coal ships. However, such claims are not supported by the numbers. In 2014, Queensland's record export of 216 million tonnes continued a long-term growth trend of around 5% per year. Continuation of that growth trend would see Queensland coal exports at around 280 million tonnes by 2020, massively shy of Greenpeace's predicted one billion tonnes. As for the number of coal ships calling at coal ports in Queensland, the latest forecast from the Australian Maritime Safety Authority is for just under 2500 coal ships by 2020, or seven ships a day. Currently on any given day, around 40–50 commercial ships carrying various bulk commodities are traveling in the GBR zone. In comparison a ship arrives or leaves the Port of Singapore every two to three minutes.

The campaign also grossly exaggerated shipping numbers to portray the inevitability of a reef grounding and also to exaggerate the requirement and impact of port dredging. In reality, a modest dredging program involving the relocation to land of 1.1 million tonnes of sediment would be required at Abbot Point to support Adani Mining's Carmichael project in the Galilee Basin. To put this into perspective, CSIRO, the world-renowned Australian science organization, estimated that in an average year, up to 17 million tonnes of sediment, nutrients, and agricultural chemicals enter the GBR lagoon from 35 river catchments (unrelated in any way to the ports).[7] Notably, the proposed dredging site is 19 and 30 km away from the nearest coral communities. Scientific modeling has found that sediment will be highly localized to the dredging site and will not impact these coral communities.

The GBR does face environmental challenges. In 2013 a Reef Scientific Consensus Statement by 50 of the world's leading marine scientists concluded: "The overarching consensus is that key GBR ecosystems are showing declining trends in condition due to continuing poor water quality, cumulative impacts of climate change and increasing intensity of extreme events."[8] While these impacts are concerning for Australia and

Abbot Point terminal is the newest of Queensland's coal export facilities.

the world, they should not be confused with any impacts from exports around the GBR.

Similarly, in its 2014 Outlook Report, the GBR Marine Park Authority said that the greatest risks to the GBR are climate change, poor water quality from land-based runoff, impacts from coastal development, and some remaining impacts of fishing.[9] The report went on to say that the effects of port activities are relatively more localized than the broad-scale impacts from land-based runoff. A recent report card focused on improving water quality around the GBR emphasized the "need to accelerate the rate of change and drive innovation" in the agriculture industry to protect GBR water quality, while the exports industry was not even mentioned.[10]

"QRC is committed to ensuring the protection of the GBR through the rigorous and comprehensive implementation of the Reef 2050 Plan."

THE WAY FORWARD

Australian governments have heeded the views of the WHC in developing a positive long-term response to their concerns, including a ban on marine disposal in the GBR of capital dredging material (material removed for port expansions). This again raises the bar for shipping management in the GBR. QRC believes that over time the ban will inevitably mean that some necessary port developments to keep pace with trade growth will not proceed or will have to be scaled back.

QRC is grateful that the WHC based its decision on the resounding scientific consensus and resisted the call from environmentalists to declare the GBR world heritage "in danger". Although campaigns to halt expansion will continue, it is important to consider the benefits to Queensland, Australia, and the world—including the poor in developing Asia who are in need of reliable energy.

QRC is committed to ensuring the protection of the GBR through the rigorous and comprehensive implementation of the Reef 2050 Plan. That commitment has been recognized by the Australian and Queensland governments in QRC's appointment to the multi-stakeholder Reef 2050 Advisory Committee, which is chaired by the Honorable Penelope Wensley, former Governor of Queensland and former senior diplomat. Queensland's coal industry looks forward to continuing its role as the state's leading exporter while working responsibly alongside one of the world's natural treasures, the Great Barrier Reef.

The Great Barrier Reef is listed as a World Heritage Site due its exceptional natural biodiversity.

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What Will It Take for CCS to Have a Future in the European Union?

By Samuela Bassi
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Carbon capture and storage (CCS) can play a considerable role in tackling global climate change. By capturing CO_2 and storing it underground, CCS allows coal- and gas-fired power stations to produce low-emissions electricity. Furthermore, it is the only technology that can reduce carbon emissions from large industrial installations, such as steel and cement plants. If successfully applied to bio-energy generators, CCS technology could also result in "negative emissions", that is, it could actually remove CO_2 from the atmosphere.

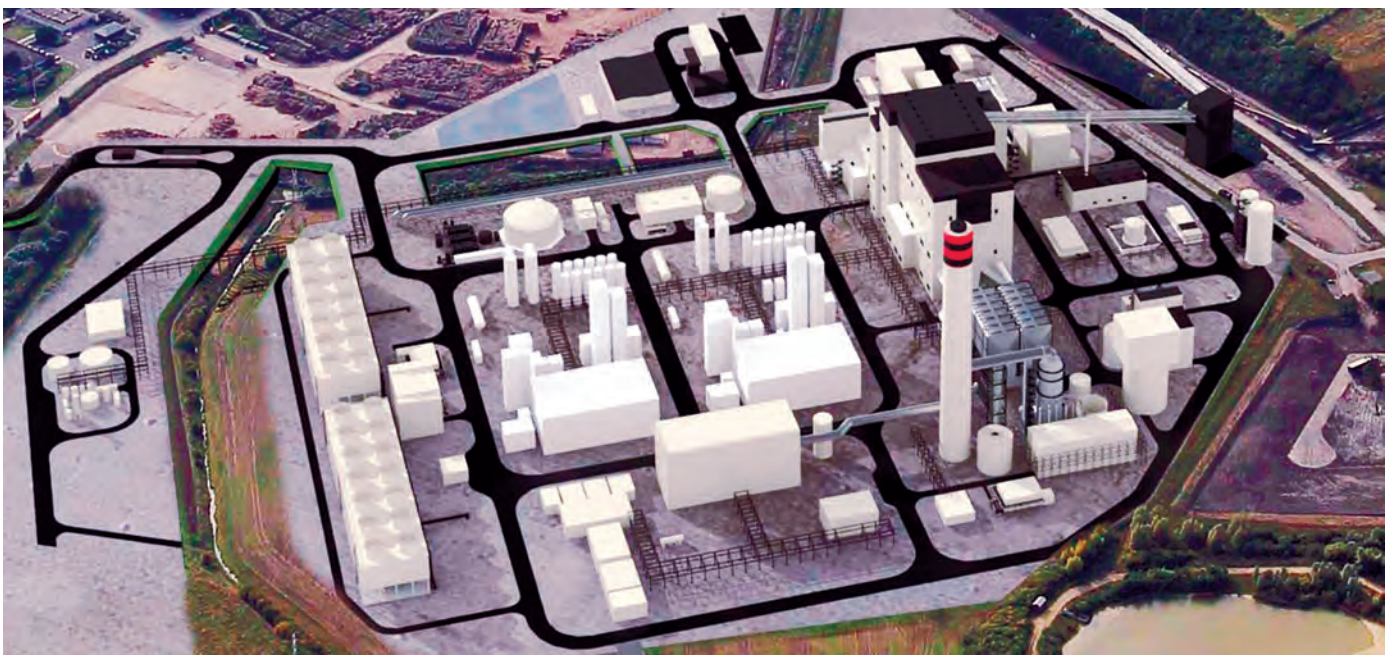
For these reasons CCS is included in a wide range of authoritative energy models forecasting future low-carbon energy portfolios, including models developed by the International Energy Agency (IEA)[1] and those included in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).[2] Most analysts agree that it may be much more expensive, if not infeasible, to limit warming to 2°C without CCS.

The case for CCS is also strong in the European Union. All the scenarios developed in the EU's Energy Roadmap 2050, which aims to reduce emissions by 80–95% below 1990 levels by 2050, involve using CCS.[3] According to these scenarios, CCS should be applied to between 7 and 32% of electricity generation in the EU by 2050.

To achieve the emission reductions outlined in the Energy Roadmap 2050 scenarios, CCS must be deployed in Europe from 2020 onward. However, momentum for CCS on the continent appears to have dwindled, and progress has been painfully slow.

"The EU and its member states must show much greater urgency and determination to develop and deploy CCS."

A recently published study by the Grantham Research Institute at the London School of Economics and Political Science and the Grantham Institute at Imperial College investigates the barriers to CCS development in the European Union and



The White Rose project in the UK is one of two CCS projects advancing in the country. (Credit: Capture Power)

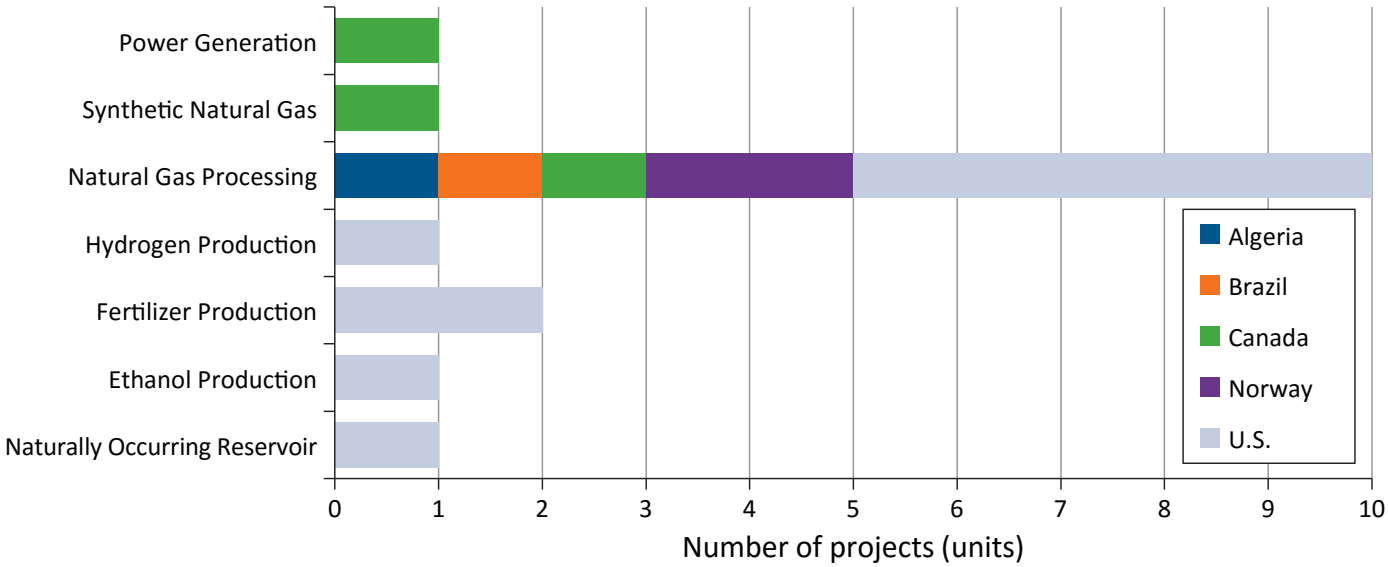


FIGURE 1. CCS installations in operation by sector and country, 2014[4,6,7]

recommends a European-wide strategy to speed up investment.[4] This article shares key findings from that study.

SLOW DEVELOPMENT OF CCS IN THE EUROPEAN UNION

Although no explicit target has ever been enforced, the European Council did once aspire to have up to 12 CCS demonstration projects operating by 2015.[5] Despite this, the pace of CCS development in the European Union has been very slow. Not a single CCS plant is even in construction in the EU. By comparison, North America already has 13 CCS installations in operation and six under construction (see Figure 1).

This does not mean that efforts have not been made by some EU member states. Six CCS plants are now at various stages of planning, five of which are in the UK with the other one being in the Netherlands. It remains unclear how many of these projects will secure enough financing to be fully realized. At the moment only two of them—the White Rose and Peterhead projects in the UK—are relatively close to a final investment decision, but the outcome is not certain. Notably, last September the White Rose project lost the support of one of its three commercial bakers, Drax Group PLC, allegedly due to a recent cut in low-carbon energy subsidies in the UK.

WHY IS CCS LAGGING BEHIND?

High upfront costs present the biggest barrier to the widespread use of CCS. While the technology is well understood, it is still far too expensive to be commercially competitive with unabated coal- and natural gas-fired power stations.

Based on the current cost of CCS technology, between €18 billion and €35 billion may need to be invested by 2030 in the EU to deliver the 10 GW of CCS power plants with CCS envisaged by the Energy Roadmap 2050. Just €1.3 billion of public European funding, coupled with some private investment, has been allocated to CCS to date—just a fraction of what is needed to make CCS technology commercially viable.

The costs associated with CCS are expected to decrease over time thanks to technological innovation, economies of scale, and increasingly efficient CO_2 transport and storage infrastructure. However, realizing these advancements would require investment in fully operational plants as soon as possible.

There is already much being learned from existing projects. The developers of the world's first operating CCS power plant, the Boundary Dam project in Canada, claim that they could save up to 30% of the costs building an identical CCS plant today, thanks to the knowledge gained in the course of the project. Other, more theoretical, estimates suggest that costs could decrease by 15–40% by 2030, especially through improvements in CO_2 transport and reductions in the cost of financing projects.

The financing of CCS projects is particularly important. Currently, perceived risks surrounding first-of-a-kind CCS projects impair access to suitable finance, raising the cost of capital. UK estimates suggest the cost of capital faced by CCS developers could be in the order of 12–17% (mid-point 14.5%).[8] By comparison, the cost of capital faced by more established low-emissions technologies, such as solar photovoltaic or offshore wind projects, is between 6 and 9%.

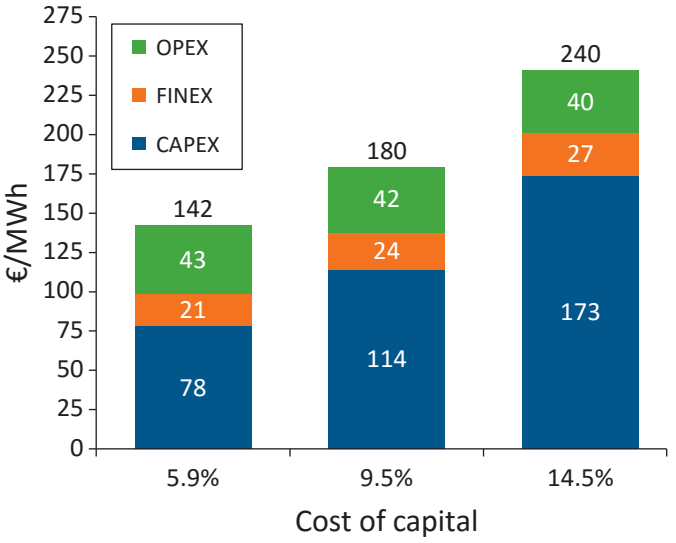


FIGURE 2. Estimated LCOEs based on the Boundary Dam project and different assumptions on cost of capital[4]

A simple financial model based on publicly available information from the Boundary Dam CCS power plant shows how different costs of capital can affect the average cost of electricity from a CCS power plant, measured in terms of levelized cost of electricity (LCOE). With a cost of capital of 9.5%, the LCOE would be around £180/MWh. For a cost of capital at 14.5%, the LCOE increases to £240/MWh (see Figure 2).

The policies introduced to support CCS in the European Union have so far failed to deliver the expected results. Notably, the price of carbon in the European Union Emissions Trading System (EU ETS) has been very low and is unlikely to increase to the level required to make CCS competitive with unabated fossil fuel installations.

Notably, the carbon price would need to increase from less than €8 to between €35 and €60/tonne $CO_{2\text{-eq}}$ if a coal-fired power station fitted with CCS is to be competitive with conventional coal-fired plants. For gas-fired power stations with CCS to be competitive, the carbon price would need to be even higher, between €90 and €105 per tonne. It is very unlikely that the EU ETS will achieve these levels for at least another decade or so.

Public funding programs have also been set up to support CCS development and deployment, such as the European Energy Programme for Recovery (EEPR) and the New Entrant Reserve (NER) 300. These too, however, failed to deliver strong results. This is partly because funds available through the NER 300 depended on the price of 300 million EU ETS allowances earmarked to CCS, and their selling price ended up being lower than expected. In addition, CCS projects were in competition with other low-emissions technologies for funding. Eventually only one of the 39 projects funded by NER 300 actually involved CCS.

In the coming years, additional financial resources are expected to become available through the new Innovation Fund (or NER 400), the Modernisation Fund, the European Fund for Strategic Investment, and the European Structural and Investment Funds. However, the scopes of these programs are much broader than CCS. It is unclear if, and to what extent, CCS projects will be financed through these channels.

Another challenge faced by CCS developers is that existing regulation imposes significant costs and liabilities on CO_2 storage site operators, which discourages investment. In particular, site operators are requested to provide financial coverage for the cost of compensation in case of CO_2 leakage. This financial liability is linked to the price of allowances in the EU ETS. The uncertainty over the amount of CO_2 that could leak and the future EU ETS carbon price make this liability potentially open-ended.

STRONGER, BETTER COORDINATED POLICY IS NEEDED

The European Commission must provide leadership on CCS if it is to keep on course with its Energy Roadmap 2050. Europe needs an overarching strategy to stimulate much needed action to advance CCS. But what would a strategy on CCS involve?

"The European Commission must provide leadership on CCS if it is to keep on course with its Energy Roadmap 2050."

First, such a strategy should encourage member states to assess their potential for CCS and characterize potential storage sites. It should provide policy guidance, set milestones to measure progress, and coordinate transport infrastructure planning.

Second, the strategy should identify additional market-based mechanisms to mobilize investment in the short to medium term. These would complement existing policies like the EU ETS.

These could include more direct funding for research and development, a new funding mechanism to finance early-stage CCS development projects, and financial incentives for electricity generation using CCS.

The full report by the Grantham Institute on Climate Change and the Environment investigates barriers to CCS in the EU.

Furthermore, improvements to the existing European legislation will be required to allow the first demonstration projects to be developed in a timely manner and to create the right conditions for future investment. A key action would be to set an initial cap on long-term liability for CO_2 leakage, to be reviewed as risks become better understood and private insurance mechanisms develop. This is not dissimilar to the way risk has been handled in the nuclear industry. A financial mechanism for damage remediation, such as a liability fund or private insurance, would also help spread risk across CCS site operators. Special treatment of early demonstration projects—for example, through a public liability scheme—would also be warranted, given the higher risks faced by first movers.

THE ROLE OF PUBLIC AND PRIVATE SECTORS

If CCS is to be successfully deployed in Europe, the private sector will also need to act. For instance, large, incumbent energy utilities could be well placed to develop the first CCS projects, as they have the size, experience, and capacity to undertake diversified, large-scale, and complex investments while minimizing many of the barriers and inherent risks to CCS projects.

This is not to say that large-scale energy utilities will find it easy to invest in CCS. In the current economic and political environment they are facing significant funding constraints. Furthermore, CCS project financing has a different risk profile compared to traditional capital-intensive energy infrastructure projects. In particular, the risks associated with construction of CCS installations differ considerably from the risks associated with its operation. Investors may be willing to absorb some of the risks, but the long-term nature of CCS means that risks will endure and can only be managed by private investors to a certain degree.

"Without action now, the EU will likely be unable to meet its targets for reducing greenhouse gas emissions. It will certainly be more costly to meet these targets without CCS."

These complexities highlight a need for the involvement of public financial institutions. For instance, the European Investment Bank (EIB) or the European Bank for Reconstruction and Development (EBRD) could contribute convening power and know-how to attract additional private financing sources.

Upstream producers of fossil fuels—whether privately or publicly owned—should also contribute much more strongly to advancing of CCS in the EU. Ultimately CCS will increase the amount of their assets that can be potentially realized in compliance with climate change targets. It is likely that fossil fuel companies may oppose an additional tax to fund CCS development. However, I believe there is a case for encouraging the creation of a private-sector fund for CCS. These companies' desire to lower the costs of CCS technologies could be fostered by simple agreement between key players to exploit a shared interest in developing CCS.

CONCLUSIONS

The EU and its member states must show much greater urgency and determination to develop and deploy CCS. Without action now, the EU may be unable to meet its targets for reducing greenhouse gas emissions. Evidence indicates that it will be more costly to meet these targets without CCS.

Thus, there is a strong case for stepping up ambition and action on CCS in the EU. The creation of a European Energy Union provides a timely opportunity to revamp European policy on CCS. The European Commission and the Energy Union, in particular, have a strong responsibility to engage and guide member states, helping them meet their emissions reduction targets at the least cost.

The first CCS installations will require significant public and private resources. This will likely be realized through a mix of higher carbon pricing, subsidies, and increased private investment. Further measures, however, need not be monetary in nature—these ought not to be difficult to implement in the short term. For instance, inviting member states to assess their own potential for CCS, and identifying the cost of alternative routes for decarbonization, may be a sensible first step. This could also lead to the identification of a coalition of countries willing to collaborate more closely on CCS.

At the very least, the European Union needs more certainty about which low-emissions energy technologies warrant investment. If the promotion of CCS is considered politically unfeasible, the EU's stated expectations for CCS would have to be revised in a timely manner and alternative options should be explored immediately.

Ultimately, the public and private sectors both have a role to play. Within the private sector, the burden of investment in CCS has fallen especially on energy suppliers. However, these companies are not often in a position to invest in large multi-billion projects without sufficient public backing. Other players could be well placed to be more involved, such as upstream producers of fossil fuels. It is time to think about how to scale up investment on CCS, by improving public policy as well as further mobilizing private finance from a multiplicity of actors.

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This article is based on a report by the Grantham Research Institute at the London School of Economics and Political Science and the Grantham Institute at Imperial College, "Bridging the gap: Improving the economic and policy framework for carbon capture and storage in the European Union", by Samuela Bassi, Rodney Boyd, Simon Buckle, Paul Fennell, Niall Mac Dowell, Zen Makuch, and Iain Staffell. The report is available for download from the Grantham Research Institute website: www.lse.ac.uk/GranthamInstitute/publication/bridging-the-gap-improving-the-economic-and-policy-framework-for-carbon-capture-and-storage-in-the-european-union/ The lead author can be reached at s.bassi@lse.ac.uk

The Implications of the U.S. EPA's Clean Power Plan

By Roger Bezdek
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On 2 June 2014, under President Obama's Climate Action Plan and using the authority of Clean Air Act (CAA) section 111(d), the U.S. Environmental Protection Agency (EPA) proposed guidelines, termed the Clean Power Plan (CPP), to reduce CO_2 emissions from existing fossil-fueled power generating units.[1] In early August 2015, the EPA released the CPP final rule, which is stricter than the initial proposal.[1] EPA contends that the CPP would achieve CO_2 emission reductions from the power sector of 32% by 2030 compared to 2005 levels.

