



GROWING JOBS. EXPANDING TRADE.

A Path Forward

Carbon Capture, Use and Storage Technologies and
Reducing CO₂ Emissions

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Introduction

Background

The world faces both dilemma and opportunity with its energy future. Climate change is an urgent challenge that must be addressed. Yet fossil fuels provide the very basis for the developed world's energy infrastructure. And the World Health Organization, among others, identifies global priorities that include reducing energy poverty — such as simply providing electricity for cooking, clean water and refrigeration — in developing nations in Asia and Africa.

Bill Gates summarized this sharply in his blog *Gates Notes* last year:

"Many developing countries are turning to coal and other low-cost fossil fuels to generate the electricity they need for powering homes, industry, and agriculture. Some people in rich countries are telling them to cut back on fossil fuels. I understand the concern: After all, human beings are causing our climate to change, and our use of fossil fuels is a huge reason.

"But even as we push to get serious about confronting climate change, we should not try to solve the problem on the backs of the poor. For one thing, poor countries represent a small part of the carbon-emissions problem. And they desperately need cheap sources of energy now to fuel the economic growth that lifts families out of poverty. They can't afford today's expensive clean energy solutions, and we can't expect them [to] wait for the technology to get cheaper.

"Instead of putting constraints on poor countries that will hold back their ability to fight poverty, we should be investing dramatically more money in R&D to make fossil fuels cleaner and make clean energy cheaper than any fossil fuel."

Governor Jay Inslee and other energy policy leaders recognize the very real challenges of climate change but understand also that significantly limiting coal consumption without a viable alternative in the near term for developing and developed countries would have dire consequences for people and the sovereign nations that represent them. So while the urgency of each of these priorities is plainly apparent, such urgency does not by itself determine the best mix of solutions.

The Path Forward

Further investment in and development of advanced coal technologies is part of the most promising path forward. These key technologies include carbon capture, use and storage (CCUS), as well as more efficient coal consumption.

The International Energy Agency (IEA) is an autonomous organization comprising 29 member countries. It works to ensure reliable, affordable and clean energy for these member countries and beyond. The IEA has four main areas of focus: energy security, economic development, environmental awareness and engagement worldwide. It is at the heart of the global dialogue on energy, providing authoritative statistics and analysis. The IEA is headquartered in Paris, and funded by its 29 members and the revenue it generates from its publications.

The IEA has concluded that CCUS is the only large-scale technology that can mitigate CO₂ emissions from fossil fuel use for electricity generation and key industrial sectors. As the organization stated in *Tracking Clean Energy Progress 2015*, "... strategic action on clean energy technologies at national, regional and international levels has the capacity to move the world closer to shared goals for climate change mitigation while delivering benefits of enhanced energy security and sustainable economic development." The IEA also notes that the current pace of technology innovation must be increased.

As then-Congressman Jay Inslee noted in his and Bracken Hendricks' 2008 book *Apollo's Fire*, "We have tons of coal. We have tons of innovative energy. We may be able to combine both for a couple of centuries of coal without the carbon, but only if we pick the right places to mine America's rich vein of innovative talent."

The IEA echoed these sentiments this year: "This is the time to construct a clean energy future that works for everyone, and for our leaders to have the wisdom to seize the power of innovation to benefit from the best that technology offers."

Good progress is currently being made on CCUS technologies. This summary report describes some of this progress and related efforts, focusing on Washington state's innovation in the energy and clean technology industries, and highlighting other promising work in the United States and around the world.

Washington

Several significant advanced coal technology and clean energy research and development efforts are underway in Washington state. These include government-funded laboratory work, university programs, international collaborations and private sector activity.

Pacific Northwest National Laboratory

The Pacific Northwest National Laboratory (PNNL) is the primary major Washington-based research entity exploring CCUS. It is operated and managed by Battelle, one of 10 U.S. Department of Energy (DOE) Office of Science national laboratories. PNNL began operations in 1965, and in 2014 had \$1.02 billion in R&D expenditures.

PNNL's involvement in the study and mitigation of CO₂ emissions can be traced at least as far back as 1996, when PNNL researchers designed a technically based, integrated approach to evaluate economically efficient ways to mitigate such emissions. In 1999, PNNL developed one of the first climate models to analyze global warming. The model examined potential impacts on agriculture, recreation, water resources and salmon stocks.

PNNL has been actively engaged in CCUS research and development for several years, focusing on both capture and storage technologies. These efforts have taken many forms, including laboratory research, study and development of solutions, field work, expansion of scientific knowledge through hundreds of scholarly publications, public courses, development of tools (software), and the creation of the Environmental Molecular Sciences Laboratory (EMSL), a national scientific user facility available to the global research community.