There is extensive ongoing debate concerning the costs and benefits, economic effects, impacts on the coal, natural gas, power, and related industries, disparate regional impacts, legality, and other issues. While legal challenges certainly lie ahead, it is worth exploring the projections of what the EPA and energy industry experts believe the CPP would accomplish and also what it would cost.

BACKGROUND ON THE CPP

When legislating the CAA, Congress recognized that the opportunity to build emissions controls into a source's (e.g., power plant or other emissions source) design is greater for new sources than for existing sources. Thus, it established the two separate approaches to set standards:

- Section 111(b) is the federal program to address new, modified, and reconstructed sources by establishing standards.
- Section 111(d) is the state-based program for existing sources. EPA establishes guidelines, and states design programs that fit those guidelines.

On 20 September 2013, EPA proposed CO_2 emissions standards for new power plants under 111(b) and initiated the process of establishing emissions standards for existing power plants under 111(d).[2] The prospect of undertaking such a significant regulatory program under the authority of 111(d)—a little-known provision of the law that has only been used five times in the history of the CAA—is the source of many of the questions surrounding legality.[3]

"According to multiple studies, the CPP would significantly increase energy costs, and these higher prices 'force' the economy to undergo a significant shift in energy utilization and fossil fuel consumption."

The CPP would regulate CO_2 emissions of existing generating units through state-level CO_2 emission rate standards. The final rule requires that states submit plans to EPA for review and approval. Those plans must identify how each state will impose and enforce the specified standards. The CPP does not make specific orders, such as which measures each state must use or a required level of emission reductions from each type of measure. Instead, each state must determine its optimal plan design and components. If a state refuses to come up with a plan, as several have threatened, the EPA has provided a default emissions reduction plan.

The Clean Power Plan is projected to result in the premature closure of coal-fired power plants in the U.S.

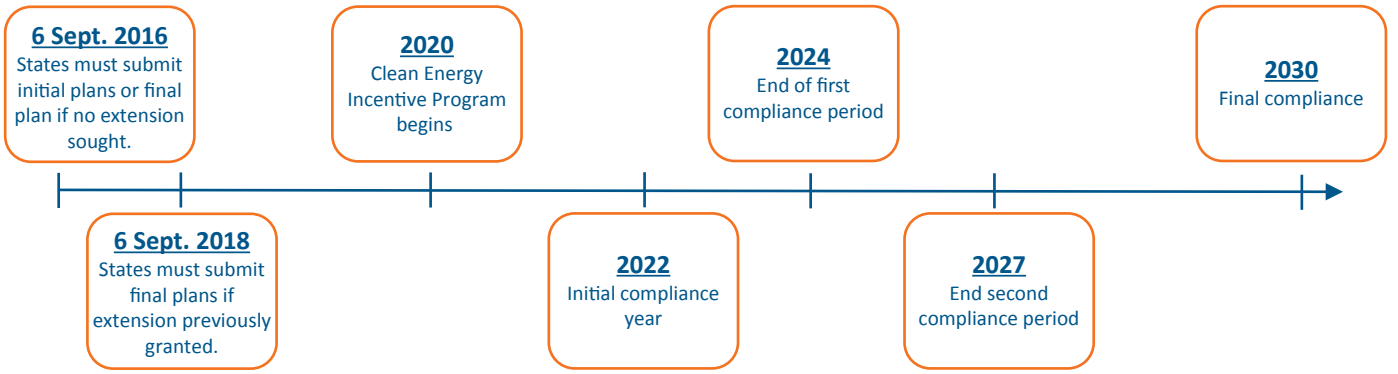

FIGURE 1. Clean Power Plan implementation schedule[1,2]

According to the CPP timeline (see Figure 1), initial state plans will be due to EPA for review by September 2016, with final plans due by September 2018, as two-year extensions are available. States will have to continue their emissions reduction efforts through the stages that comprise the rulemaking process.

After receiving more than four million comments on its proposed rule for existing power plants, the EPA released its final rule. The final CPP rule differs in important respects from the proposed rule. For example, the final rule:

- Is more stringent than the proposed plan: 32% vs. 30% reductions by 2030 (compared to 2005)
- Begins compliance in 2022, and has three "step down" periods
- Broadens the regulatory focus from coal to fossil fuels and reduces the benefit to natural gas
- Specifies an emission performance rate of 1305 lb CO_2/MWh for coal and 771 lb CO_2/MWh for NGCC
- Proposes a Clean Energy Incentive Program (CEIP), designed to incentivize early deployment and increase requirements for renewable energy (RE) as well as energy efficiency (EE)
- Increases the share of RE generation capacity in 2030 over 25% compared to the proposed rule (28% versus 22%)

PROJECTED ECONOMIC AND ENERGY IMPACTS

As with any new regulation, there are considerable disparities between projections about the benefits and costs of the Clean Power Plan. The EPA claims that carbon emissions from the power sector will decrease 870 million tons per year (based on 32% below 2005 levels) and SO_2 and NO_x emissions will be reduced by 90% and 72%, respectively. Although the EPA acknowledges an implementation cost of $8.4 billion for the CPP, it justifies this with an estimated $34–54 billion per year in projected health benefits.[4]

The EPA's cost estimate differs from those of some industry experts. Between June 2014, when the proposed rule was issued, and August 2015 several comprehensive studies were published by various research firms that analyzed the likely impacts of the proposed rule.[5,6] Similar estimates based on the final rule were still under preparation when this article was completed. However, since the final rule is more stringent than the proposed rule, the impacts of the CPP discussed here based on the proposed rule are, if anything, conservative and optimistic, and may even represent a "best case" scenario.

"As with any new regulation, there are considerable disparities between projections about the benefits and costs of the Clean Power Plan."

According to multiple studies, the CPP would significantly increase energy costs, and these higher prices "force" the economy to undergo a significant shift in energy utilization and fossil fuel consumption.[5,6] Further, there are also significant opportunity costs involved. The huge expenditures required to achieve compliance or replace *prematurely* one source of electricity generation (coal) with others represents unproductive use of capital, which implies that the spending in pursuit of regulatory compliance will lead to an overall decline in U.S. economic output. The subsequent negative impacts on GDP and employment will reduce disposable incomes and consumer spending.[5] Over the forecast period, unproductive capital dedicated to the CPP is projected to result in reduced wages and incomes, lower commercial and industrial output, lower GDP, and lower employment. Note that these job losses are net of any new jobs that may be generated by increased spending on RE, EE, clean coal technologies, or other programs.

TABLE 1. CPP compliance expense breakdown[5]

Incremental cost item	*Incremental cost ($billion, real 2012$)*
Power plant construction	339
Electric transmission	16
Natural gas infrastructure	23
CCS pipelines	25
Coal plant decommissioning	8
Coal unit efficiency upgrades	3
Coal unit stranded costs	30
Demand-side energy efficiency	106
Operations and maintenance costs	-5
Fuel costs	-66
Total incremental costs	478

With respect to the proposed CPP, researchers at IHS—a global research and analytics firm—found that regulating CO_2 emissions at the thousands of existing fossil fuel-fired electricity generating plants in the U.S. would lead to $478 billion in total compliance expense (see Table 1 for details), peak GDP losses over $100 billion, hundreds of thousands of lost jobs, higher electricity costs for consumers and businesses, and more than $200 per family on average every year in lower disposable income.[5]

Much of the cost associated with the CPP would be associated with the unproductive deployment of capital resulting from forcing the retirement of coal-fired power plants as the plan does not encourage the development or deployment of low-emissions technologies for fossil fuels. Under the CPP, IHS has predicted that the U.S. power sector would prematurely retire 114 GW of coal capacity, or nearly 40% of 2013 coal capacity, and replace it with new generating resources that are primarily a blend of combined cycle natural gas turbines (CCGT) and renewables (see Figure 2).[5] When added to the coal retirements resulting from competition from natural gas and the MATS rule, about 60% of the U.S. coal fleet, the study found that 199 GW (or more) will retire by 2030.

The most salient result of the shift away from coal-fired generation is that much of the compliance costs will be passed on to consumers via higher energy prices (see Table 2). Higher energy prices have the effect of a tax increase, ultimately reducing consumers' disposable income.[7] This affects consumer behavior, forcing reductions in discretionary spending as consumers forgo purchases and lower their household savings rates. The rising costs of electricity will be felt most acutely by those in lower income brackets, by minorities, and by those living on fixed incomes.[8] In addition to absorbing higher electricity prices into its cost structures, industrial sector production in the U.S. would decline.

Researchers forecast that GDP will average about $51 billion lower than in the Reference Case to 2030, with a peak decline of nearly $104 billion in 2025 (see Figure 3).[5] While higher energy prices will curtail consumption, the dominant driver of

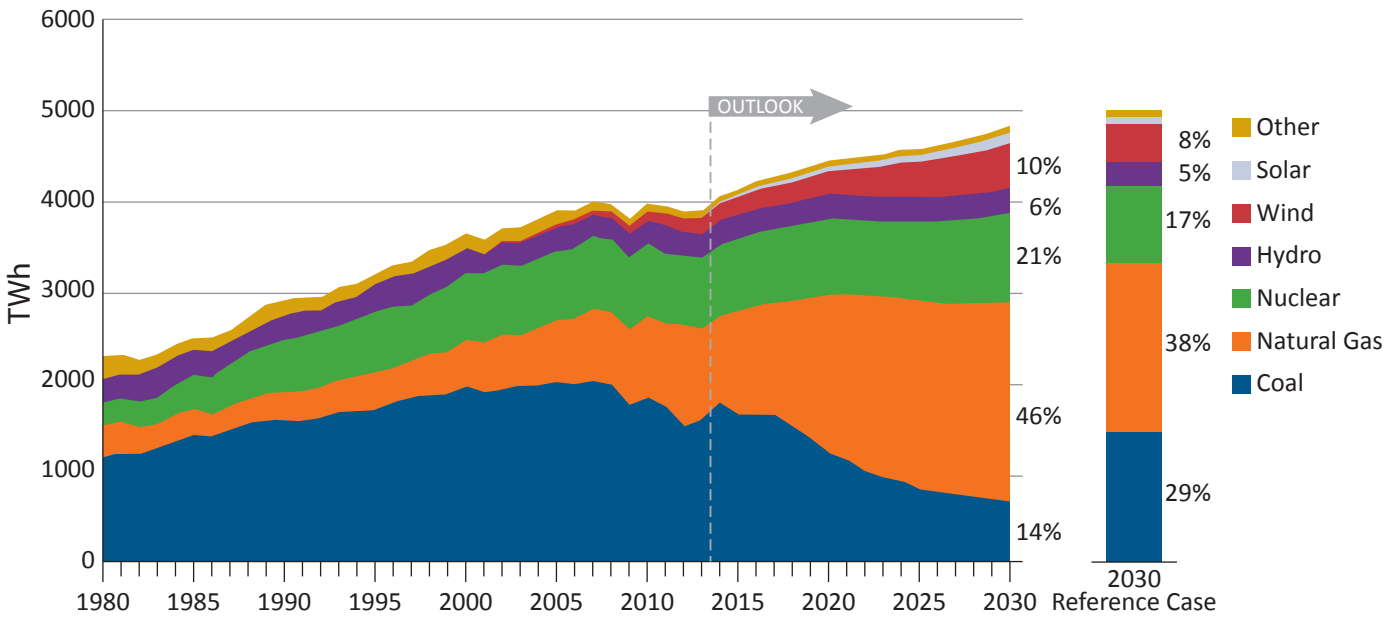

FIGURE 2. U.S. electricity generation mix under the CPP

TABLE 2. U.S. energy cost increases resulting from the CPP, 2012–3030[6]

All sectors	*2012*	*Dollar increase*	*Increase (%)*
Total electricity cost (billions)	$364	$376	104%
Total natural gas cost (billions)	$107	$190	179%
Total cost (billions)	$471	$566	121%
Residential			
Average electricity bill (annual)	$1288	$710	54%
Average natural gas bill (annual)	$675	$525	78%
Total	$1963	$1266	62%

lower GDP will be the unproductive investment dictated by the CPP. Not investing in productive initiatives will lead to forgone GDP and lower economic growth, with maximum GDP declines of just over $100 billion in 2025.

Consistent with the forgone GDP resulting from the CPP, employment levels will be lower. Thus, substantial GDP losses (Figure 3) will be accompanied by large job losses. On average, from 2014 to 2030, the U.S. economy will have 224,000 fewer jobs (Figure 4). These job losses represent lost opportunities and income for hundreds of thousands of people that can never be recovered.

POLITICAL OPPOSITION

The projected costs and impact on growth of the CPP have not gone unnoticed. After the EPA published its proposed and final rules, criticism quickly ensued, with some of the most vocal coming from coal-producing states.[9] The reason is clear, since

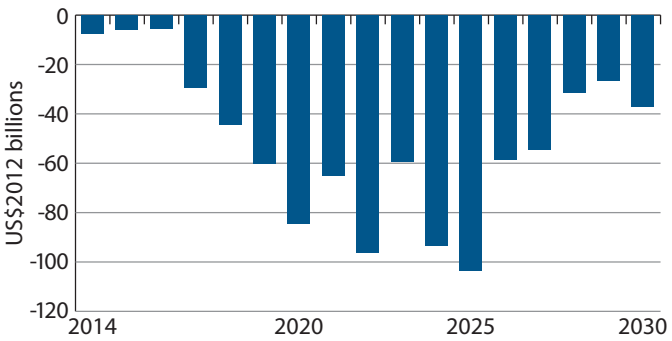

FIGURE 3. Annual GDP impact of CPP, 2014–2030[5]

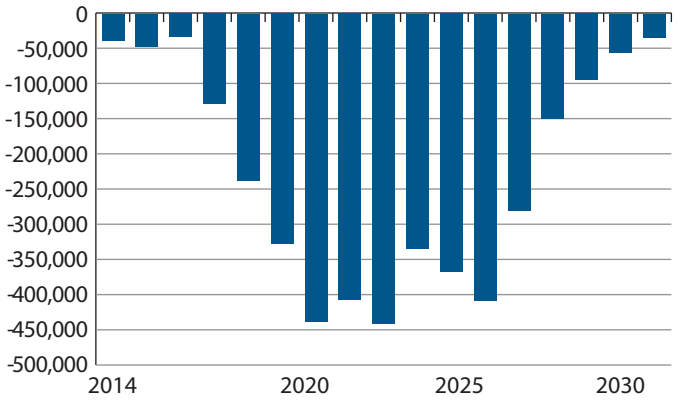

FIGURE 4. CPP estimate impact on employment[5]

by nearly all accounts the CPP will effectively limit or prevent the construction of any new coal-fired power plants in the U.S. and result in the closure of numerous existing plants. However, other fossil fuels are not safe. The final CPP rule starts to lay the groundwork to also phase out natural gas—differing notably from the proposed rule—by its increased requirements for RE and decreased emphasis on natural gas.[10]

"The projected costs and impact on growth of the CPP have not gone unnoticed."

Those opposed to the CPP have raised many concerns, from the computation of state budgets to EPA's authority to promulgate such a rule.[11] For example:

- The president of the Kentucky Coal Association argued that the EPA had no legal foundation to authorize the rule, warned that discussions need to be held on the continuing reliability of the country's electricity supply should coal be phased out, and stated that the livelihoods of the 36,000 Kentuckians who depend on the coal industry were being jeopardized.
- State representatives echoed these sentiments. U.S. Senator Shelley Moore Capito, a Republican from West Virginia, testified that "[w]ith this unprecedented rule, the EPA has gone far beyond requiring existing coal plants operate as efficiently as possible." She charged that "[t]he federal government has no business picking winners and losers in the energy economy, but that's exactly what the EPA's new rule would do."[9]
- As soon as the final rule was released, key lawmakers and industry groups vowed to battle the measure in Congress

The 2016 elections will see a new president, who could alter or revoke the Clean Power Plan.

and in the courts. Senate Majority Leader Mitch McConnell, a Republican from Kentucky (a state that gets 90% of its electricity from coal), declared in the Senate his intention to "do everything I can to fight" the regulation, stating "I will not sit by while the White House takes aim at the lifeblood of our state's economy."[12]

- In August 2015, 15 states went to a federal court, seeking to temporarily block the CPP while they mount a legal challenge to the rules. The states asked the court to issue an emergency stay blocking the rules, noting that they would be required "to spend significant and irrevocable sovereign resources now" to be in a position to meet the initial deadline of September 2016 for states to submit compliance plans to EPA. This stay was not granted.

While the November 2014 mid-term elections saw Republicans gain control of the Senate and increase their majority in the House, the party does not have the votes to repeal the EPA regulations. Instead, they intend to use their new powers to delay, defund, and otherwise undermine them. For example, Senator James Inhofe, Chairman of the Senate Environment and Public Works Committee and a prominent climate skeptic, has opened investigations into EPA and called for cuts in its funding and to delay the CPP as long as possible.

The considerable opposition and legal challenges could delay or derail the CPP. In addition, perhaps one of the most important threats are the 2016 elections. A new president unfriendly to the CPP could also halt it, since it was not legislated by Congress. Increasing their majorities in the House and Senate would also allow Republicans greater leverage to stop implementation. The path forward for the CPP will be tumultuous, and is certainly worth continued attention.

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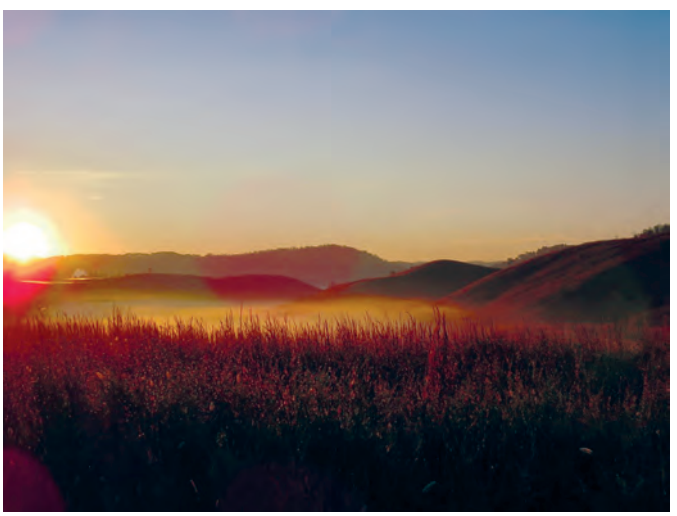
Upholding Strong Environmental Values: A Key Strategy at Arch Coal

By Jim Meier
Director of Environmental Affairs, Arch Coal

Coal is an important, naturally occurring energy source that provides numerous life-enhancing benefits to the global community. Out of respect for the land that bears this valuable resource, Arch Coal is committed to superior environmental protection during each phase of the mining process. Protecting the environment carries such importance that upholding strong safety and environmental values is a key element in Arch's four-point operating strategy. While we take pride in our industry-leading environmental performance, we are constantly striving to better ourselves, our techniques, and our processes.

Protection of the environment is integrated into every phase of the mining process, from exploration and development to active mining and reclamation. Even before beginning the permitting process, we assess—through a series of onsite studies—the potential for environmental impacts, and implement mitigation plans to minimize those effects. As a result of this dedication to environmental excellence, Arch has received numerous U.S. Department of the Interior and state environmental protection and reclamation awards. These awards recognize such diverse projects as establishing woodlands, greenlands, and wetlands, as well as natural habitat restoration and enhancement.



The sun rises over the eastern portion of the Left Fork reclamation area in West Virginia.

Arch is the most geographically diversified coal producer in the U.S., with large-scale mining operations in every major coal basin. A majority of Arch's subsidiaries operate in either Appalachia in the eastern U.S. or the Powder River Basin (PRB) in the west. Each area has distinct terrains, habitat, and wildlife, which creates both challenges and opportunities. Thus, reclamation projects are approached differently based on the local ecosystem to ensure that mined land is restored to its original pre-mining condition or better. Often land that has been reclaimed is indistinguishable from surrounding terrain within just a few growing seasons.

"Protection of the environment is integrated into every phase of the mining process, from exploration and development to active mining and reclamation."

APPALACHIAN RECLAMATION REQUIREMENTS SPUR INNOVATIVE SOLUTIONS

Appalachia's mountainous terrain presents unique challenges throughout the reclamation process. Surface mining in this region represents a very small percentage—less than 3%—of Arch's overall production platform, but we take great pride in our reclamation efforts in this segment of our business. We return the land to its approximate original contour while also providing opportunities to develop areas that are attractive and useful to both the animal inhabitants and local residents.

For instance, Arch's Mingo Logan's Left Fork surface operation implemented reclamation practices to ensure area wildlife can thrive in a post-mining environment. This award-winning site is unique as all phases of surface mining can be observed on a single-permit area—from preparation of new mining areas through 15-year-old mature reclamation. Mingo Logan personnel worked closely with the National Wild Turkey Federation (NWTF) to prepare multiple wildlife food plots across the permit area with the goal of supplementing food supply for native species during times of lean mast production (i.e., low

production of acorns, other forest tree nuts, and fruit-bearing trees).

These plots were planted with newly developed "Arch Tree Mix"—a seed blend collaboration between the West Virginia Department of Environmental Protection (WVDEP) and the mine operation. This seed blend has been proven to grow quickly, preventing erosion while enhancing soil chemistry. The plots are also supplemented with chicory and turnips, to provide additional nourishment to a range of species, including deer and bears, well into the winter months. These restoration efforts have been a centerpiece of many of Mingo Logan's Mountain Laurel's environmental awards—including state reclamation awards and the coveted National Good Neighbor award given by the U.S. Interior Department.

Arch also has successfully created more than 200 acres of new wetlands on reclaimed lands in Central Appalachia—where wetlands are scarce. These new water sources, as well as the open fields and diverse terrain that exist after reclamation, attract and sustain an abundance of native wildlife, including rabbits, turkey, deer, fox, owls, hawks, and black bears.

WESTERN TERRAIN REQUIRES DIFFERENT RECLAMATION TECHNIQUES

The Powder River Basin (PRB) is a significant coal mining area. Arch estimates that the electricity used by one out of every six homes and businesses in the U.S. is produced from coal mined in Wyoming. It is also an important operating area for Arch Coal and its Thunder Basin Coal Company (TBCC) subsidiary. TBCC operates two surface mines in northeastern Wyoming: Black Thunder, one of the largest coal mines in the world, and Coal Creek. Although it supplies more than 11% of America's coal supply, Black Thunder's mine footprint comprises only 1/4000th of Wyoming's land area.

Many wildlife species thrive on TBCC reclaimed lands and active mining areas. Reclamation efforts include returning the land to the former native habitats: grasslands, short-grass prairies, shrub-steppes, and riparian areas. Rock piles provide cover for rabbits and other small animals, which in turn attract predators. Herds of elk, mule deer, and pronghorn antelope benefit from more plentiful water sources and vegetative cover on previously mined lands.

Pronghorn Lake supports a diverse group of waterfowl year round.

GREATER SAGE-GROUSE SUCCESS STORY

Arch's successful integration of mining and reclamation with habitat protection results from going above and beyond regulatory requirements, as well as working closely with state and federal regulatory agencies and local communities. Protection and propagation of the greater sage-grouse is just one example of a positive outcome of these efforts.

TBCC, and the broader coal mining community, worked extensively for more than five years with state and local conservation groups to protect the greater sage-grouse and to ensure that coal mining in northeastern Wyoming could continue without endangering the species. The greater sage-grouse is the largest grouse in North America, found in sagebrush country in the western U.S., including Wyoming. The bird's numbers began declining in the latter 20th century in many areas, which resulted in the U.S. Fish and Wildlife Service's proposal to list the grouse for protection under the Endangered Species Act.

As a preventive measure, Wyoming's governor created a task force, including members of TBCC's operations, to develop core protection areas and to provide stipulations for development within these areas to conserve and to expand the species through habitat enhancement. Sage-grouse conservation practices put in place at Arch's Black Thunder and Coal Creek mines include restricted hunting, mosquito control in surface water impoundments to reduce West Nile virus, management of invasive species, dust control measures, removal and marking of fences near breeding grounds, and habitat enhancement projects on both reclaimed and native lands that will not be mined. As a result of these efforts, and the efforts of others, the Department of Interior decided in September 2015 that it was not necessary to list the greater sage-grouse as an endangered species.

TBCC'S AVIAN PROTECTION AND MITIGATION PRACTICES

While supporting the natural habitat for all wildlife indigenous to the Powder River Basin, TBCC has made substantial efforts to provide particular protection for the area's avian population on both reclaimed lands and active mining sites. These efforts have included providing adequate habitat on reclaimed lands, providing new and replacement nesting structures, rescuing

and relocating birds as needed, and developing a comprehensive Avian Protection Plan (APP) for both mines.

The protection plan was prepared in accordance with the "Suggested Practices for Avian Protection on Power Lines: The State of the Art in 2006"[1] developed by Edison Electric Institute's Avian Power Line Interaction Committee. The goal was to inventory all onsite electrical structures for possible avian hazards and to outline a remediation plan to replace or retrofit problem structures.

The initial work needed to locate, evaluate, and prioritize risk for each structure was a major undertaking. All TBCC aboveground electrical structures, including power poles, portable and permanent substations, and metering points, were scrutinized and the location of each structure was recorded with a hand-held GPS device.

Once the initial evaluation was completed, a five-year plan was developed to retrofit or remove problem structures, and was then submitted to the U.S. Fish and Wildlife Service for review and approval. Since the plan was implemented in 2011, TBCC has worked to eliminate potential hazards, including removal of power lines and poles, insulating jumper and guy wires, putting insulating caps on bushings, removing older electrical structures, and providing alternate perches near substations. Consequently, there has been only one avian fatality suspected to be related to mining operations at Black Thunder, with no incidents at Coal Creek, since mid-2010.

A key component of the protection plan provided that all TBCC employees be educated about state and federal laws protecting avian species, and additional public outreach was conducted with mine-site neighbors. Each year TBCC management meets with local ranchers whose operations are near the mine sites to communicate mining plans and to review federal laws protecting eagles and migratory birds. At these meetings, participants discuss how they can help protect birds on their property and what to do if they find an injured raptor on their ranch.

Employees also routinely work with local rehabilitation centers to rescue and return injured birds to the wild.

AVIAN PROTECTION PLAN: A SAFE HAVEN

A number of reclamation practices are used to ensure that Arch's reclaimed habitat provides the needed forage, nesting, and cover to protect the avian population. Specific seed mixes using native cool- and warm-season grasses, shrubs, forbs, and trees species were developed to replicate the original habitat, and the reclaimed surface topography was designed to simulate the native contour. Habitat features incorporated into final reclamation practices include rock piles, brush piles, tree plantings, and tree snags to simulate native conditions.

Arch's reclaimed land creates a safe haven for golden eagles and other avian species.

Raptor mitigation and monitoring plans were developed and implemented at the mines in the 1980s. These plans are reviewed and revised periodically to address future mining plans and any potential impacts to nesting birds. A series of nesting platforms were erected around the mine sites to replace existing nests and to entice birds to nest on reclaimed land for the first time.

Mitigation nest sites also were constructed for golden eagles, ferruginous hawks, red-tailed hawks, Swainson's hawks, great horned owls, burrowing owls, and American kestrels. The most commonly used mitigation structure is a platform placed on poles ranging from six feet to 20 feet above the ground with nesting material placed atop the platform.

Other types of mitigation nest sites have been constructed using natural substrate including trees, rock outcrops, banks, and the ground. Ferruginous hawk mitigation nest sites were constructed on rock piles placed in reclaimed areas.

Pelicans rest on an island of the Black Thunder reclamation site reservoir, an area that provides an adequate food source during spring migration.

Burrowing owls are common visitors to this area and are under consideration for listing as an endangered species. Black Thunder personnel have installed burrowing owl boxes in reclamation areas to help this struggling species survive and to provide additional nesting habitat.

There are a number of great horned owls in the mine's vicinity. Nesting boxes have been placed next to an equipment yard where the owls have been known to use site equipment as nesting sites. Hopes are that the nesting boxes will be more attractive to the owls than the equipment, and potential disturbance due to movement will be minimized.

Tree snags also have been placed around the mine sites. Tree snags are trees growing in areas that will be mined, or ones that are dead but still standing. These trees are cut off at the ground and re-erected in reclaimed areas and around the site in advance of mining to provide attractive areas for nests and to detour birds away from active mining areas.

WATERFOWL AND SHOREBIRD MITIGATION EFFORTS

Two specific aquatic habitats provide a snapshot into Arch's dedication to protecting waterfowl and shorebirds.

Prior to the area being mined, Reno Reservoir was located on Little Thunder Reservoir's main stem in what is now the center of Black Thunder's reclamation site. Pronghorn Lake was built as a replacement reservoir not far from Reno Reservoir's original site on a combination of TBCC-owned land and U.S. Forest Service grasslands. It is a 600-acre-foot reservoir with a surface area of approximately 60 acres with several features designed to enhance wildlife habitat. The irregular shoreline supports breeding waterfowl by providing visual barriers between territorial pairs of the same species. The lake is designed to maintain a water depth of five feet or less to encourage emergent vegetation, and it is also designed to spill frequently to maintain water quality. Deeper sections of the lake provide excellent fish habitat, while the gently sloping shoreline allows safe and easy access to the water for livestock and other animals.

The lake also includes a large island, which provides a predator refuge for birds and an additional breeding ground. The island is designed so that it is not subject to excessive wind and waves or high-velocity flow, preventing shoreline erosion, which enhances vegetation growth and reduces sedimentation.

Downstream, TBCC built a 240-acre-foot reservoir with a surface area of 40 acres that serves as ultimate sediment control for a good portion of Black Thunder lands. A number of features not normally associated with a sedimentation reservoir were incorporated into the construction to enhance wetland, fishery, and waterfowl habitat, including islands that provide protected nesting habitat for various waterfowl species. Pools were incised next to the islands to increase water depth for fish during drought periods, while irregular shorelines encourage emergent vegetation and provide wind protection.

Both reservoir designs provide complementary features for waterfowl and other wildlife. Pronghorn Lake is a deeper pond, although the sediment reservoir is shallower. These two areas provide water year round for waterfowl, as well as staging areas during spring and fall migration. Recent wildlife surveys documented nearly 40 different species of shorebirds and waterfowl using these two areas.

Waterfowl surveys also indicate the lakes' ecosystems have developed enough to support a diverse group of waterfowl including fish-eaters. In the past, these species had been just

Canada Geese enjoy the reclaimed land.

overnight visitors as there was not an adequate food source. More recently, pelicans were documented residing at these lakes for more than a month during spring migration.

Double-crested cormorants also have been observed sharing the island in Pronghorn Lake with Canada geese. Cormorant brooding success was documented at Pronghorn Lake, further evidence that the reclaimed reservoir's ecosystem has developed enough to provide ample habitat for yet another species to rear its young.

In addition to traditional waterfowl, bald eagles, which are winter visitors to this region of Wyoming, are frequently seen on Pronghorn Lake.

THE RESULTS ARE EVIDENT

TBCC's avian protection and mitigation practices have been quite successful in supporting the area's native bird species. In fact, the program was awarded the 2014 Wyoming Reclamation award by the Department of Interior's Office of Surface Mining Reclamation and Enforcement. Annual wildlife data show that the reclaimed area provides the needed avian habitat, and raptor mitigation efforts have been successful. Studies also show that the reclaimed area provides adequate habitat for the birds as both migrants and residents.

Wildlife monitoring also documented that certain species observed in the area are successfully breeding on reclaimed areas. Mitigation efforts have been successful in minimizing mining impacts on nesting raptors with the successful relocation of nests. Reclaimed water features provide ample habitat for both migrant and nesting waterfowl, and efforts to minimize impacts due to electrical hazards have been extremely effective. Both Black Thunder and Coal Creek mine sites and their reclaimed areas continue to attract avian species, including those that are sensitive to human activities, as they arrive on site and migrate through, or become residents who successfully raise their young.

ARCH'S ONGOING COMMITMENT

Arch is acutely aware that a core component of long-term business success is effective environmental management. From the top of the organization down, our employees are committed to adhering to the highest standards of environmental protection. While our past success is demonstrated by our award-winning reclamation efforts and achievement of final stage bond release across our operating platform, we are constantly striving to improve.

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For more information on Arch's reclamation activities, please visit www.archcoal.com/environment/reclamation.aspx

The Colowyo Mine:
A Case Study for Successful Mine Reclamation

By Juan Garcia
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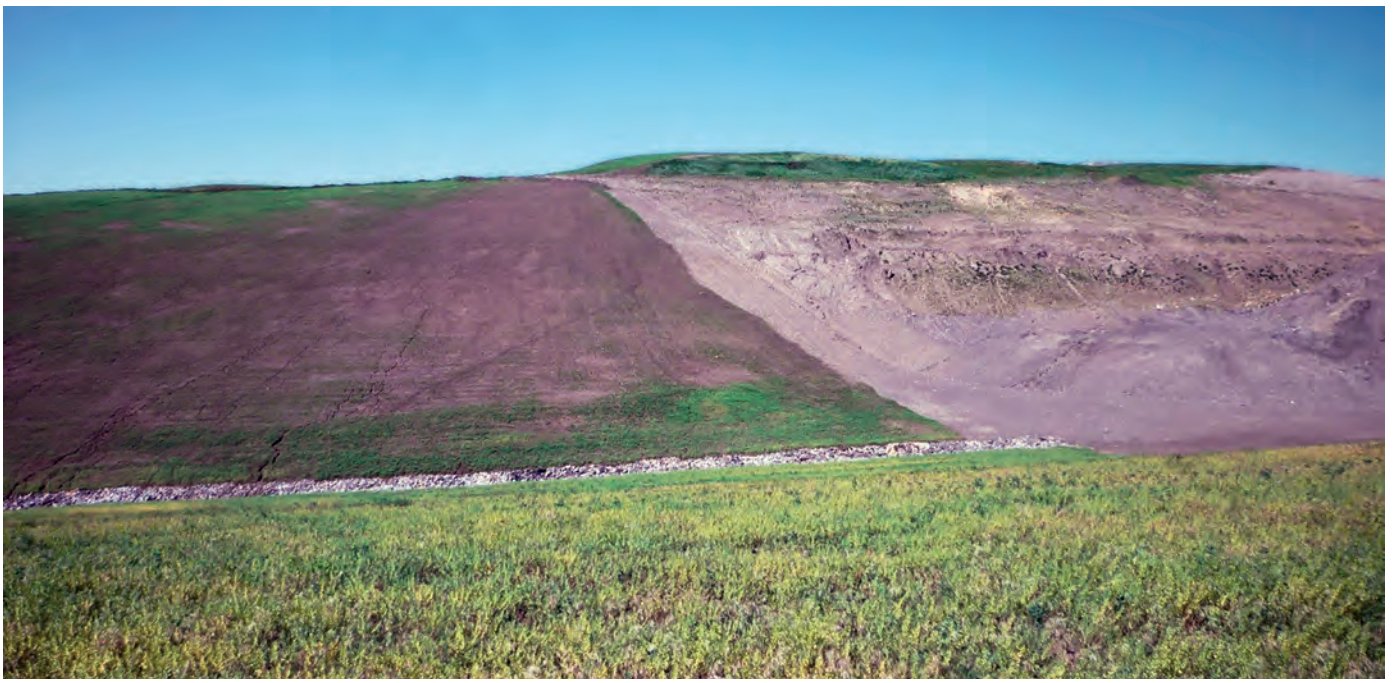
In northwestern Colorado, U.S., coal mining has been a critical part of the culture and economy since the turn of the 20th century. The history of the Colowyo Mine (Colowyo), currently operated by Western Fuels-Colorado, LLC, and owned by Tri-State Generation and Transmission Association, Inc. (Tri-State), dates back to 1908 when the underground Collom Mine operated in the 24-foot-thick Collom coal seam. Starting in 1976, Colowyo transitioned to a highly efficient multiseam dragline and truck-shovel surface mine that today produces approximately 2.5 million tons per year of high-quality, low-sulfur, sub-bituminous coal that is used for coal-fired electrical generation.

The coal produced from Colowyo feeds Craig Station, the second largest coal-fired baseload power plant in Colorado. This power station uses modern emissions control technologies to produce approximately 1300 MW, or one third of the coal-fired electricity generated in Colorado. The electricity generated at Craig Station is an important component of the Tri-State portfolio of power generation. Tri-State is a not-for-profit wholesale power supplier to 44 electric cooperatives and public power districts serving 1.5 million members throughout 200,000 square miles in Colorado, Nebraska, New Mexico, and Wyoming.

"Colowyo practices responsive resource extraction … and a dedication to reclaiming the land to a beneficial use that is comparable to or better than the land use that existed prior to mining."

The Colowyo mine has provided coal to produce reliable, cost-effective electricity for nearly four decades while minimizing the environmental footprint.



Land currently undergoing the reclamation process at Colowyo

The state of Colorado is known nationally for its snow skiing, big game hunting, fishing, hiking, sightseeing, rafting, and many other types of outdoor recreation—an industry that yields $13.2 billion in state revenue each year.[1] Colorado has 53 mountain summits in excess of 14,000 feet (4267.2 m) and vital water derived from the Colorado watersheds sustains municipalities and agricultural industries in vast areas of the arid southwestern U.S. In recent years, the state's population has grown at twice the national average. Thus, meeting increasing energy demand in Colorado must be done in a way that minimizes impacts on the natural world. In line with such values, Colowyo practices responsive resource extraction with minimized harm to the environment and a dedication to reclaiming the land to a beneficial use that is comparable to or better than the land use that existed prior to mining.

Colowyo is a mature mining operation composed of the active South Taylor Pit, the fully mined out West Pit undergoing reclamation, and substantial areas that have already undergone successful reclamation. Reclamation begins as soon as mining in a particular area is finished, minimizing the environmental impact and footprint of the mine at any one time.

COLOWYO'S APPROACH TO MINE RECLAMATION

Colowyo's reclamation objective is to restore the mined area to a land use capability equal to or better than the land condition that existed prior to mining. This commitment begins with the Tri-State Board of Directors, which has made reclamation projects a priority and has dedicated the necessary resources to ensure completion at or above industry standards. The desired end results of all reclamation practices are to stabilize the soil, maintain hydrologic and vegetation resources, and restore the approximate original contour of the mined area. Ultimately, the goal is to return the mined areas to a condition that can support its original use as rangeland and the watersheds to their approximate pre-mining character. In general, the long-term appearance and usefulness of the mined area will be similar to that which would have been encountered prior to any mining.

Colowyo has worked cooperatively through the years with Colorado State University, the University of Idaho, the Colorado Division of Reclamation, Mining and Safety (CDRMS), the Colorado Department of Parks and Wildlife, and the U.S. Bureau of Land Management to develop innovative reclamation techniques, including the following practices:

- Hauling topsoil immediately from the salvage area to the final reclamation surface to preserve soil nutrients and seed sources within the topsoil;
- Chisel-plowing the newly spread topsoil to break up soil compaction to help prepare an optimum seed bed;
- Using a rangeland drill to plant a diverse mix of shrub/grass/forb seeds below the soil surface;
- Seeding only in the fall so the seed lies dormant through the winter and germinates in the spring to take advantage of snow melt precipitation and the spring growing season; and

- Placing discontinuous contour furrows in the topsoil when seeding to capture and hold precipitation to sub-irrigate plant root zones.

The Colowyo site has won numerous reclamation awards for outstanding professionalism and performance in conducting mining and reclamation operations, use of innovative approaches in addressing reclamation problems, successfully obtaining environmental permits approving work in several excess spoil disposal fill areas, supporting longstanding efforts to reestablish shrubs on reclaimed mined land through the testing of various seeding and planting techniques, and innovative topsoil replacement methods to enhance shrub establishment and develop beneficial and diverse wildlife habitat. In fact, since 2010, Colowyo has received six Colorado Mining Association Environmental Stewardship and Pollution Prevention awards and three Colorado Division of Reclamation, Mining and Safety Excellence in Reclamation awards.

"The Colowyo site has won numerous reclamation awards for outstanding professionalism and performance in conducting mining and reclamation operations..."

OUR RECLAMATION PROCESS

The reclamation process at Colowyo begins with the salvage of topsoil before mining commences. Topsoil salvage ensures that soil rooting material, with the associated nutrients and organic matter, is transferred back to the land after mining has ended. Thus, during reclamation much of the area that is temporarily disturbed by mining is covered by soils that provide an excellent source of plant growth media. These soils are deep, dark, and loamy with physical and chemical properties well suited for revegetation. Topsoil is either directly hauled from salvage areas or hauled from topsoil stockpiles and uniformly distributed over the entire regraded landform.

Backfilling and regrading operations, also important during reclamation, are conducted according to the reclamation plan approved as part of the CDRMS permit to mine. These operations return the surface topography to the approximate original pre-mining contours. Post-mining drainages are constructed to reestablish stable drainage basin areas, land profiles, and channel configurations. These drainages are designed to ensure the channels and associated drainage basins remain stable and are not prone to erosion. Contour ditches may be placed in drainage basins to route surface flow to rock-lined channels. These are especially important immediately after topsoil placement and seeding while vegetation is becoming established to prevent or minimize erosion of the topsoil resource.

Diverse vegetation types are selected based on the post-mine land use approved in the mining permit. Since Colowyo's post-mine land use is rangeland, the reclamation areas are seeded with native species of grasses, forbs, and shrubs to reestablish vegetative communities such as sagebrush, juniper, grassland, and riparian. The eventual size and location of these various post-mine vegetative communities are based on factors such as surface topography, elevation, and the direction the landform is facing. Variable depths of topsoil may be replaced in targeted areas to best meet vegetative requirements. Studies have shown that establishment of some shrubs is enhanced by the placement of shallower (4–8 inches) topsoil depths. This potentially precludes the establishment of thick stands of grasses that can out-compete shrubs and forbs for soil moisture and nutrients. Conversely, thicker (12–18 inches) layers of topsoil can enhance the establishment of predominantly grassland communities.

Native elk on Colowyo reclaimed mine land

SUCCESSFUL LAND REHABILITATION

Reclaimed mine lands are becoming an increasingly important land use component within the Colowyo mining area. Over 2400 acres of reclaimed land, which continues to expand, provides year-round habitat to local birds and both small- and big-game wildlife populations, including small mammals, birds of various species, elk, mule deer, and pronghorn antelope. It is quite common to observe young animals and birds of every species that were born on or in the near vicinity of the reclaimed mine lands.

This final surface configuration provides home and shelter for all wildlife. The regrading and revegetation plan reestablishes diverse food sources, establishes escape cover, creates south-facing slopes that do not accumulate deep snow levels, which aids wintering animals, and creates small drainages and water catchment areas where stock ponds and small catchments provide necessary water.

Ultimately, there are two measures of successful mine-land reclamation: full reclamation bond release and the establishment of the targeted post-mine land use. Colowyo has received full bond release on 987 acres by achieving the regulatory-mandated standards set by the CDRM. These bond release standards include requirements for vegetative diversity, density, and production, as well as soil stability and essential hydrologic function. True vegetative success is ultimately measured by the ability of the vegetation to be self-sustaining and flourish under all natural weather conditions without the aid of any artificial intervention. All bond-released areas readily meet this stringent criterion.

"Colowyo continues to work toward building a proud reclamation legacy for all generations to use and enjoy."

The newly reclaimed rangeland is composed of the two primary subcomponents: livestock grazing or grazing land and wildlife habitat or greater sage grouse (GSG) brood-rearing habitat. GSG habitat preservation or reestablishment was of particular concern since the bird species had been identified as potentially eligible for Federal Endangered or Threatened Listing status. On 22 September 2015, the U.S. Department of the Interior determined that the GSG does not require Endangered Species Act protection, but regardless of that decision, Colowyo will continue to reestablish quality wildlife and

Colowyo will continue to reestablish grouse habitat during reclamation.

grouse habitat. Livestock grazing has always been precluded at Colowyo on reclaimed areas to ensure that vegetation is well established. In the future, livestock grazing will be introduced to coincide with regional land use.

Indigenous wildlife, such as elk, mule deer, and pronghorn antelope, have already discovered the abundant food resources and secluded habitat available on the reclaimed mine areas and have established either seasonal or year-round residency. Sage, sharptail, and dusky grouse; songbirds from many diverse species; hawks, eagles, owls, and falcons; and many other bird species have already reestablish occupancy in the reclaimed areas as the vegetation has matured. Small mammals such as chipmunks, ground squirrels, cottontail rabbits, jackrabbits, weasels, voles, and mice all find refuge and home in the mined reclamation areas.

Taken collectively, these many indicators point to a true reclamation success story that Colowyo is proud to be a part of and glad to share. Colowyo has always been open in sharing best reclamation practices with other coal mining companies, state and federal regulatory agencies, and academia to ensure that healthy and self-sustaining post-mine environments exist long after mining has ceased. Colowyo continues to work toward building a proud reclamation legacy for all generations to use and enjoy.

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Detailing Yancoal Australia's Reclamation Best Practices

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Yancoal Australia (Yancoal), a coal mining company that operates exclusively in Australia, but is majority-owned by the Chinese company Yanzhou Coal Mining Co. Ltd., produces thermal and metallurgical coal from its seven mines, most of which are opencast, located in some of the Australia's richest coal reserves in New South Wales and Queensland (see Figure 1). The company also manages an opencast mine in Western Australia's Collie Coal Basin south of Perth and an open cut mine in Queensland's Surat Basin on behalf of Yanzhou. Yancoal also has access to key port and rail infrastructure, including shareholdings or allocated capacity in major coal terminals. Much of the 32.5 million tonnes of coal mined by Yancoal in 2014 was exported to South Korea and Japan, with a relatively minor amount being exported to China.

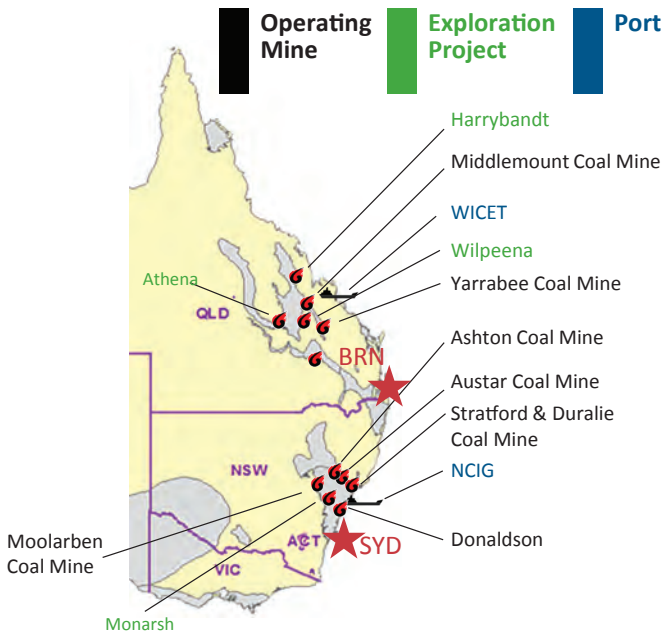


FIGURE 1. Yancoal's mining operations

YANCOAL'S COMMITMENT TO RECLAMATION

As Yancoal has become a major coal producer in Australia, the company has worked extensively to ensure that it meets Australia's stringent environmental regulations, including those that relate to mine reclamation.

> ***"Protecting Australia's ecosystem while carrying out mining is a practice that has been successfully demonstrated by coal producers in the country for years."***

In Australia, coal is mined primarily in Queensland, New South Wales, and Victoria. In fiscal year 2013–14, ~431 million tonnes of coal were mined, most of it in opencast mines, of which ~375 tonnes were exported.[1] The Australian landmass is generally relatively barren with a thin layer of topsoil, especially in mining areas. Moreover, the country's plant and animal species are relatively unique, making it critically important to protect the ecology around mining areas. Thus, timely and successful reclamation is necessary to ensure that the environmental impact of mining activities is minimized. Today about 80% of land disturbed for mining in Australia has been reclaimed and the country is a global leader in the field.

The ultimate goal of Yancoal's reclamation programs are in line with those of other mining companies in Australia: to establish stable, compatible landforms on mined areas, revegetated with native species. This allows the original plant and animal communities to become re-established and aims to leave a positive legacy for future generations—such as recreation areas, aquaculture options, or, in many cases, a nature reserve.

RECLAMATION THAT BEGINS PRIOR TO MINING

An important aspect of best practices of mine reclamation in Australia is working with various levels of government throughout the entire process: from before mining begins, during mining, and throughout the full reclamation process.[2]

After the exploration rights are issued for the mine, a detailed mining operations plan is created. This plan includes forecasting land disturbance, a draft land reclamation plan, and projection of reclamation costs. Projected costs are verified through feedback from the local community stakeholders and experts.

Mining companies must hire independent reclamation experts to determine the extent of the land that will be disturbed and subsequently survey the topography, soil, animals, plants, historical artifacts, water drainage, etc., to fully assess the potential impact of the mining project. From this, a management plan is drawn up and a specialized survey research report is compiled.

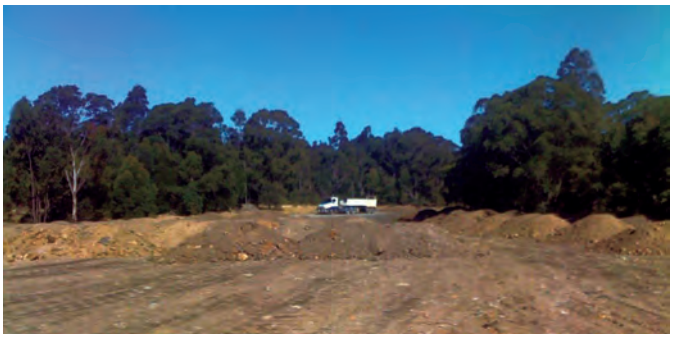
After the report is finalized and the mining company obtains the proper permissions to mine, a security deposit must be paid by the mining company prior to any actual excavation. This is a relatively common practice in many countries that ensures funds are available for reclamation, even in a case where a mining company becomes fiscally insolvent or for some other reason there are delays in the reclamation process.

CASE STUDY: RECLAMATION OF YANCOAL'S ASHTON COAL MINE

Yancoal works to protect the delicate Australian ecosystem through a multi-step reclamation process, including the initial clearing out of animals and plants, plant storage, topsoil collection, mining operations, surface reshaping, water drainage design, gypsum scattering, deep plowing, rocks removal, topsoil addition, and vegetation restoration. This process has been implemented at the company's opencast mines, including the Ashton coal mine. Like many opencast mines, Ashton works through the reclamation steps in one part of the mine even as coal is being actively mined elsewhere.

Relocation of Animals and Plants

Before mining begins in any area of the Ashton mine, plants and animals are relocated. This process requires authorization from the state environmental department. Per regulations and rules, environmental and ecological experts complete an inspection and assessment of the area within 12 months prior to the commencement of mining. To minimize the disturbance and improve the chance of successful reclamation using original species, trees that do not host animal habitats are the first to be cleared. Trees that may have animal habitats are kept for longer and are then only cleared under the instruction of experts and are saved for reclamation.



Collection and transfer of topsoil

Plant Storage

At the Ashton mine, the plants cleared without any animal habitats can be saved or mulched, based on the recommendations of ecology experts. Those plants that provide animal habitats are transported to other locations where they can continue to grow until they are needed for reclamation. Keeping original plants and reusing them to the greatest extent possible offers the added benefit of improving soil fertility.

Topsoil Collection and Storage

As Australia has a relatively thin layer of topsoil, its protection and use during reclamation is quite important. Thus, Yancoal collects topsoil prior to the commencement of mining. Ideally, the collected topsoil is used immediately in an ongoing reclamation effort nearby. Otherwise, it is stored and used when its original home undergoes reclamation. If the topsoil is not used immediately, it is protected by planting grass on its surface, which prevents water loss and erosion, and protects important microorganisms.

Refill and Ground Surface Reshaping

Once mining is complete in a specific area at Ashton mine, active reclamation begins, even as other parts of the mine are in operation. The first step is to refill the ground with gangue and reshape the surface, according to the specifications set in the original mining permits and determined based on the original terrain.

Water Drainage

Ensuring proper water drainage is achieved on reclaimed land at Ashton is particularly important and has been designed with the local topography in mind. Stones are used in water drainage ditches to prevent water loss and soil erosion or ponding.

Gypsum Addition

Gypsum can improve soil's physicochemical structure, increase its stickiness, and thus reduce soil erosion. For these reasons, gypsum is regularly used by Yancoal in its reclamation efforts. It is scattered on the surface of the gangue after refill, and at the same time, suitably added to the topsoil as needed based on soil tests. As a general practice to prevent repeated disturbance to the reclaimed soil, Yancoal mixes the gypsum with the topsoil at the storage area, before it is used at the reclamation site.

Deep Plowing and Removal of Rocks

To prevent compaction, Yancoal deep plows the backfill (i.e., 0.6-m depth). By applying the process of deep plowing, Yancoal is able to remove rocks larger than 200 mm in diameter from the topsoil. Notably, this is a specific requirement set by the New South Wales Department of Mining under which the Ashton mine operates.

Topsoil Cover

Yancoal structures the terrain and at least 100 mm of topsoil is added. Subsequently, the ground is leveled off, and at the same time, plant fragments, gypsum, lime, or compost are added to the soil based on the original soil conditions to improve it and help the original ecology recover more rapidly.

Vegetation Restoration

During reclamation Yancoal reintroduces the original landforms and vegetation to the mining site to the greatest degree possible, working to equal or even boost ecological productivity compared to the original state. However, vegetation restoration is a gradual process as plants must be allowed to take root and grow. As land is reclaimed at Ashton mine, grass is usually first to be planted, season permitting. After a turf is formed, shrubs or trees are then planted.

The result of deep plowing after refill

Reclaimed land at Ashton mine after planted grass has taken hold

Post-reclamation Management

At Ashton and its other mines, Yancoal monitors the progress of reclamation, which can continue for decades, including the state of the plants, animals, soil, and water drainage. Ensuring the success of plant species requires monitoring plant diversity, density, rate of coverage, height, and grass varieties and growth condition. Animal activities are also monitored, including the species type, populations, and successful breeding sites. Monitoring the soil includes regular analysis of its quality and thickness, while water drainage monitoring requires inspections monthly and after major rainfalls.

CONCLUSIONS

Protecting Australia's ecosystem while carrying out mining is a practice that has been successfully demonstrated by coal producers in the country for years. Yancoal is proud to become a part of this legacy and is working to contribute to the responsible operation of the country's coal industry.

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Reclaiming Indian Mines

By A.M. Shah
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Unlike much of the world, India is expecting fast growth in the near term—in the second quarter of 2015, the country reported GDP growth at a rate of 7%. The country registered US$31 billion in foreign direct investment in FY15—up 27% over the previous year.[1] Most in the current federal government believe that India's economy will grow by as much as 9% by 2019. In addition to this projected economic growth, Prime Minister (PM) Narendra Modi's "Make In India" campaign—an initiative to push domestic manufacturing[2]—will require India to have access to reliable energy, which is underpinned by recent mining-sector growth of 4% and electricity growth of 3.2%.[3] Based on the country's resources, the largest component of India's energy makeup will have to be coal—principally from domestic sources (coal capacity currently stands at about 168 GW).[4]

Even as the country increases coal production, India's leaders are under pressure to reduce the environmental impact from the production and use of coal and other energy sources. Minimizing the impact of mining on the environment during and after mining practices is a critical component of protecting the environment. This means that ecological reclamation of mining land in backfilled and overburden dump areas, plantation in and around mines, avenue plantation, and restoration of flora and fauna must become more widespread and receive increased oversight in India.

Pond created at a newly-reclaimed mining site in India.

INDIA'S MINING AND RECLAMATION PROFILE

In FY15 (ending March 2015), India's principal coal mining company, Coal India Limited (CIL), produced about 494 Mt,[5] with total coal production in India at 624 Mt—85% of this was from opencast mines. In the same fiscal year, CIL also reported a growth of 10.5% in moving overburden—the rock or soil that overlies the coal deposit and must be removed to mine—and an increase in coal production of 32 Mt (7%). CIL projects that it will further increase production by at least 60 Mt in FY16.[6] India has also re-auctioned 20 coal mines to private-sector players with more slated to be auctioned in the near future—these are also opencast mines. Land reclamation is increasingly important as India's coal production grows. However, successfully reclaiming mining lands is an area in which India has much room to improve, despite some headway of late.

"Land reclamation is increasingly important as India's coal production grows."

A BIRD'S-EYE VIEW OF CHALLENGES

Progress on coal mine reclamation began as early as FY08, when all CIL subsidiaries were asked to reverse local environmental impact after completion of mining activities. This increased attention to reclamation was in response to public sentiment regarding the poor state of land post-mining in the country.

For its part, CIL has made some progress. In FY15, out of CIL's 617 km^2 of mine leasehold area in 50 opencast projects monitored in 2014–15, the total excavated area was 356 km^2.[7] Of this, 165 km^2 has been planted (i.e., biologically reclaimed), 116.69 km^2 has been or is being technically reclaimed (i.e., backfilled), while 75 km^2 is still being actively mined.[7]

Despite this progress, there is still an underlying issue with land reclamation in India. It remains a low priority and, in some cases, progress has been slow, stalled, or has not started in earnest. For example, some previously mined lands have been designated as critical since 2010. Efforts are slated to reverse the lost green space, but, by any standards, progress has been slow.

Green space surrounding a former CIL mine

Notably, there is hardly any agriculture on reclaimed land, even though India is in need of increased agricultural production. However, agriculture on reclaimed land can only be successful if the topsoil overburden is conserved based on scientific standards.

There is also some controversy about the validity of claims made about reclamation. As of the end of FY15, CIL claimed to have planted nearly 83 million trees in around 34,945 hectares of reclaimed land, increasing green cover by 85 hectares in 50 opencast mines, with 685 hectares of land fully reclaimed. However, these figures have been disputed. While CIL has demonstrated that the overburden pile height has been reduced (due to reclamation efforts), in some places Google Maps has revealed a lack of green cover where the company had claimed it had already planted trees. Investigations continue into why this is the case.[8]

Increased oversight is required, as a 2010 audit found poor performance on CIL's mine reclamation efforts. The auditors inspected 18 mines and concluded that overburden was not stacked safely in 10 mines and the plantation density was also far below expected norms.[9] In addition, the audit found that most of the mines did not restore topsoil properly and CIL subsidiaries had a backlog of over 12,000 hectares of land filling and technical reclamation.[10]

To facilitate better monitoring, the Central Mine Planning and Design Institute constituted an internal Geomatics division equipped with technologies including remote sensing, GIS, GPS, digital photo-grammetry, LiDAR, and terrestrial and mine surveys. The data gathered is also shared with the mine operator (e.g., CIL in the case of most coal mines), along with the department of forestry of the concerned state, and an officer of the Ministry of Environment. This technology will allow improved monitoring of land reclamation activities and, thus, will hopefully increase the ability to manage reclaimed green space.

With India's hunger for domestic coal increasing, there is an increased focus on abandoned mines that could be reopened to extract additional coal. CIL is offering majority stakes to private-sector miners, especially from the conglomerates, to extract the remaining coal.[11] Unfortunately, these mines have historically been abandoned without reclamation, and many of them may be damaged beyond repair. Ministry of Environment officials, along with their counterparts in the Ministry of Coal, are gathering data on the existing damage, and attempting to map out approaches to reduce the environmental impact, before allowing CIL or any other operator to restart any mining operations.

POLICIES TO PROMOTE RECLAMATION

Currently, CIL is required to provide funds for planting saplings and, under the provisions of compensatory afforestation, the forest conservation agencies of the respective states carry out the planting. However, previously processes may have been hindered by a lack of coordination between the agencies at federal and provincial levels. The current government is focused on making the state agencies bigger stakeholders,

A greater role for local government in reclamation efforts could lead to reclaimed land being maintained, such as the park above.

and has thus allowed them to retain royalties from the mines recently auctioned and also participate in subsequent decision-making about the mines in their jurisdiction.

Meanwhile, to extract more coal and increase the use of modern mining technologies, India is moving toward encouraging other miners and reducing reliance on CIL, and has already advanced some enabling legal provisions. The policy, which is expected to bring in new players and subsequently regulate them, may be fully enacted by end of FY16 or beginning of FY17.[12] In the interim, the country's leaders need to make clear the priority of land reclamation, including afforestation. Currently there are no standards, and no policy, to push private players and no penal provision if an operator violates the norms.

In May, Minister Javadekar placed the Compensatory Afforestation Fund Bill, 2015 in the lower house of Parliament (Lok Sabha), seeking to establish funds at the national and state levels to receive money collected for compensatory afforestation.[13] The Ministry of Coal is also going through the final draft of the Coal Regulatory Authority Bill, which may be tabled soon, to closely monitor the land reclamation process and give penalties to those miners in violation. If increased reclamation slows production in the country, it is possible that more imports may be necessary, at least in the near term.

ASIA'S LARGEST OPENCAST MINE AS A MODEL

Unquestionably reclamation efforts in India face challenges, but there is reason for optimism. The largest opencast mine in Asia now serves as an example of CIL's improvement in its reclamation efforts.

After a two-hour drive down a bumpy road from the railway station in Bilaspur (Chattisgarh state's second largest city), one arrives at the Gevra mine, operated by South Eastern Coalfields Limited (SECL), a wholly owned subsidiary of CIL. The mine is spread over about 19 km^2 and is the single largest source of thermal coal in India. It has the potential to extract 45 Mt annually and has produced 400 Mt since it became operational in 1981. An estimated 10 billion tonnes of reserves remain. If extracted successfully, the remaining reserves could fire all India's existing coal-fired power plants for the next decade.[14] The amount of coal that can be mined economically is less than the total reserves, but the Gevra mine can be considered a major production site for the near- and medium-term future.

"The largest opencast mine in Asia now serves as an example of CIL's improvement in its reclamation efforts."

One of the pits, where shovels and dumpers were busy extracting coal a few years ago, now hosts a lake. According to officials (with whom I spoke), migratory birds have started visiting the lake, and reptiles and other animals high on the food chain have been spotted among the surrounding vegetation.

Located at the heart of Indian coal reserves, the Gevra mine is neighbored by Northern Coalfields Limited's Singrauli mine in Madhya Pradesh and other coal mines in Jharkhand—an area that also hosts various mine-mouth power plants. Recently, Gevra has begun using the fly ash from many of these power

This image, taken in 2010, is of a pond created during one of CIL's earlier reclamation projects.

plants as a fill, in addition to backfill using the original overburden. Company officials at the site say most of the areas no longer being mined were reclaimed within the first year of reclamation activities.

In 2008, the first year in which its reclamation efforts were documented, SECL reclaimed 6.06 km^2, in comparison to 2.43 km^2 in FY03.[15] The new landscapes include parks, lakes, and green shrubs, and most of the trees planted are in mangroves.

With Gevra in expansion mode, set to extract 10 Mt more coal annually, the mine will be required to break and remove 1267 million m^3 of overburden.[15] Later, this can be used for reclamation. SECL is also reclaiming 159 km^2 of land at their 10 mines,[7] the largest amount of any CIL subsidiary after Northern Coalfields Limited (NCL). NCL is undertaking land reclamation in their 10 mines covering a 174-km^2 area.[7]

While prominent, the Gevra mine and SECL's efforts around reclamation serve as just one example of the reclamation work of CIL and its subsidiaries. In fact, in FY16 CIL is undertaking land reclamation at 50 large mines and 113 smaller ones. Although the actual effectiveness of these reclamation efforts is currently under investigation by the federal government and has become a point of contention when considering future mining activities, there is no question that reclamation has improved since earnest efforts began in 2008.

BUILDING ON LESSONS LEARNED ABROAD

India will continue to rely on coal for the foreseeable future. Improving reclamation around the country by building on the progress made to date is essential to reducing mining's environmental footprint. Even as oversight is being increased, those charged with reclamation may benefit from increased participation in international working groups on the topic, in order to make reclamation in India more efficient and more successful. Numerous successful opencast mine reclamations are underway or completed around the world. India's mining sector has an opportunity to increase the success of reclamation practices in the country by building on lessons learned and best practices abroad. With a goal of producing one billion tonnes per year domestically, now is the time for India's mining companies, especially CIL, to place an emphasis on effective reclamation.

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Mining Site Restoration by Spontaneous Processes in the Czech Republic

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Despite a recent decline, mining has a long tradition in the Czech Republic and continues to represent an important part of the country's economy. Thus, the mining industry continues to have a significant impact on landscape and nature in the country—about 0.8% of the area has been directly affected by various mining activities, not including historical mining.[1] In total, the amount of land impacted by mining in the Czech Republic is close to the world average, about 1%.[2] Coal mining contributes the most to this figure, followed by stone quarrying and sand and gravel extraction. About 60 million tonnes of coal, including brown and black coals, are extracted annually. This coal contributes 55% of the country's energy production, and no substantial decrease is expected in the near future.[3]

As coal will continue to play an important role in the Czech Republic, it is important to minimize the environmental impact of mining. This article focuses on spontaneous processes as an alternative option for reclamation of the spoil heaps left after coal mining, which is important because they are extensive and their formation continues even today.

The oldest (nearly 60 years) spontaneously revegetated spoil heap in the Most region, Czech Republic

"Our research indicates that when reclaiming mining lands and spoil heaps, spontaneous processes can be a suitable option for restoration of ecologically desirable ecosystems on the disturbed sites."

Currently, the total estimated combined area of spoil heaps in the Czech Republic is around 270 km^2—and approximately the same area has been heavily impacted by coal mining in other ways.[1] Our research indicates that when reclaiming mining lands and spoil heaps, spontaneous processes can be a suitable option for restoration of ecologically desirable ecosystems on the disturbed sites.

APPROACHES TO RECLAMATION OF MINING SITES

Mining sites are most often technically reclaimed—an approach that is encouraged in the Czech Republic by both legislation and the economic interests of various firms dealing with reclamation. However, in my opinion, and based on decades of research, this often disregards scientific findings on best practices for reclamation. Technical reclamation is largely preferred based on the assumption that initial environmental conditions in post-mining sites are highly unfavorable, thus restricting the early establishment of plants and other organisms. However, this is not usually the case. Technical reclamation mostly involves remodeling surfaces, covering them with an organic material, often imported topsoil, and planting saplings in orchard-like rows or, alternatively, sowing a species-poor grass-legume mixture. While this can be important to gain forest or agricultural land in some regions or countries, in the Czech Republic there is no need for new agricultural or forest land. Another recent

Spontaneously revegetated spoil heap from brown coal mining 20 years after dumping

technical measure is to inundate (i.e., flood) the disused mines which seems to be a reasonable option. However, usually steep banks are formed which does not enable development of ecologically valuable littoral ecosystems.

Restoration using spontaneous ecological succession (i.e., passive restoration) or slightly manipulated or directed spontaneous succession, which can be considered active restoration, has been used rarely. This approach includes minimal intervention and allowing the natural world to do the work to reclaim spoil heaps. Spontaneous succession works with diverse landscapes, relies upon natural species composition and soil formation, and includes limited habitat management, if any.[4] We estimate that only 0.01% of the spoil heaps from coal mining in the Czech Republic have been intentionally reclaimed using spontaneous processes.[1]

SUCCESSFUL MINING SITE RECLAMATION USING SPONTANEOUS SUCCESSION

After being studied for more than three decades, the Most region in the northwestern part of the Czech Republic now serves as an example of successful reclamation of coal mining lands through spontaneous succession.[5,6] There are about 150 km^2 of heaps with another 100 km^2 that were directly disturbed by mining activities. The heaps in this region were commonly known as a "moon landscapes" due to their appearance shortly after heaping. However, the appearance of the heaps began to change dramatically, and immediately, after the start of spontaneous succession. In total, about 400 species of vascular plants are found on this land today—representing about 15% of the total Czech flora. This spread has occurred as plant seeds were naturally dispersed onto the heaps by wind, by animals, and sometimes also by humans during the heaping process.

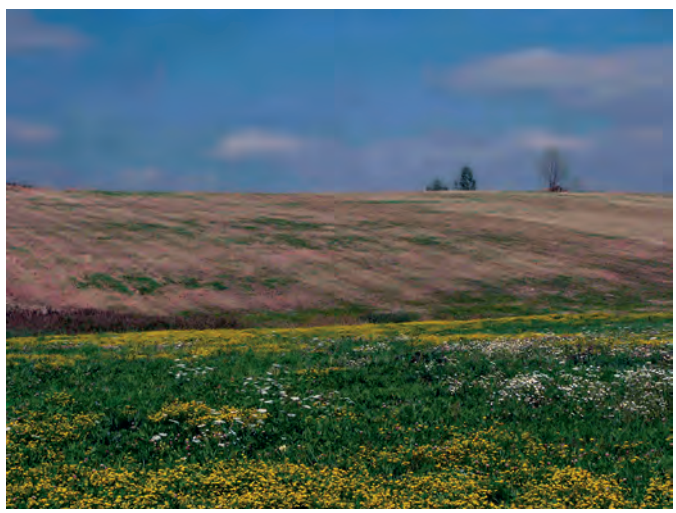
The process of spontaneous reclamation of spoil heaps in the Most region can be broken into several stages. Annual and biennial plant species dominated in approximately the first five years. Total land coverage by plants in this stage was relatively low, usually less than 30%. However, these sparse habitats can be crucial for many threatened arthropods and birds.[7,8]

Between five and 15 years of the succession process, broad-leaved herbs prevailed, followed by grasses. As the region has a relatively warm, dry climate, woody species have a comparably low cover, about 30% on average, even in late successional stages. The cover of woody species is much higher on wetter sites and in close vicinity to forests.

Around 25 years into the succession process, a semi-natural forest steppe was formed, a state that can persist for a long period.[6] This sparse woodland habitat serves as a refuge for forest-steppe arthropods, birds, and meadow and woodland plants and fungi.

The majority of the mining heaps has a potential to develop following this process, with the exception of wet depressions and sites formed by acid sands (with pH <3.5). The latter were generally characterized by no or rare vegetation. However, even such habitats offer value. They are important for some groups of invertebrates, mainly soil-dwelling bees and wasps, butterflies, and neuropteran insects.

Wetlands are especially valuable; these form quickly in depressions inside or along the heaps. They host some rare vascular plants, algae, amphibians, and aquatic and semi-aquatic arthropods. Spoil heaps are especially critical for amphibians and dragonflies and can contribute on a level



Part of the same heap as in the previous photo, but after recent technical reclamation.

important to the entire country.[7,9] Unfortunately, technical reclamation usually eliminates these valuable habitats in the Czech Republic.

COMPARISON OF TECHNICAL VERSUS SPONTANEOUS RECLAMATION PRACTICES

Studying technically and spontaneously reclaimed sites reveals that technically reclaimed afforested heaps host a lower number of species than those that are spontaneously overgrown (see Figure 1). The push for technical reclamation is also based on concerns that spontaneous succession occurs much more slowly. However, technical reclamation in the Czech Republic usually begins on average eight years after heaping concludes. When that time lag is taken into consideration, as well as the fact that planted trees require time to grow, it is obvious that spontaneous succession is comparably as fast, or even faster, than technical reclamation.

Thus, the use of spontaneous succession for restoration of spoil heaps is quite convenient from an ecological point of view and should be used much more in the Czech Republic today. The disproportion in using technical reclamation versus spontaneous succession can be illustrated by the present situation of a large spoil heap in the Most region. The area of the heap is 1250 hectares out of which only 60 were reclaimed using spontaneous succession, which has now been ongoing for 20 years. Today, there are many rare and endangered plants present in the area reclaimed by spontaneous succession and none were found according to my research in the area technically reclaimed. Some sites on this heap have recently been altered through technical reclamation even after spontaneous succession has successfully taken hold. Such an approach is undesirable not only for nature conservation, but also economically, as no ecological benefit justifies the extra financial expenditure for this spoil heap. In this example, the technical reclamation cost has been around a billion Czech crowns (US$42 million).

BEST PRACTICES FOR RECLAMATION IN THE CZECH REPUBLIC

For successful implementation of ecologically justified restoration of post-mining sites, there are several main principles.[4]

First, reduce the extent of traditional technical reclamation and include spontaneous (or directed) succession in restoration schemes, because almost the entire mining area has the potential to be restored spontaneously if the land is not needed for other purposes. Technical reclamation can, and will, still play a vital role. Considering other interests (erosion control, recreation, or sport activities, etc.), it would be

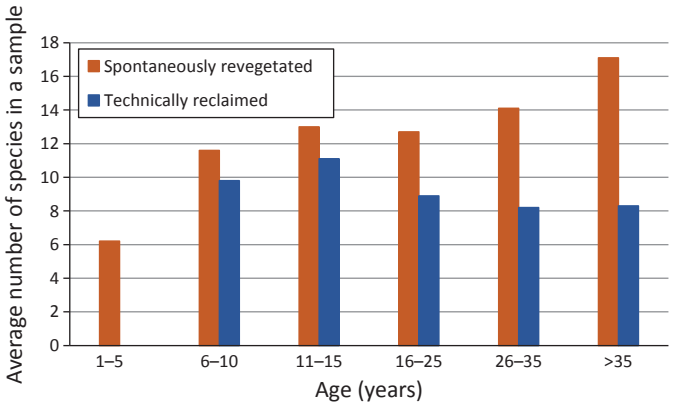


FIGURE 1. Average number of vascular plant species in samples 5×5 m in size recorded in spontaneously and technically restored and afforested spoil heaps from brown coal mining in the Most region, Czech Republic. Adapted.[10]

desirable to leave about 60% of the mining area to spontaneous succession, but in the present reality of regulations in the Czech Republic, a minimum of 20% is suggested. Spontaneous succession offers particular value at smaller mines, which usually demonstrate ecological growth even more quickly. Hence, the entire area of such mines could be left to spontaneous succession.

Second, it is important to form a heterogeneous (i.e., varied) surface during the mining or heaping processes (high geodiversity implies high biodiversity). Depressions enable the formation of usually highly valuable wetlands, including shallow aquatic habitats.

Third, in the case of technical afforestation, it is important to maintain at least the heterogeneous surface and not to drain the wetlands if it is not necessary for operational and safety reasons.

Fourth, nutrient-rich topsoil should be removed from the mining sites and should not be returned. When such topsoil is returned to a mining site, only a few competitively strong, often invasive species are supported and biodiversity strongly decreases.

Some additional considerations are also important throughout the entire mining and reclamation cycle. For example, prior to mining it is important to conduct a biological inventory of the locality, both in the mining area and its surroundings. It is desirable to direct mining in a way that maintains maximum natural habitats in the close surroundings. Most species colonize post-mining sites just based on close proximity.[11]

In addition, restoration schemes and environmental impact assessments should be prepared by specialists who are aware

Spontaneously developed woodland on a 25-year-old spoil heap was partly replaced by planted saplings of Norway spruce (front).

of the most recent findings in the field of restoration ecology and also of the possibilities and limitations of mining technologies. Mines should be monitored during mining, which can reveal the presence of endangered species and communities, and valuable geological and geomorphological phenomena. Mining should be modified accordingly if technically and economically reasonable.

If endangered species and communities occur on the post-mining site, proper management should be applied to maintain them. The expense of such management could be paid from the funds of mining companies dedicated to reclamation, or public funds dedicated to nature conservation. Invasive species should be monitored before, during, and after the mining process. If they represent a serious potential threat to successful restoration, they should be eradicated.

The most valuable post-mining sites should be declared as nature reserves. In addition, some spontaneously overgrown post-mining sites can be used for surface-disturbing human activities, (e.g., motocross, paint-ball, etc.). The irregularly disturbed surface usually supports biodiversity. [4]

CONCLUSIONS

In many cases, post-mining sites can be beneficial for biodiversity, but this value may be optimally recognized through spontaneous succession. An extremely important characteristic of spontaneous-succession mining sites is that many endangered species often survive in such sites. High natural value exists in the nutrient-poor habitats offered by spontaneous-succession mining sites, often in contrast with the surrounding eutrophicated landscapes. Thus, mining sites can provide refuge, especially for competitively poor species.

Restoration using spontaneous processes is not always the best approach to reclaim post-mining sites. For example, in arid regions or on toxic substrates, or when the land has specific uses that require it, technical reclamation is justified.[12] However, spontaneous succession should be included more frequently in restoration schemes and legislation so as to be considered at least equal to technical reclamation from the perspective of environmental protection and remediation.

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DICE—A Step Change Opportunity for Coal?

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The power plants serving tomorrow's electricity grid must overcome challenges that include higher penetration of renewables, and thus a need for increased flexibility, lower emissions, and water constraints. Even as these challenges are met, electricity will need to remain affordable. While DICE (direct injection carbon engine) is unlikely to displace ultra-supercritical baseload generation, the technology presents a very real chance to use coal to follow dramatic load changes in markets with high renewables penetration and to add smaller electricity generation in remote areas without reliable grid access.

THE DICE OPPORTUNITY

DICE combines the superior thermal efficiency, flexibility, and lower capital cost of the diesel engine with the low cost and availability of coal.[1] The technology dates back to the development of the diesel engine by Rudolf Diesel in 1892, which was originally intended to use pulverized brown coal as fuel, but then the inventor turned to peanut oil after difficulties with the injection equipment. The modern variant of DICE uses finely ground low-ash carbons (e.g., coal, lignite, and biomass) slurried with water—a fuel called micronized refined carbon (MRC). MRC is a liquid fuel (similar in consistency to acrylic paint), which can be used in diesel engines that have been adapted with a slurry fuel injection system and hardened cylinder components. The DICE fuel cycle is depicted in Figure 1.

"DICE combines the superior thermal efficiency, flexibility, and lower capital cost of the diesel engine with the low cost and availability of coal."

DICE is based on using adapted diesel engines, which are a mature power generation technology. Such engines play a minor role in baseload power production in today's market due to the high cost of diesel fuel, higher maintenance costs, and, in the past, the relatively small unit size. Currently, the largest diesel engine in commercial production is 76 MW—a size used principally for large ships. If larger capacity engines were required, the manufacturer MAN B&W have a K108 engine design, which in its 18-cylinder form would generate around 120 MW. MAN B&W believes that engines up to 150 MW are technically feasible using current engine and manufacturing technologies.[2] In addition, there are a range of options to optimize large marine engines for land-based power generation to reduce both capital and operating costs.

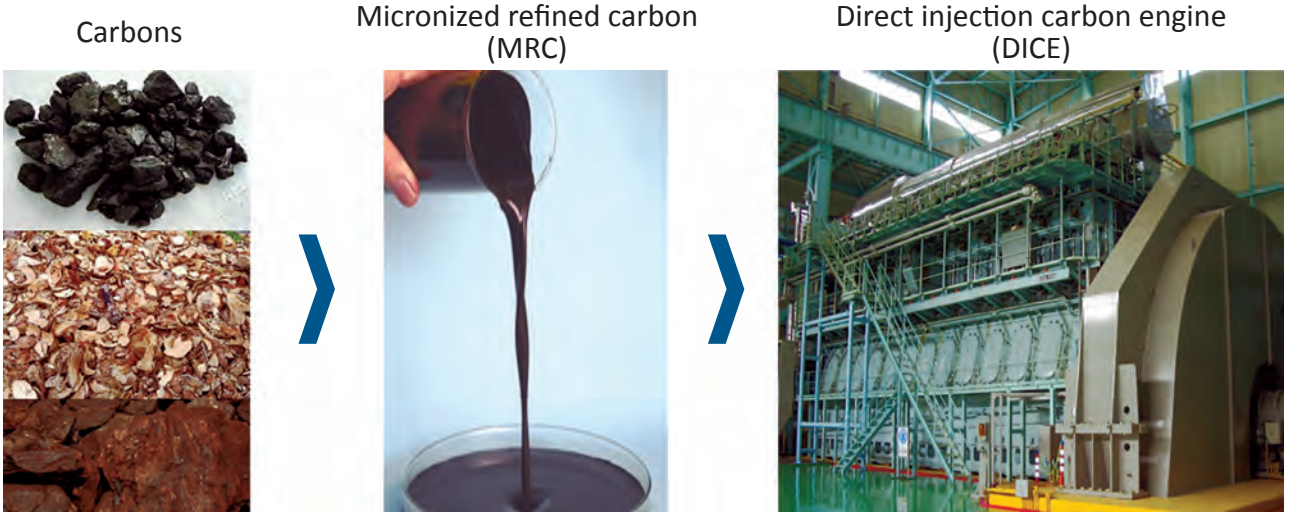

FIGURE 1. DICE fuel cycle

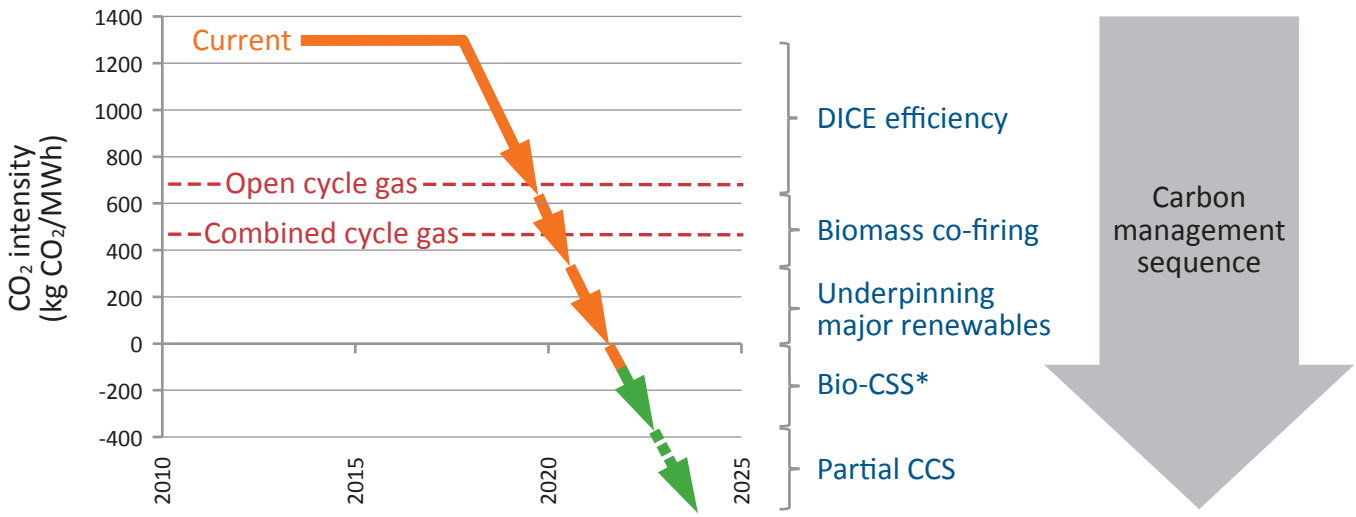

FIGURE 2. Victorian pathway to net negative CO_2 emissions using DICE

*Landscape & soil carbon sequestration credits

However, in contrast to conventional coal-fired power plants, which gain economy of scale via increased unit capacity, diesel (and gas) reciprocating engines obtain economy via modularity and multiple units (e.g., a 1000-MW reciprocating gas-engine power plant has been constructed near Salvador using 120 medium-size gas engines). It is anticipated that the same modular approach could apply for DICE.

Regarding fuel for DICE power plants, MRC fuel could become a new global commodity for low-emissions power, given that MRC is nonflammable, environmentally benign, and can be safely transported and stored. This option is being actively considered in Victoria, Australia, with the potential to efficiently convert vast reserves of brown coal to export MRC, at around one third of the cost of LNG. In Australia, MRC fuel also costs less than fuel oil and most gas, and could reduce power generation costs for remote or decentralized generators. This would also enable lower cost electricity for off-grid communities (especially in developing countries) and assist sustainable mining development by providing cost-effective power for mines and communities.

Like other reciprocating engines (gas or diesel), DICE power plants could be modular and can be ramped relatively quickly, and can thus be used for load following and even baseload generation in some circumstances.

Development of DICE faltered historically largely because the intended purpose was to use coal as a substitute for oil in shortages that did not materialize. However, today, DICE is being pursued not to replace oil, but as a unique high-efficiency, low-emissions (HELE) coal technology that can support a grid with increased renewables and water constraints, and with decreased emissions.

DICE as a HELE Coal Technology

DICE could play a role in the transition to a lower emissions energy sector as it is a cost-competitive, lower emissions technology in its own right. See Figure 2 for an example based on Victoria, Australia, showing the cumulative effects of an integrated carbon management scheme.

DICE provides a higher efficiency coal-based generation technology, with a step reduction in CO_2 emissions of 20–35% for black coals and 30–50% for brown coals (ranges based on new DICE and new ultra-supercritical pulverized coal–new DICE and an old subcritical coal-fired power plant in Australia). Greater emissions reductions can be achieved if MRC composed of a coal/biomass blend is used, where the biomass is likely to be in the form of a char. However, coal must make up some of the MRC for DICE as it improves the combustion characteristics.

Further reductions in CO_2 emissions could be achieved by providing backup and load-following power to enable the cost-effective and increased use of intermittent renewables without the loss in efficiency incurred from load following by conventional thermal power plants. DICE also could assist in the uptake of carbon capture and storage (CCS), delivering a 30–40% cost advantage (in terms of \$/t CO_2 abated)[A] compared to CCS on conventional coal-fired power generation through increased efficiency and the ability for waste engine heat to provide at least 65% of the CO_2 stripper heat requirement.

Flexibility: An Increasing Challenge

Increased flexibility is a challenge for grids—one that is growing in magnitude with the ever-higher penetration of

intermittent renewable generation in response to policy initiatives. Continued growth of renewables over the long term will further exacerbate the need to provide more flexible and distributed generation capacity.

Natural gas combined-cycle and conventional coal-fired power plants can follow load demand, although their efficiency decreases at lower loads and maintenance requirements increase due to thermal swings. In addition, due to their large unit size, which helps to optimize efficiency, most conventional coal-fired power plants have low ramp rates on the order of about 1%/min, although some plants in Europe have reported ramp rates of about 4%/min. In comparison, DICE provides superior flexibility with ramp rates of 10%/min.

The flexibility of DICE is not limited to load following. The technology provides an option for customers seeking new power generation capacity at various sizes. DICE is modular (in 10–100-MW increments). In addition, for cash-strapped customers that need immediate capacity, DICE requires half the capital investment (US$1.1 million/MW for four-stroke DICE and US$1.6–2 million/MW for low-speed two-stroke marine engines; 2015 estimate) of conventional coal-fired power plants.

DICE could also provide users of natural gas with the option of installing multi-fuel gas engines and retrofitting with a DICE conversion kit in the future if natural gas prices become uneconomic. This approach could prevent stranded assets. Such a conversion is not possible for gas turbines, regardless of mineral content of the MRC fuel, due to intolerance to alkalis.

The Water–CO_2 Nexus

Cooling water (for noncoastal installations) has become a serious issue for Rankine cycle thermal plants in many parts of the world. Taking coal-fired power plants as example, at the lowest cost and highest efficiency such plants use ~2000 L of water for condenser cooling for every MWh generated. This level of water consumption is becoming intolerable in some locations (e.g., Australia, India, South Africa, and China), requiring the use of dry cooling. Although this reduces water consumption to around 300 L/MWh, dry cooling increases plant costs, delivered electricity cost, and CO_2 intensity—the last by up to 5%. Thus, dry cooling can result in an additional 1000 kg CO_2 being emitted for each 30 tonnes of water saved.

DICE is well suited to provide backup for intermittent renewables.

"The flexibility of DICE is not limited to load following. The technology provides an option for customers seeking new power generation capacity at various sizes."

DICE is much easier to dry cool because the temperature at which heat is rejected is much higher. This enables much lower cost dry-cooling (radiator) systems and completely avoids the need for cooling water. Water is needed for MRC fuel production, but this is at a rate similar to that for a dry-cooled conventional coal-fired power plant. Notably, fuel preparation for DICE can be located remotely from the power plant (i.e., fuel preparation can be co-located with reliable and abundant sources of water).

NATURAL GAS VERSUS DICE

Although natural gas-based generation can be considered an easy option for reducing CO_2 intensity, to compete with coal for baseload electricity natural gas must be a sufficiently low price (without excessive volatility), and have security of supply. The "dash for gas" in Europe has abated due to gas price increases, with recent mothballing of gas generation capacity (both combined and open cycle) in some countries. As examples, GDF Suez has closed gas power plants with a combined capacity of over 7 GW; in the UK, the Keadby 750-MW power station (commissioned in 1996) was mothballed last year; and RWE is closing its Claus C plant in the Netherlands, just two years after it was commissioned.

Based on the availability of unconventional natural gas, the U.S. has expanded natural gas-based generation, although price volatility remains an issue (particularly in winter). As an extreme example, the price in New England in January and February 2014 rose to $17/GJ, whereas the average gas

price for the U.S. for the same period was US$7.4/GJ, and the average coal price was US$2.3/GJ (data from U.S. EIA Electric Power Monthly).

Overall, considering fuel options that can respond to demand should provide new opportunities for coal—providing the technology is highly efficient, highly flexible, and CCS ready. DICE potentially has all of these attributes, and is well suited to balance the additions of intermittent renewables to the grid, but does not suffer from the high prices and/or price volatility often associated with natural gas.

"Although DICE needs considerable development and demonstration, it has an enormous advantage via the ability to carry out a near-commercial-scale demonstration at a relatively small size…"

DEVELOPMENT REQUIREMENTS

Despite the many potential advantages, the use of coal in DICE has required addressing a number of technological issues (especially injector nozzle and piston ring wear), which were essentially solved for smaller engines (i.e., <5 MW) in a comprehensive U.S. Department of Energy (DOE) program (1978–1992).[3–5] Since the DOE program ended, a number of significant technology developments have occurred in both coal processing and engine design and materials. These, combined with the use of larger, lower speed engines (and many new drivers), are expected to significantly increase both the technical and the economic viability of DICE.[6]

In past programs, the cost of coal processing reduced the cost advantage of DICE, and, together with falling oil prices, was a key factor in the termination of the DOE program. Fuel production now has the advantage of large and efficient mills for micronization (e.g., IsaMill™) and improvements in fine-coal cleaning.[7] These technological advances provide a step reduction in processing cost and also allow cost-effective recovery of MRC from tailings. Thus, in Australia, MRC is now estimated to cost AUD$2–3/GJ (US$1.4–2.2/GJ) for Victorian brown coal and AUD$4–6/GJ (US$2.9–4.3/GJ) based on bituminous coal. Economic assessments have shown that the increased cost of coal processing is more than offset by increased grade

Standard diesel generators are limited by fuel prices and infrastructure—challenges that DICE can overcome.

recovery, lower capital cost, and reduced fuel rate of DICE (together with a range of environmental benefits).[8]

The largest challenge facing the development of DICE may be a non-technical one. There is no clear owner or champion for the technology, but many interested parties, including the coal industry, technology providers, engine producers, and power producers. Although DICE needs considerable development and demonstration, it has an enormous advantage via the ability to carry out a near-commercial-scale demonstration at a relatively small size (around 10 MW), both quickly and at relatively low cost. This should enable DICE to leapfrog the usual technology development steps, resulting in a time to first commercial deployment of five years, and as low as US$70 million, including fuel processing and logistics. An international umbrella organization, DICEnet (www.dice-net.org), has been established to help coordinate efforts, and a staged, integrated DICE development program has been devised for both black and brown coals with a goal of a large-scale demonstration after 2020.

Currently, a number of groups are investigating the DICE fuel cycle in Australia, Europe, China, Japan, the U.S., and South Africa. MAN Diesel and Turbo have engaged with a number of MRC proponents, and are considered the industry leaders in DICE development. MAN has established a staged development program with a specially adapted low-speed 1-MW single-cylinder test engine at Mitsui in Japan. Development efforts will also benefit from recent experience from firing engines with bitumen slurries and residual fuel oils (e.g., Orimulsion and MSAR®).[9–11]

CONCLUSIONS

Combining the superior thermal efficiency, flexibility, and lower capital cost of the diesel engine with the low cost and availability

of coal provides an innovative step change technology that could markedly increase the competitiveness and reduce the environmental footprint of coal-based power generation. Australian R&D over the last five years has focused on "derisking" the fuel cycle, and confirmed the potential of this alternative technology for coal and other carbons. Internationally there are many opportunities for DICE, including:

- Incremental replacement of less efficient coal generation plants—175 GW of smaller/older capacity identified (e.g., below 300 MW and older than 40 years)
- Smaller incremental capacity for developing nations
- A cost-effective/CO_2-equivalent technology for replacing open-cycle natural gas turbines used for load following and backup duty
- New capacity for ancillary services to underpin growth in renewables
- A replacement technology for high-cost diesel generation in remote mining sites and communities, especially in developing countries
- Replacement capacity for uneconomic gas generation

Recent technology assessments have shown no major technical barriers in developing DICE to a commercial scale. Some further development work is required to optimize for a range of coal types and engine technologies, but the development-to-deployment time scale could be as short as five years based on an assessment by MAN Diesel & Turbo.[B] The costs to commercialization (from R&D to demonstration and first commercial plant) would be comparatively low (i.e., estimate of US$70 million).

"Recent technology assessments have shown no major technical barriers in developing DICE to a commercial scale."

Development and deployment of DICE provide an opportunity for the coal industry, the electricity generation sector, and governments to support a breakthrough technology—for the combined benefit of coal and renewables-based electricity systems.

NOTES

A. Based on personal communications with, among others, Barry Hooper of CO2CRC in May 2013, regarding CO2CRC's calculations on the use of the UNO MK3 capture system for DICE.
B. This information is taken from a series of conversations with Larry Silva, Managing Director, MAN Diesel & Turbo Australia—especially those based on an internal report (#LDF1-20120014), "A first plan for the development of a stationary low-speed two-stroke engine to be operated on coal water slurries," issued by MAN Diesel & Turbo on 29 June 2012.

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Construction and Operation of the Shenhua Anqing High-Efficiency, Low-Emissions Power Plant

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Primary energy reserves in China are largely based on coal, with small contributions from oil and gas. In fact, coal accounts for over 90% of China's total fossil energy reserves, meaning that China will continue to rely heavily on coal over the long term. However, China is working to reduce the environmental footprint of coal utilization, including emissions of particulate matter (PM), sulfur dioxide (SO_2), nitrogen oxides (NO_x), and CO_2. Thus, a major focus in the country is to increase the use of high-efficiency, low-emissions (HELE) coal technologies and meet the dual objectives of providing power and realizing environmental and social responsibility.

Shenhua Shenwan Energy Company's Anqing Power Plant Phase II's 2×1000-MW expansion project is a prominent example of HELE coal-fired power in China. In this project, Shenwan adopted a series of design innovations to optimize environmental performance based on the specific features of China's coal-fired power sector as well as Shenhua Group's development strategy to be a world-class supplier of clean energy. Using the latest technological achievements, Shenwan constructed a high-capacity, efficient, and low-emissions coal-fired power plant, which is currently considered to be the state of the art in China. For example, the plant boasts the highest steam parameters in China (see Table 1), resulting in the efficient utilization of coal with extremely low emissions.

The state-of-the-art Shenwan Anqing Power Plant

PROJECT BACKGROUND

The Anqing Power Plant is located in the middle and lower reaches of the Yangtze River. With recent continuous growth of the regional economy, insufficient power supply has emerged as a bottleneck restricting economic and social development. The construction and commissioning of the Anqing Power Plant's Phase II 2×1000-MW units have fundamentally alleviated the power shortage in the Anqing region and have increased the stability of the local grid. This has supported increased growth in industrial and agricultural production and an expanding service sector in the region and the larger province.

"This power plant can serve as a model for China and the international community about what can be achieved regarding construction costs, economic indicators, and emissions reductions when the best HELE technologies are implemented."

The scope of the construction of the Anqing Phase II project included two identical ultra-supercritical coal-fired power units, including limestone-gypsum wet desulfurization (FGD) and selective catalytic reduction (SCR) denitrification facilities that were built simultaneously.

Construction commenced on 1 March 2013, and the two units were commissioned with the compulsory 168 hours of full-load testing on 31 May and 19 June 2015. Thus, the effective construction period was just over 22 months. The project investment was 6.096 billion yuan (US$950 million) or 3048 yuan/kW (US$478/kW).

The main operating indicators as measured during the full-load test prior to commercial operation are as follows: unit #3

TABLE 1. Anqing Power Plant Phase II operational values

Name	Unit	Operational value
Boiler		
Superheated steam flow	t/h	2910.12
Superheater outlet steam pressure	MPa (gauge)	29.15
Superheater outlet steam temperature	˚C	605
Turbine		
Rated main steam pressure	MPa (absolute)	28
Rated main steam temperature	˚C	600
Rated reheat steam inlet temperature	˚C	620
Generator		
Rated capacity	MVA	1112
Maximum continuous output capacity	MVA	1222

consumed 272.5 g/kWh of coal with a parasitic energy consumption rate of 4.01%; unit #4 consumed 273.9 g/kWh of coal with a parasitic energy consumption rate of 4.06%. Thus, both units operated more efficiently than an average 1000-MW unit in China in 2014, which consumed 287.65 g/kWh of coal with an average parasitic energy consumption of 4.08%.[1]

The emissions were also measured during the full-load test and were lower than the national emission standards for natural gas-fired power plants. Since passing the 168-hour test, the units and their emissions control systems have continued to operate at the same high standards. In addition to low emissions, 100% of the fly ash, slag, and desulfurization by-products are utilized during normal operation and no wastewater is discharged.

CONSTRUCTION OPTIMIZATION

Through research and collaboration between engineers, technicians, and design institutes, the optimization of cost and key operating parameters was carried out concurrently. This helped to save more than 40 million yuan (US$6.3 million) in project investment.

By optimizing purchasing, maximizing competitiveness, and lowering the procurement cost, the best possible price performance ratio was obtained. For the desulfurization system's absorber alone, the cost was reduced by 12 million yuan (US$1.9 million) compared to the original project budget.

Construction Cost Controls

With effective control of construction costs, the project investment of 6.096 billion yuan (US$950 million) was 547 million yuan (US$85.7 million) lower than the approved project budget of 6.643 billion yuan (US$1.04 billion), and the construction costs were reduced by 8.2%. The unit investment of 3048 yuan/kW (US$477.5/kW) was 152 yuan/kW (US$23.8/kW) lower than the budgeted amount. Cost-saving measures meant that the total project investment was less than that for comparable units in China.

HIGH-EFFICIENCY TECHNOLOGIES

Efficiency was maximized at the Anqing Phase II units mainly by increasing the initial steam parameters and adopting new technologies. Eighty-five new technologies were adopted at the plant, raising the power plant efficiency significantly and reducing coal consumption and emissions.

Perhaps the most important factor related to efficiency was the installation of the ultra-supercritical (USC) steam turbines, which decreases the amount of coal needed per unit of power produced compared to plants that operate at supercritical or subcritical steam conditions. The USC Anqing units are able to operate at steam cycle pressure and temperatures of 28 MPa/600˚C/620˚C—the first time such high parameters were used in China on a plant of this size. Currently, the rated pressure upstream of the main valve of the top three 1000-MW ultra-supercritical steam turbine plants is 25 or 26.25 MPa. Among them, the Waigaoqiao No. 3 plant has the highest pressure, 27 MPa, at the main valve, with main steam and reheat steam temperatures of 600˚C (see Figure 1). After considering all technology options, a main steam pressure of 28

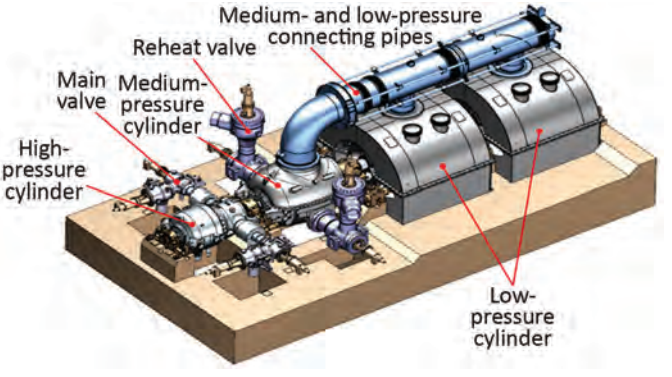

FIGURE 1. Steam turbine of the Anqing Phase II 1000-MW ultra-supercritical units

MPa and a reheat steam temperature of 620˚C were selected. Compared to the steam parameters used by conventional 1000-MW units, the Anqing steam turbines' heat consumption is 53 kJ/kWh lower and the standard coal consumption for power generation was reduced by 1.94 g/kWh. The annual savings, based on standard coal costs, are about 19.8 million yuan (US$3.10 million).

Many other technological approaches were also taken to improve the efficiency. For example, grade-9 regenerative extraction (i.e., extracting steam from nine different locations in the turbine to optimize boiler feedwater heating) was adopted. As compared to the typical grade-8 regenerative extraction, heat consumption was reduced by 10 kJ/kWh and standard coal consumption for power generation was reduced by 0.34 g/kWh.

A high-yield water cooling tower designed to save energy compared to a conventional cooling tower (see Figure 2) was used for the first time at a 1000-MW unit in China, reducing the circulating pump lift by 10–11.5 m and reducing noise by 8–10 dB. About 3790 kW/hr of parasitic energy was saved, reducing the plant's power consumption by 0.38%, and the standard coal consumption for power generation was reduced by about 1 g/kWh.

Another approach to saving energy was capturing the waste heat in the flue gas and using it to preheat the boiler feedwater. Operating at the designed full load, the flue gas heat exchanger recovers 44,000 kW of heat, which reduced heat consumption by 45 kJ/kWh, and reduced the plants' standard coal consumption by 1.65 g/kWh.

Minimizing the backpressure on the steam turbines is another approach to increasing the efficiency of the power plant. Thus, at the Anqing units the backpressure for the units was optimized to improve overall efficiency, with an operating design value of 4.89 kPa. Based on this rated backpressure, heat consumption was reduced by 30 kJ/kWh and the standard coal consumption for power generation was reduced by about 0.75 g/kW for every 1 kPa of reduction in the turbine backpressure. In comparison to a standard unit backpressure of 5.1 kPa, heat consumption was reduced by 6.3 kJ/kW and the standard coal consumption for power generation is reduced by about 0.21 g/kWh.

Through the 11 energy-saving projects that have been implemented, the total heat consumption reduction was 152.1 kJ/kWh in total, and the standard coal consumption for power generation was reduced by a total of 5.51 g/kWh. Assuming an annual operating time of 5500 h, 30,305 tonnes of standard coal can be saved by each of the Anqing units per year.

Comparing the Anqing units with China's national average for similarly sized plants, their coal consumption is 15.15 g/kWh lower, saving 83,325 tonnes of standard coal per unit every year—a combined savings of 166,650 tonnes of standard coal each year. This means that CO_2 emissions can be reduced by about 416,700 tonnes per year, which is a 5% decrease compared to the average 1000-MW plant in China. Compared to the national average of new coal-fired power plants (i.e., 318 g/kWh in 2014) these two units represent a nearly 15% decrease in CO_2 emissions.

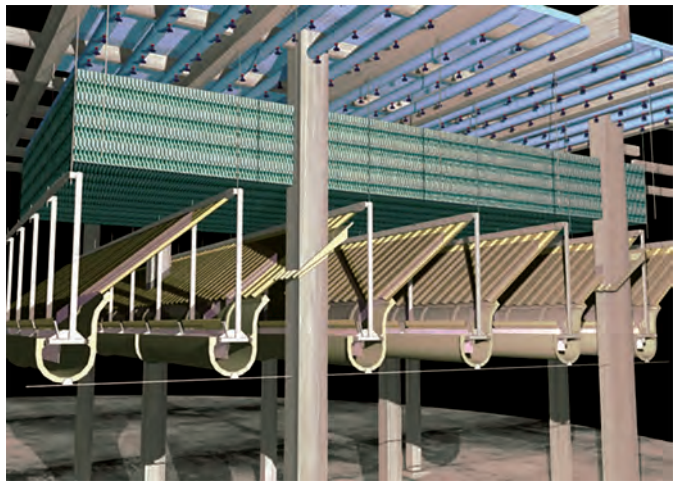

FIGURE 2. Internal structure of high-level wet cooling tower

ULTRA-LOW EMISSIONS TECHNOLOGIES

The Anqing Phase II project incorporated highly advanced flue gas treatment technologies, based on an ultra-low emission technology roadmap. The roadmap includes an electrostatic precipitator (ESP) with a low-temperature economizer, spin exchange coupling FGD, and a rotary tube bundle PM demister. Several of these flue gas treatment devices offer cobenefits that further reduce net emissions.

There are three separate processes in the power plant that remove PM from the flue gas. The high-frequency ESP with three chambers and five electric fields forms the first segment of particulate emissions control. The removal efficiency of PM in the ESP is up to 99.86–99.9% with a concentration around 25 mg/Nm^3. The secondary PM removal segment is the efficient spin exchange coupling FGD that removes 60% of the remaining PM. The third approach to PM removal is the low-temperature economizer + rotary tube bundle PM demister, which has a PM removal efficiency of more than 70%. Compared to other PM capture options, the investment and operating costs for the advanced tube bundle PM removal technology were lower, it takes up less space, and it fits well into the general layout of new construction and retrofit projects. In total, the final target of an outlet concentration of PM less than 3 mg/Nm^3 can be achieved—exceeding the requirement for a natural gas power plant in China.

TABLE 2. Measured emissions and emission limits

Emission (mg/Nm³)	*Emission limits for coal-fired units in key areas (6% O_2)*	*Gas power unit emission standards (15% O_2)*	*Actual emissions measured from Anqing unit #3 (6% O_2)*	*Actual emissions measured from Anqing unit #4 (6% O_2)*
PM	20	5	2.6	2.3
SO_2	50	35	6.5	5.2
NO_x	100	50	21.5	19.7

The efficient spin exchange coupling wet FGD removes SO_2 with an efficiency of 97.8–99.7% (see Figure 3). In the spin exchange coupling efficient-FGD technology, a device termed a "turbulator" has been added between the entering flue gas and first level of the FGD tower, which changes the flow state of the incoming gas from laminar to turbulent and reduces the gas film resistance, so as to increase the liquid-gas contact area, increase the gas-liquid mass transfer rate, and thus increase FGD and PM removal efficiency. This system also requires less power consumption than other FGD systems. In the compulsory 168-hour unit test run, the FGD efficiency reached 99.7%.

For removing NO_x, low-NO_x combustion and SCR using urea as a reducing agent results in a minimum denitrification efficiency of 95%.

Together, this low-emissions technology chain drastically reduces emissions of PM, SO_2, NO_x, heavy metals, etc. Not only are the emissions less than the national standards where the Anqing plant is sited,[2] they are also lower than the emission limits for newly built coal-fired power units in the central regions. In addition, the new units at Anqing actually surpass the limits for gas-fired units as prescribed in the "Action Plan for Coal Energy Saving, Emission Reduction, Upgrading and Alteration (2014–2020)" from the National Development and Reform Commission, Ministry of Environmental Protection and National Energy Administration (see Table 2 for emissions results from the 168-hour test run).[3]

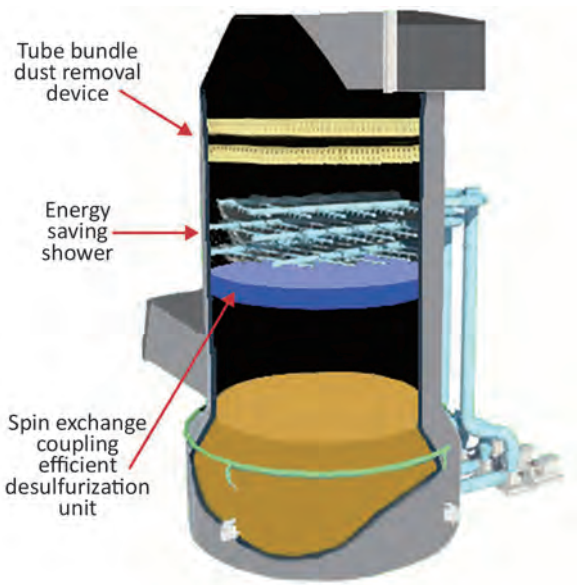

FIGURE 3. FGD system based on spin exchange coupling and energy-saving spray

OUTLOOK

Anqing Phase II's 2×1000-MW ultra-supercritical expansion project is Shenhua Shenwan Energy Company's first project to integrate state-of-the-art HELE technologies. The resulting operations have met the expected efficiency and emissions goals. This power plant can serve as a model for China and the international community about what can be achieved regarding construction costs, economic indicators, and emissions reductions when the best HELE technologies are implemented. Through additional optimization of operations, key indicators are expected to further improve. This project is a significant demonstration of the clean and efficient utilization of coal, and the associated reduction in the environmental impact, which is a story worth telling.

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Cryogenic Carbon Capture™ as a Holistic Approach to a Low-Emissions Energy System

By Larry Baxter
Cofounder, Sustainable Energy Solutions (SES)
Professor, Chemical Engineering, Brigham Young University

Reducing global carbon emissions requires a a diverse portfolio of low-emissions technologies, including renewable energy and carbon capture and storage (i.e., CCS and CCUS).[1,2] Without using the full portfolio of low-emission options, the costs for reducing global emissions will be higher and the probability of successful climate change mitigation decreases. Each technology, however, faces its own set of challenges. For example, although the deployment of renewables has accelerated in recent years, the issue of intermittency remains a major challenge. Similarly, CCS is lagging behind the projected amount of demonstration projects needed. Sustainable Energy Solutions (SES) has developed a low-cost, integrated energy storage and CO_2 capture technology, called Cryogenic Carbon Capture™ (CCC), that can help address the major challenges faced by renewables and CCS.

THE CCC TECHNOLOGY

The foundation of the CCC process relies on refrigeration to cryogenic temperatures, rather than a chemical reaction, to separate CO_2 from flue gas from a power plant or industrial source. Typically, refrigeration cycles consume large amounts of energy, but this is only true if the final products are at lower temperature than the incoming streams, e.g., air conditioning. While the CCC process relies on refrigeration process principles, the products are at nominally the same temperature as the incoming flue gas, and thus the energy efficiency is much higher than for typical refrigeration processes. For comparison, the energy efficiency of an air conditioner could be similarly high if it delivered air at the same temperature as the outdoor air, which, of course, defeats the purpose for that application. However, since the purpose of the CCC process is to separate CO_2 from the other constituents in flue gas, with cooling as only an intermediate step, recuperative heat exchange drives most of the temperature change.

"Without using the full portfolio of low-emission technologies, the costs for reducing global emissions will be higher and the probability of successful climate change mitigation decreases."

There are two possible implementations of the CCC process. Figure 1 illustrates the major process steps of the external cooling loop (CCC-ECL™) version, which is the implementation that enables large-scale energy storage. Alternatively, the

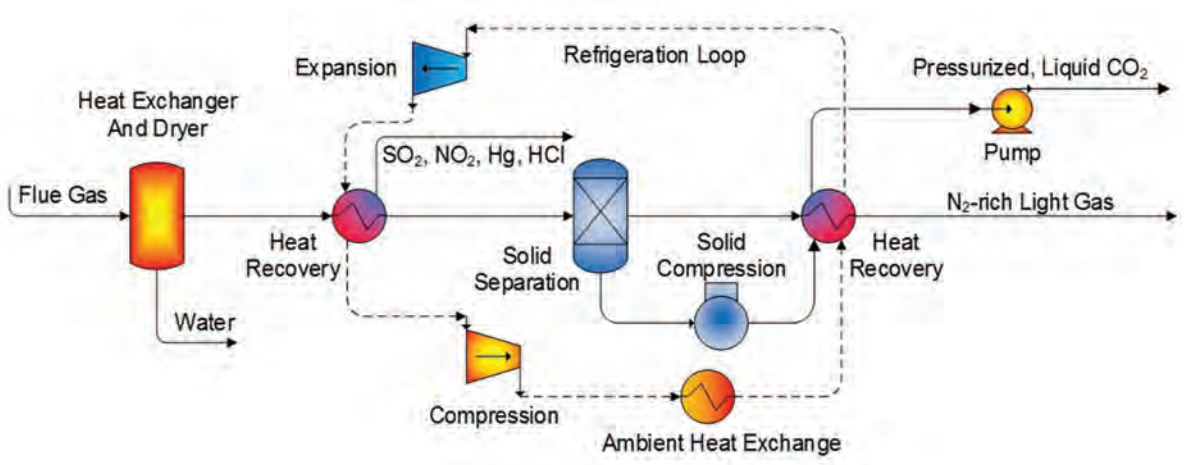

FIGURE 1. Simplified flow diagram of the CCC-ECL™ process

compressed flue gas (CCC-CFG™) version of the process differs from the ECL version in that it does not include an external refrigeration loop but rather uses the flue gas as its own refrigerant. This article focuses on the ECL process to highlight the opportunity to meet the dual challenge of CCS deployment and energy storage; more information on the CFG process is provided elsewhere.[3–5]

CO_2 Capture

The flue gas enters the capture system and cools in a series of heat exchangers until it reaches a temperature at which the CO_2 freezes to form a nearly pure solid that separates easily from the remaining gases. The process pressurizes the solid CO_2 to force out all the gases from between the solid particles. Two separate streams exist at this point in the process: the pressurized solid CO_2 stream and the CO_2-lean flue gas stream at ambient pressure. Both streams warm to ambient temperature by cooling the incoming gases in recuperative heat exchangers. These recuperative heat exchangers are important because they accomplish most of the sensible cooling in the process. As the solid CO_2 warms, it melts to form a liquid. The process delivers a liquid stream of nearly pure CO_2 at 150 bar and a gas stream at atmospheric pressure, with both streams near ambient temperature. This process can capture more than 99% of CO_2 from a large-point source emitter. One substantial advantage of this approach is the ease with which emission sources can be retrofit. Although the process uses electricity, it does not require the extraction of steam or any upstream modifications.

Simultaneous Emissions Control

As the flue gas cools in a series of heat exchangers (for simplicity, only one is shown in Figure 1), most gases other than N_2 and O_2 condense at component-specific temperatures. Thus, as part of the CO_2 capture process, the CCC process also captures SO_x, NO_x, Hg, HCl, particulate, VOCs, etc. In fact, the CCC process removes all gas constituents less volatile than carbon monoxide (CO), which includes nearly all other currently and foreseeably regulated emissions.

Energy Storage

The CCC-ECL™ process stores energy in the form of cold, condensed refrigerant. If there is excess power from renewables on the grid, the extra electricity generates and stores excess refrigerant. The CO_2 capture process recovers this energy in periods of high power demand by increasing the net power plant input, using the stored refrigerant, rather than compressor power, to drive the carbon capture and reduce parasitic losses. Refrigerant generation represents over 80% of the energy required in the CCC-ECL™ process (see Table 1). The same approach allows dispatchable power plants to follow dynamic load without changing steam generation rates or temperatures.

TABLE 1. Summary of energy demands in the CCC-ECL™ process

Energy source	*Percent of total*
Flue gas blower	11.6
Refrigerant compression	83.0
Separations compression	2.1
Condensed-phase pumping	3.3
Total	100

SES has completed detailed transient analyses of the energy storage and recovery processes.[7] For example, an 800-MW_e power plant can stabilize up to a ±400-MW_e swing in power demand on a typical U.S. grid with intermittent wind and dispatchable gas and coal power. The estimated economic benefit of the energy storage exceeds $20/MWh, because the system can utilize energy which would otherwise be curtailed or is generated using low-cost baseload resources during off-peak times.[1] The process also largely decreases the need for spinning reserve and other high-cost backup systems. The value of the energy storage nearly equals the carbon capture cost in many markets.

PROJECTED PERFORMANCE AND ECONOMIC COMPARISONS

Economic analysis completed by SES, based on application of the technology in the U.S., indicates that, even without considering the economic advantages of energy storage, the CCC process is more efficient and cost effective than leading alternative approaches to CO_2 capture.

SES has completed quantitative estimates for the energy consumed by its CCC processes and compared them to that of a post-combustion liquid amine CO_2 capture system. The results based on the CFG and ECL systems appear in two forms: a bolt-on version and implementation with some integration. The bolt-on versions consume about 0.71 GJ_e/tonne of CO_2 captured. An integrated system (1) uses a portion of the heat collected in the first condensing heat exchanger to preheat boiler feedwater and (2) reduces the energy demand associated with the control of other emissions (e.g., SO_x, NO_x, etc.) by capturing them as part of the CCC process. These integration steps reduce the effective energy demand to a little less than 0.6 GJ_e/

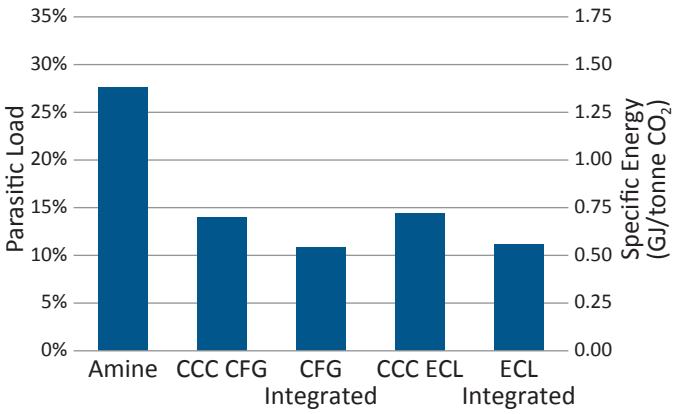

FIGURE 2. Estimated parasitic load for amine[6] and CCC capture processes

tonne of CO_2. In both the bolt-on and integrated configurations, CCC is predicted to consume significantly less energy than post-combustion liquid amine-based CO_2 capture (see Figure 2).

The primary sources of energy savings compared to liquid amine systems come from two factors: (1) the CCC process does not require large thermal swings or recycling materials (e.g., water and amine in the liquid amine CO_2 capture process, distillation reflux in oxyfuel systems, etc.) and (2) the CCC process pressurizes the CO_2 in a condensed phase, rather than as a gas. Condensed-phase compression requires far less expensive equipment and far less energy than gas compression.

While the parasitic energy is a major component of costs, the economics of all CO_2 capture processes also depend strongly on financing and capital costs. To provide some means of comparison with other technology options, SES obtained vendor quotes for major equipment and otherwise made stride-for-stride identical assumptions and used the same software (to the greatest extent possible) as used in detailed cost estimates provided by the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) (see Figure 3).[6]

In all configurations, the CCC CO_2 capture cost estimates per unit of electricity fall well below those of leading alternatives. The CCC processes are predicted to increase electricity costs by about 2.5 ¢/kWh, possibly much less if the processes are fully integrated and/or the energy storage option is used.[4] The energy storage, as previously discussed, might provide up to 2 ¢/kWh of additional savings, which is close to the total CO_2 capture cost for the fully integrated systems.[8] For context, the average U.S. residential retail electricity price is about 13 ¢/kWh.

DEVELOPMENT STATUS AND CHALLENGES

SES has built and successfully tested the CCC-CFG™ and CCC-ECL™ versions of the process at lab, bench, and skid scales up to 7–8 tonnes of flue gas/day (1 tonne of CO_2 per day). The largest of these test systems occupies two shipping containers and is mobile. Field tests have included flue gas slipstreams from subbituminous coal, bituminous coal, biomass, natural gas, municipal waste, tires, and blends of these fuels. These field tests occurred at utility-scale power plants, industrial heat plants, cement kilns, and pilot-scale reactors. SES is

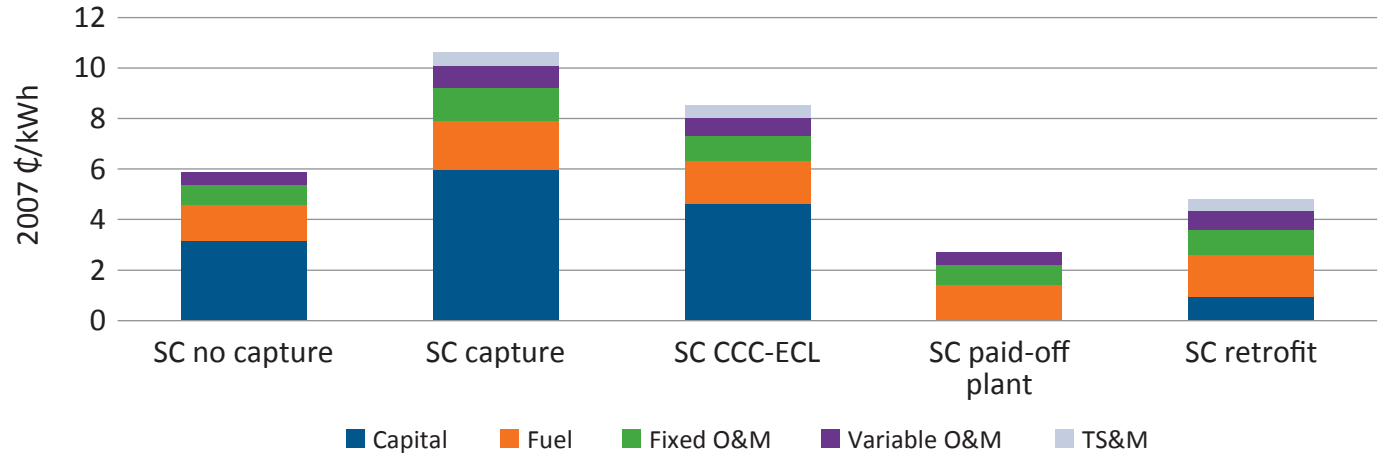

FIGURE 3. Incremental increases in the cost of electricity relative to a non-capture supercritical (SC) plant for an amine system[6] and for CCC with varying degrees of integration. The bars represent estimated cost of electricity for a new SC coal plant with no carbon capture, a new SC plant with 90% capture via aqueous amines, a new SC plant with 90% capture by CCC, the cost of power for an existing plant with paid-off capital (i.e., most existing plants in the U.S.), and cost of power from an existing SC plant retrofitted with CCC. The first two of these bars are based on results published by NETL[6] and the others are SES results using the same assumptions.

CCC-ECL™ process test skid

actively seeking technology partners capable of constructing the equipment for the next two phases of the project: a 5-MW_e equivalent (100 tonnes/day of CO_2) pilot plant and ultimately a 150–200-MW_e demonstration plant.

Several of the essential components of the CCC processes are in commercial use in the power and other industries. Examples include the condensing heat exchanger, many of the intermediate heat exchangers, slurry and cryogenic liquid pumps, dryers, and water treatment facilities. The primary equipment that is not currently available commercially, and thus the focus of current and future technology development efforts, includes cryogenic solid-fluid separations equipment and desublimating heat exchangers that continuously process solids-forming streams without fouling or plugging.

The remaining challenges in the scale-up of the CCC technology include assessing potential long-term issues with construction materials and engineering details related to solids handling at large scale. Water purification, multi-pollutant handling, and other process steps also still require demonstration, but should be manageable using currently available commercial technologies.

CONCLUSIONS

The CCC-ECL™ process affordably reduces emissions from fossil-fueled power plants while enabling more and better use of renewables on the grid. The CCC process offers major advantages over alternative capture technologies, including lower energy consumption, lower costs, optional energy storage, easier retrofit, lower water use, and optional criteria emission control. Based on its multiple advantages, the CCC process could become one of the most strategically important components of a low-carbon power industry.

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Catalyzing Coal Conversion Globally:
An Exclusive Interview With Li Yong-Wang of Synfuels China

By Holly Krutka
Executive Editor, Cornerstone

Dr. Li Yong-Wang, President of Synfuels China Technology Co., Ltd

Dr. Li Yong-Wang is the founder and president of Synfuels China Technology Co., Ltd., a Beijing-based company focusing on advanced conversion technologies for coal, natural gas, and other energy assets since 2006. Dr. Li has also built up a series of subsidiary companies around the world. Synfuels China's business is founded upon the expertise gained from research and development (R&D), three operational coal-to-liquid (CTL) plants, and the construction of the largest CTL plant in the world—producing 100,000 barrels of liquids per day (bpd), with an investment of about US$10 billion.

Considered one of the world's top scientists focused on Fisher–Tropsch (FT) technology, Dr. Li is also a leading professor at the Chinese Academy of Science (CAS) in the Institute of Coal Chemistry. As the director of the Chinese National Engineering Laboratory of Indirect Coal Liquefaction and the National Energy Research Center for Clean Fuels From Coal, Dr. Li leads a research team that carries out advanced research projects in industrial coal and gas conversion processes.

Dr. Li has published more than 400 scientific papers, obtained more than 50 authorized patents, and holds one software copyright. His FT-focused research has won several international awards, such as Germany's Alexander von Humboldt Award, several Chinese National Technology Invention and Scientific Innovation awards, and CAS's Outstanding Science and Technology Achievement Prize.

Cornerstone sat down with Dr. Li to discuss what he sees in the future of coal conversion and the most pressing technological developments needed to address today's energy challenges.

Q: ***What do you see as the advantages of Synfuels China's indirect liquefaction technology?***

A: Conventional FT slurry-phase processes operated in low-temperature mode, ~220–250°C, can produce 400 tons of C_{3+} hydrocarbon products per ton of iron-based catalyst consumed. Employing a medium-temperature mode, ~275°C, Synfuels China has pushed the productivity even higher, to 1200 tons of high-quality C_{3+} products per ton of proprietary iron-based catalyst used. Synfuels China's CTL technologies and process demonstrates the further following advantages:

- The slurry-bed FT reactor can scale to a single-stage design producing 12,000 bpd, while other technologies can require dual-stage systems.

- The FT reactor can operate with a uniform temperature distribution, efficient recovery of reaction heat, easy catalyst-wax separation under automatic control, and online catalyst replacement to ensure the stable operation of the plant.
- The iron-based catalyst has high activity, high selectivity for C_{5+} (greater than 92%), and low methane selectivity (less than 3% by weight).
- There is a lower solid catalyst charge due to the ultra-active catalyst used.
- The FT process produces high-quality synthetic crudes with low oxygenates and about one-third fewer acids.
- The proprietary FT and product refining technologies are easily retrofitted to CTL and gas-to-liquids (GTL) processes.

While other global companies may have a longer history of commercial technology deployment, Synfuels China has a rigorous R&D process that combines scientific knowledge with engineering expertise. By using the company's proprietary technology, a potential partner has access to the most recent scientific research underlying that technology to develop the most efficient plant based on the project goals.

Synfuels China uses an integrated approach to project design and implementation that focuses on improving efficiency based on fundamental scientific research, discipline, and knowledge. Since each plant and process is unique, we are able to offer engineering design and construction plans based on the need of the client, so there is no "one-size-fits-all" plant design and each project is customized according to the techno-economic objectives for the proposed plant. Every case is different and different potential sites require different strategies—Synfuels China dedicates significant time from conceptual design to implementation to ensure the success of each project.

Q: ***Can you give us some insight into what you feel are the most pressing technology development needs for coal conversion and how Synfuels China's research and development efforts are contributing to addressing these issues?***

A: Converting coal to valuable end-products is an important technology in many parts of the world where coal is abundant, and natural gas or oil reserves are low. There are many areas where technological development is needed. For the FT process, the catalysts and the reactors work, but they are not optimal and improvements are needed. For example, through our integrated and rigorous R&D process, Synfuels China has already improved the overall energy conversion of its iron-based catalyst to close to the technical maximum of 45% and developed an efficient method for separating the wax from the catalyst. The challenges facing current conversion processes also include economic and environmental issues, such as wastewater management.

Synfuels China customizes each plant from the conceptual design to full-scale implementation.

Synfuels China is working to address these challenges through improving the overall energy efficiency of their technology, which leads to lower costs and lower air and water emissions. Our most recent R&D effort focused on the proprietary step-wise liquefaction technology. This technology uses the newly developed direct hydro-treatment of coal, extracting part of the oil from low-rank and chemically active coals, and leaving the residue for syngas production. The syngas is then converted with our medium-temperature FT technology, leading to a significant improvement in energy conversion efficiency—for specific types of active coal, the overall energy efficiency of a plant is improved from 40–45% to 50–58%. The first project based on this new development is now in the planning stages and will combine the step-wise liquefaction technology with the company's proprietary refining technology to produce super-clean gasoline.

Q: ***Specifically looking at catalysts for FT processes, scientists and engineers are principally focused on cobalt- and iron-based catalysts. What are the advantages and disadvantages of these approaches and what do you believe should be the focus for future FT catalyst development?***

A: The catalyst is the fundamental key to the success of the FT process. BP, ConocoPhillips, Gulf, ExxonMobil, IFP, Johnson Matthey, Sasol, Shell, Statoil, and Syntroleum are among the companies that have developed a cobalt catalyst. At higher temperatures, cobalt catalysts produce excessive amounts of methane, so most development is focused on low-temperature FT synthesis applications. The catalyst must be designed with the choice of reactor predetermined. The reactor is also important as research has shown that cobalt catalysts are more active in fixed-beds, compared to slurry-bed reactors. However, slurry-bed reactors normally operate at a higher temperature (230°C) than fixed-bed reactors (210°C), so the productivity per gram of catalyst is actually higher in slurry-bed reactors.

Compared to the other metals suitable for FT reaction catalysts, iron is a cheap raw material and is, on average, 250 times less

expensive than cobalt. Economically, aside from the raw material cost, a catalyst with higher activity and stability will last longer and cost less. While iron is believed to be more tolerant to poisoning (e.g., sulfur), the disadvantage is the iron catalyst can deactivate quickly, which requires additional catalyst input.

While the advantages of iron catalysts are numerous, the mechanism behind FT synthesis and the complexity of the iron catalyst transformations during activation and FT reactions are not fully understood. Some of this uncertainty is controlled by utilizing chemical-grade raw iron with minimal impurities. Structural and chemical promoters are used to improve the selectivity, activity, and reduce sintering compared to unmodified and unpromoted iron catalysts.

FT processes that use iron catalysts have greater control over product selectivity, either via changes in the process conditions or catalyst composition. For example, selectivity shifts from lighter to heavier hydrocarbons as the temperature is lowered. The product stream using iron-based catalysts depends predominately on the FT temperature, where low-temperature (200–250°C) FT reactions typically produce hydrocarbons longer than C_{21} and high-temperature (275–350°C) reactions will produce mostly light hydrocarbons.

Given the difference in the temperature and pressure at which cobalt and iron catalysts optimally operate, comparing catalysts tested at different conditions is potentially misleading. One of the critical objectives for developing more efficient catalysts is improving the useful life, activity, and stability of the catalyst so that it may be reused indefinitely with minimal additional catalyst input. Other general requirements for improving catalysts are high selectivity for desirable products (e.g., low methane and high C_{5+}) and mechanical robustness (e.g., the optimal particle size and density). All of these characteristics are impacted by the reactor type, as well as the operating conditions and climate in which a plant is sited. A catalyst may react very differently in a lab environment versus, for example, a commercial-scale plant in Inner Mongolia.

A FT synthesis slurry bed reactor operating in China today.

The iron-based catalyst researched and developed by Synfuels China for our proprietary FT process is among the best. However, future R&D will also need to improve the catalysts used for upgrading and refining the FT synthetic crude product to marketable liquid fuels and chemicals. For example, super-clean gasoline is urgently needed in large cities in China, and supply can be insufficient or difficult to obtain from current oil refineries. Synfuels China has found that refining the synthetic crudes (i.e., syncrudes), from our proprietary FT process using an iron-based catalyst, into super-clean gasoline is more economical than refining the syncrudes into diesel. While this is mostly due to current market demand for clean transportation fuels and the global dominance of gasoline-fueled vehicles, one other reason for the higher economic efficiency of gasoline produced from coal-based syncrudes is that it is not technically efficient to refine cobalt-based FT syncrudes into gasoline due to their chemical composition. Since most indirect coal liquefaction technologies to this point have used cobalt-based catalysts at low temperatures in a reactor, the comparative advantage of Synfuels China's iron-based catalyst and medium-temperature FT process is that the resulting syncrudes can be efficiently converted to a wide range of products—including diesel, gasoline, LPG, jet fuel, naphtha, etc.—whereas syncrudes from a FT process using a cobalt-based catalyst can have a more limited refining potential. While the advantages and disadvantages of each approach are too numerous to list in this interview, the future of catalyst development will need to focus on improving the activity, selectivity, productivity, stability, and lifetime of catalysts.

Q: ***What are your thoughts around how to best address the environmental challenges associated with the CTL industry, such as wastewater treatment in the FT process, energy efficiency, thermal efficiency, solid waste treatment, etc.? What is the approach of Synfuels China in addressing environmental issues compared to other global CTL leaders?***

A: Synfuels China has focused its R&D efforts on improving the economics and minimizing the environmental impacts of its technologies and processes. This focus is motivated by a company culture that uses the most recent and advanced theories, tools, and other knowledge-based methods to address how technologies and processes can be improved and adapted in a rapidly changing market. While in the short run, many environment-driven changes to a technology or process can result in a large economic impact, Synfuels China takes an integrated approach that has demonstrated there can be immediate savings from increased technological efficiency.

Key areas of environmental R&D within the company include:

- Minimizing the environmental footprint of CTL plants, including integrated water management
- Advancing waste processing and disposal
- Using step-wise liquefaction scheme to increase efficiency, for suitable coals
- Producing sulfur-free, low-nitrogen, and low-olefin fuels
- Capturing and concentrating CO_2 to greater than 99.8% (commercial grade)
- Minimizing input use, including feedstock and water, and recycling
- Using non-traditional feedstock like "waste" coal and other relatively low-cost inputs

Q: ***Specifically, what are your recommendations for CTL development in a carbon-constrained world?***

A: Without additional installed carbon capture technology, Synfuels China's existing CTL process can capture up to 70% of the CO_2 emitted as a high-purity (>99.8%) commercially ready product for utilization, through enhanced oil recovery, and storage. The comparative ease of capturing CO_2 in the CTL process makes this technology the least expensive option for initial commercial-scale demonstrations of carbon capture, utilization, and storage (CCUS) to learn more about market development, storage geology, pressure management, etc.

For some suitable low-rank coals, the step-wise liquefaction technology from Synfuels China will greatly improve the energy efficiency. That said, CTL and polygeneration plants have higher energy efficiencies than coal-fired power plants, which only access the heat potential of coal and not the potential of coal's rich chemical composition. A higher energy (or thermal) efficiency means that more of the potential energy in coal is converted to usable energy in the final products. Thus, for the same amount of coal, less CO_2 is emitted as more of the energy-rich carbon and other chemicals are converted into liquid products.

Q: ***Even if technical and environmental challenges associated with CTL are addressed, today's energy market presents additional challenges. For example, in the face of China's recent economic slowdown and transitioning energy mix and the depressed price of oil, what are the principal drivers for continued CTL projects in China and around the world?***

A: Yes, currently oil is overproduced and the global price is quite low. However, as an example, our 4000 bpd plant in Inner Mongolia is still successful with a net profit of about US$8 per barrel of fuel products at the current oil prices, while many similar plants are losing money. Due to the increasingly smooth operations over the last five years, 70% of the capital investment is already recovered. While fuel prices in the U.S. tend to vary with the global oil price, the fuel prices in China are frequently higher and not equivalent to international oil prices. This is, in part, due to the energy taxation policy of China and also the fact that about 60% of oil is imported. The real situation is that the motor fuel price (and other end products) is currently at the level of US$100 per barrel of liquids (compared roughly to the global oil price of about ~US$40 per barrel of crude) including the government tax of about US$25 per barrel of liquid fuel. This taxation policy is under discussion as the security of energy supply is a common national security concern. If China can use its own coal resources to produce liquid fuels, even on a limited scale, this may improve the affordability, availability, and quality of China's fuel supply.

With historically low—and frequently volatile—energy prices, many places globally are facing increasing demand for power, fuels, and chemicals. To meet a growing population's needs, energy security is key. Thus, even with more renewable energy and improved storage technologies, there will be a continued need for fossil-based fuels, lubricants, and chemicals. Therefore, Synfuels China and its affiliates' vision is to advance toward an energy system that demonstrates "near zero" emissions due to high efficiencies and innovative integration strategies.

Despite market challenges, there are exciting opportunities around CTL. For example, there are enormous amounts of coal assets around the world, especially in the Americas, that would be ideal feedstock for Synfuels China's proprietary CTL technology. Projects that offer plentiful coal reserves, developed markets, training for employees, comprehensive infrastructure, and adequate brackish water are prime opportunities where Synfuels China's process could thrive.

The principal driver for continued CTL projects is integrated R&D by companies, laboratories, think tanks, universities, and other energy-focused institutions already involved in the commercialization of advanced conversion technologies. An important outcome of these collaborations will be a global network of public and private institutions engaged in research, development, and training for energy conversion-based global industry ready to address the world's energy-related challenges.

Synfuels Americas, a subsidiary of Synfuels China, is already working with coal and gas producers that own energy resources that cannot be produced economically in today's market. As the energy industry struggles with fluctuating energy costs, Synfuels China and its subsidiaries will help unlock untapped energy resources.

Movers & Shakers

The Board of Directors of Peabody Energy has elected Robert Malone to the non-executive role of Chairman of the Board, effective 1 January 2016. He will succeed Gregory Boyce in the last step of a leadership continuity initiative that commenced in 2012.

Orica Chairman Russell Caplan has announced the appointment of Malcolm Broomhead to the Board, effective 1 December 2015. Mr. Caplan also announced his intention to retire from the Orica Board at the end of 2015, with Mr. Broomhead elected by the Board to become Chairman from 1 January 2016. In addition, Orica announced the appointment of Angus Melbourne as Group Executive and President, Australia Pacific and Indonesia.

Rio Tinto has reached a binding agreement for the sale of its 40% interest in the Bengalla coal joint venture in Australia to New Hope Corporation Limited.

International Outlook

Australia

Australia's Minister for the Environment, Greg Hunt, has approved Adani's Carmichael coal mine. Its original approval had been revoked by the courts. If the project moves forward it could be the country's largest coal mine with a maximum extraction potential of 60 million tonnes of coal per year.

Credit: NordNordWest/Wikipedia

Canada

Shell has officially launched its Quest carbon capture and storage project in Alberta, Canada. The project is designed to capture and store more than one million tonnes of CO_2 per year. The CO_2 is being captured from an upgrader that converts oil sands into syncrude.

China

China announced that it will begin a national emissions trading scheme in 2017.

According to the data from the National Development and Reform Commission (NDRC), China produced 3.045 billion tonnes of coal from January to October of 2015, a decrease of 3.6%. The country imported 170 million tonnes during this same time period, a decrease of 29.9%, and exported just over 4.54 million tonnes, a decrease of 6.5%.

The China Electricity Council recently released statistics on China's power industry from January to October. The total power generation was 4651.1 billion kWh, a 0.1% decrease over the same period the previous year.

Czech Republic

The government of the Czech Republic approved a plan to increase lignite mining in the country. The Trade and Industry Minister, Jan Mládek, said that the change was made because the coal is needed to ensure a secure and reliable energy supply for the country.

India

Coal India Ltd. (CIL) produced 44.37 million tonnes of coal in October, which was 5% lower than the targeted amount for the month (46.84 million tonnes). Although CIL's production has increased, its production was lower than set goals. From April to October, CIL's coal output was 274 million tonnes, missing the production target of 282 million tonnes.

International

As this issue went to press, the COP21 international negotiations on climate were underway in Paris, France. For the latest updates, the United Nations Framework on Climate Change newsroom can be accessed here: newsroom.unfccc.int/

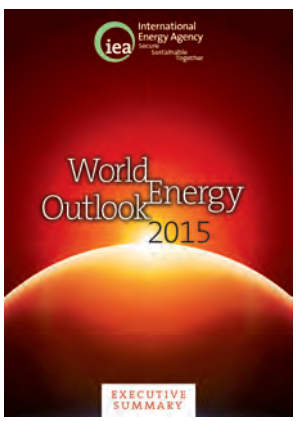
Key Meetings & Conferences

Globally there are numerous conferences and meetings geared toward the coal and energy industries. The table below highlights a few such events. If you would like your event listed in *Cornerstone*, please contact the Executive Editor at cornerstone@wiley.com

Conference Name	*Dates (2016)*	*Location*	*Website*
Energy, Utility & Environment Conference (EUEC)	3–5 Feb	San Diego, California, U.S.	www.euec.com/
World CTX	12–15 Apr	Beijing, China	worldctx.com/
Engineering Conferences International CO_2 Summit II	10–14 Apr	Santa Ana Pueblo, New Mexico, U.S.	www.engconf.org/conferences/civil-and-environmental-engineering/co2-summit-technologies-and-opportunities/
IEA Clean Coal Centre High Efficiency, Low Emissions Coal-fired Plant Workshop (HELE 2016)	23–25 May	Tokyo, Japan	hele.coalconferences.org/ibis/HELE/home
Clearwater Clean Coal Conference	5–9 Jun	Clearwater, Florida, U.S.	www.coaltechnologies.com/
International Pittsburgh Coal Conference	8–12 Aug	Cape Town, South Africa	www.engineering.pitt.edu/pcc/

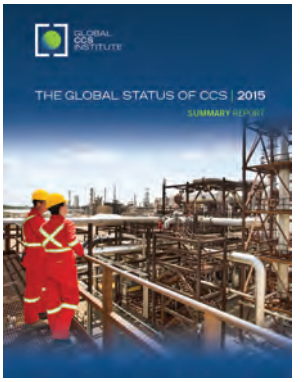
There are several Coaltrans conferences globally each year. To learn more, visit www.coaltrans.com/calendar.aspx

Recent Select Publications



World Energy Outlook 2015 — International Energy Agency (IEA) — The latest edition of IEA's World Energy Outlook (WEO) highlights the impact of lower oil prices, China's changing growth pattern and energy utilization, India's emergence as the new global leader in increasing energy consumption, and much more. Regarding coal, the WEO predicts that the global market will continue to face challenges and low prices. Although coal met 45% of the increase in energy demand over the last decade, the fuel will meet only 10% of increased energy demand to 2040. Growth in coal utilization is largely driven by a tripling of coal demand in India and Southeast Asia. In the OECD, IEA projects that coal use could fall by up to 40% to 2040, although the large gains made in Asia result in net growth. In fact, by 2040, Asia is projected to account for 80% of coal consumption. The latest WEO can be purchased at www.iea.org/bookshop/700-World_Energy_Outlook_2015/ and the Executive Summary is offered at www.iea.org/Textbase/npsum/WEO2015SUM.pdf

The Global Status of CCS | 2015 — Global CCS Institute (GCCSI) — In its sixth year, the Global Status of CCS report highlights the 28 million tonnes of CO_2 that will be captured in 2015 by the 15 operational projects, with another seven projects at various stages of planning and construction. The head of the GCCSI introduces the report, and projects that 2016 and 2017 will be trailblazing years for CCS with those seven large-scale CCS projects due to come online around the world. The report also underscores that CCS is being applied to many different industrial sectors, not just power generation. However, the report ultimately makes clear that thousands of projects are needed to meet international climate goals. In addition, the report stresses the vital role of CCS in climate change mitigation as the costs could more than double without the applicability of CCS. The summary report and key findings can be accessed here: status.globalccsinstitute.com/



Leveling the Playing Field – Policy Parity for Carbon Capture and Storage Technologies — U.S. National Coal Council (NCC) — The NCC, chartered under the Federal Advisory Committee Act in 1984, has prepared a white paper calling for creating a level playing field to deploy carbon capture and storage technologies (CCS) used for coal, natural gas, other fuels, and industrial sectors at commercial scale. This white paper was prepared at the request of U.S. Secretary of Energy Ernest Moniz in advance of the COP21. In assessing policy parity for various low-carbon energy options in the U.S., the white paper explained that renewables received 12 times the federal subsidies compared with coal in 2013—this is despite the fact that fossil fuels produced 79% of the country's energy, compared to 11% from renewables. Recommendations were provided in several key areas, including financial incentives, regulatory improvements, supporting research, development, and demonstrations, and improving communication and collaboration. The full white paper is available on the NCC website: www.nationalcoalcouncil.org/studies/2015/Leveling-the-Playing-Field-for-Low-Carbon-Coal-Fall-2015.pdf

From The WCA

WCA Calls for Greater Commitment on all Low-emission Technologies Ahead of COP21

The WCA strongly supports an effective agreement at COP21 that integrates environmental imperatives with the aims of energy security, economic development, and an end to poverty.

The WCA COP21 position highlights that:

- Without action to support deployment of low-emission coal technology, it will not be possible to achieve the 2˚C climate target.
- The WCA supports a transition from the least-efficient technology in favor of high-efficiency, low-emission (HELE) coal-fueled power generation technology.
- Global investment is required in carbon capture and storage (CCS).
- If comprehensive policy and financial support is provided for CCS over the coming decade, including policy parity, it is realistic to believe that a transition toward no new unabated fossil fuels could begin in the late 2020s.
- The WCA welcomes the opportunity to work with our partners in the oil and gas industry to support policies and projects that facilitate the large-scale deployment of carbon capture, use, and storage.

For the full position from the WCA, visit www.worldcoal.org/wca-calls-greater-commitment-all-low-emission-technologies-ahead-cop21

WCA Website Gets a New Look

To better serve our stakeholders, WCA has redesigned its website. We invite you to browse our updated website at www.worldcoal.org/

WCA Hosts Conference and Workshop on Low-Emissions Coal Use

The WCA recently hosted a conference in Brussels on low-emissions coal use. The event included three main focus areas:

- Coal and mitigation of greenhouse gas emissions
- Creating new pathways to drive deployment of technologies to reduce GHG emissions
- Coal in the global energy mix—pathways to reducing GHG emissions

Speakers at the event included key European policymakers and industry leaders, such as Dr. Ian Duncan MEP, European Conservatives and Reformists Group, EU ETS Reform Rapporteur; John Scowcroft, Executive Adviser for EMEA, Global Carbon Capture and Storage; Hans Ten Berge, Secretary General, EURELECTRIC; Paula Abreu Marques, European Commission, Head of Unit, Renewable Energy and CCS Policy; and Shamsuddin A. Shaikh, Chief Executive Officer, Engro Powergen, etc.

WCA organizes such conferences to provide a dedicated forum to discuss issues of significance to energy, climate, and development. We work to provide an opportunity for representatives of the coal sector to discuss with governments, industry, and NGOs the active contribution the coal industry plays in delivering comprehensive solutions to energy and environmental challenges.

In the near term, the conference highlighted the importance of improving the efficiency of coal-fired power plants by deploying HELE technologies, which could reduce global CO_2 emissions by about two gigatonnes per year. Moreover, deploying HELE technologies is the first step on the path to zero emissions through CCS. Thus, the conference and workshop speakers considered the technological, policy, and financial requirements for the deployment of HELE coal combustion and CCS technologies.

WCA Reviews India's Energy Trilemma

WCA has published a flagship report entitled "The Case for Coal: India's Energy Trilemma". The report focuses on the challenges of meeting India's growing energy needs, future energy demand, CO_2 abatement costs, and the role that can be played by HELE coal technologies.

Significant findings highlighted by the report include:

- The Indian government's policies to meet the growing need for electricity are focused on developing large-scale coal-fired power plants.
- India's technology choice to meet future energy requirements has significant implications on CO_2 emissions.
- A $1-billion expenditure in ultra-supercritical coal power plants in India could abate more CO_2 than the same expenditure in European renewables.
- Coal is expected to remain the most cost-effective way to abate CO_2 in India, accounting for declines in the capital cost of renewables and increased gas availability.

Benjamin Sporton, WCA Chief Executive, explains, "India has 300 million people who don't have access to electricity. As with many developing economies, India needs all sources of energy available to meet its growing energy needs using the best possible technology. With the International Energy Agency (IEA) predicting that coal will continue to make the largest contribution to electricity generation in India through to 2040 it is essential that we promote the best available technologies to ensure coal is used as cleanly as possible."

India is currently the world's third largest energy consumer; this position will be consolidated over coming years driven by economic development, urbanization, improved electricity access, and an expanding manufacturing base. In fact, the IEA forecasts that by 2040 India's energy consumption will be more than OECD Europe combined, and rapidly approaching that of the U.S.

The report highlights the clear benefits of deploying supercritical and ultra-supercritical technology. WCA analysis shows that replacing subcritical capacity currently in the development pipeline with supercritical or ultra-supercritical technology would translate into significant reductions in CO_2 emissions for India over the life of the power plants.

The full report is available at worldcoal.org/sites/default/files/WCA%20report%20-%20India%27s%20Energy%20Trilemma.pdf

WCA and SaskPower Sign MOU

WCA has signed a memorandum of understanding (MOU) with SaskPower, a leading developer of carbon capture and storage facilities, including the world-leading Boundary Dam power plant. Under the MOU, the parties will work together to advance CCUS by bringing together global technology developers, regulators, users, etc., and facilitating knowledge sharing among stakeholders. The two parties have also agreed to facilitate the funding of select projects and disseminate public communications promoting CCUS as an economically viable solution for the control of greenhouse gas emissions.

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Platform for Accelerating Coal Efficiency

The World Coal Association has published a concept paper on establishing a global Platform for Accelerating Coal Efficiency (PACE).

The vision of PACE is that when coal plants are built, the most efficient power plant technology possible is deployed. The overriding objective would be 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.

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 2 gigatonnes of CO_2 emissions now, equivalent to India's annual CO_2 emissions.

The concept paper is available for download on the WCA website www.worldcoal.org or email PACE@worldcoal.org to request a copy

The WCA has released the concept paper for stakeholder input and engagement. If you would like to provide feedback or discuss PACE in more detail, contact us at PACE@worldcoal.org

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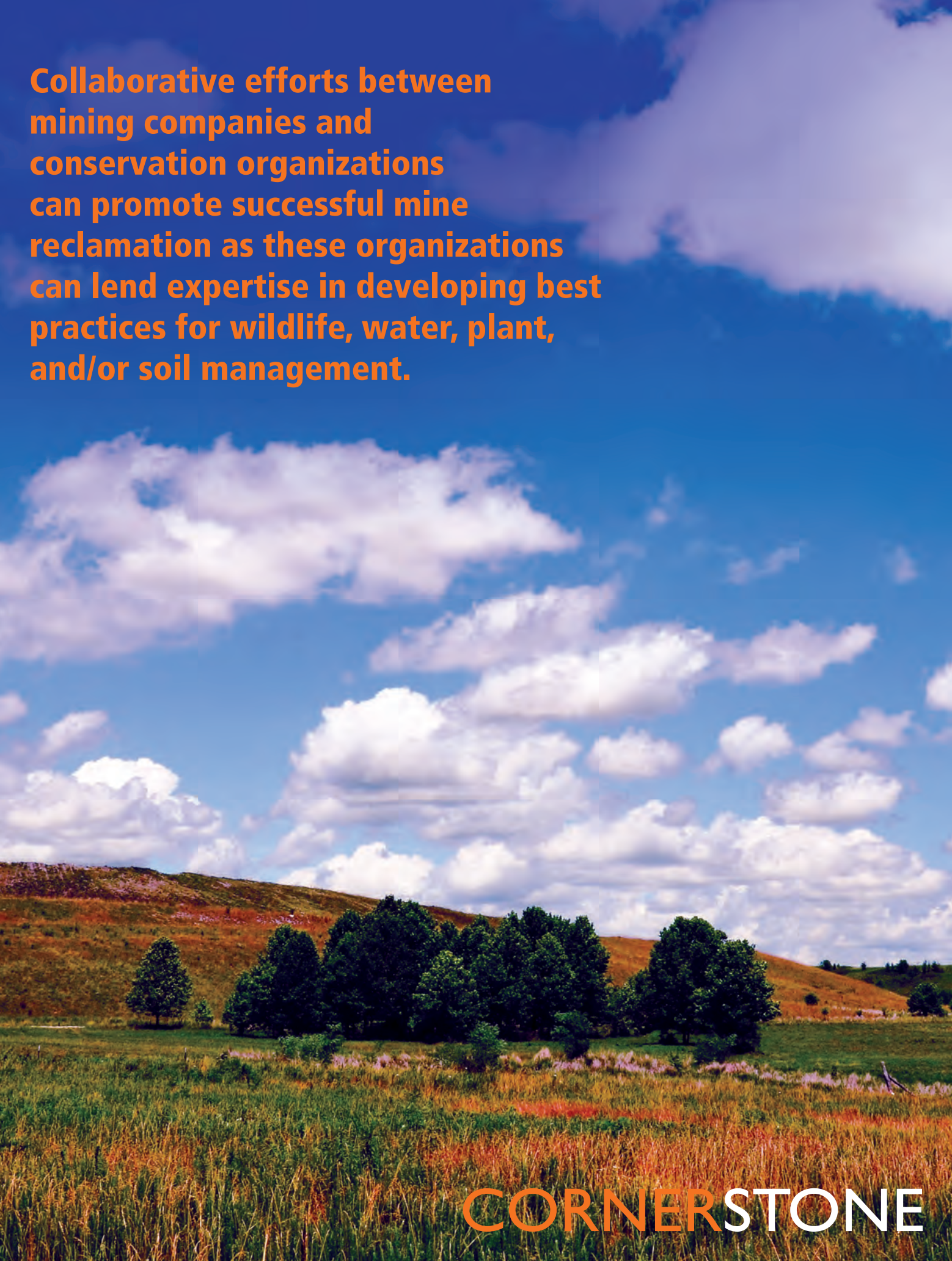
Collaborative efforts between mining companies and conservation organizations can promote successful mine reclamation as these organizations can lend expertise in developing best practices for wildlife, water, plant, and/or soil management.
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