Most of the funding for PNNL's CCUS efforts comes from the Office of Fossil Energy within the DOE. Available federal funding averages \$200 million annually, and employs more than 4,300 scientists and managers and support staff in the Tri-Cities.

Carbon Capture

Pacific Northwest National Laboratory research to date includes developing and demonstrating novel materials and technologies for capturing and separating CO₂. This work has focused on capturing flue-gas emissions from existing coal-burning power plants. PNNL's carbon capture research has included the study of new CO₂ capture materials and technologies with the objective of significantly reducing the energy penalty of current capture technology.

PNNL established the Emissions Capture Development Center to bring together PNNL laboratories, equipment, staff expertise and processes. The center targets emissions capture challenges, and is

designed to develop new technologies that can be scaled up, tested and commercially deployed. Capabilities include molecular-scale modeling for materials discovery, an emissions capture test laboratory, and a structured evaluation process designed to rapidly screen and mature technologies. The Emissions Capture Center is seen by PNNL as a key to creating new materials and turning them into commercially viable technologies.

PNNL research has already yielded important CO₂ storage developments. One such development is the design of a new material called Molexol. Molexol is molecularly engineered to selectively capture CO₂ from flue gases. This new material has two to three times the capacity for CO₂ as conventional solvents. It is also highly selective, targeting CO₂ but not nitrogen and hydrogen, gases also frequently found in flue gases.

While Molexol has some very promising characteristics, it tends to absorb water as well as CO₂. Work continues on this issue at PNNL. For example, PNNL scientists have worked to incorporate hydrophobic components into Molexol's molecular structure. This would prevent the material from absorbing water vapor while allowing it to take in even more CO₂.

Another promising technology developed at PNNL is an advanced CO₂ capture system called Polarity Swing Assisted Regeneration (PSAR). The PSAR process uses organic liquids to capture and separate out the CO₂ from flue gas. It accomplishes this separation at a much lower temperature than a previous process (thermal swing regeneration), which means much less power is required to complete the PSAR process—a lower energy penalty. By efficiently using heat from the power plant rather than valuable steam, this carbon capture process offers potential savings in energy and cost.

Carbon Storage

PNNL's work on CCUS accelerated substantially in 2009 with the Carbon Sequestration Initiative, a five-year, \$50 million investment to advance PNNL's capabilities in geologic storage. The initiative included the development of experimental techniques aimed at understanding mineral dissolution and carbonate precipitation for both aqueous and supercritical CO₂ phases under in situ conditions.

A key part of the initiative was the development of advanced computational tools and management software to help in designing and operating a carbon sequestration site. The Environmental Protection Agency (EPA) has adopted this software and computational tools for permitting carbon sequestration sites. EPA believes this is an important step forward in achieving progress in climate change objectives.

In 2013, PNNL began injecting CO₂ at the Wallula site in Southeast Washington to test deep

geologic storage. The research will help determine whether greenhouse gas can be stored safely and permanently in ancient basalt flows. This field demonstration is testing conclusive laboratory demonstrations that the unique geochemical nature of basalts quickly reacts with CO₂ and forms carbonate minerals. This particular geology has been selected as the safest and most permanent form for storage in the subsurface.

If proven viable by the Wallula field test and others that are in progress or being planned, basalt flows in many parts of the world may serve as storage locations to store CO₂ emissions. According to recent DOE estimates, the United States and portions of Canada have enough potential capacity in geologic formations to store as much as 900 years of CO₂ emissions. There are also major potential flood basalt storage sites in India and possibly Australia. This would provide considerable CO₂ storage capacity and additional geologic sequestration options in regions of these countries where conventional storage options are limited.

Another promising PNNL study published late last year shows that gas-bearing shales could also play an important role in meeting CO₂ storage needs in the United States, particularly in the Northeast where other options are limited. According to the PNNL team's findings, shales could meet up to 20 percent of total CO₂ storage demand in the most favorable case evaluated. The specific capacity percentage will depend on how well CO₂ can displace methane (CH₄) from the shale. Additional experimental and simulation efforts are in progress at PNNL and other national laboratories to further assess how CO₂ and CH₄ interact in shales.

PNNL is also assessing potential environmental impacts of carbon sequestration. For example, a PNNL team has studied whether CO₂ leaked from a sequestration site below an aquifer could increase contaminants in drinking water. Experimenting on sediment samples from aquifers above potential sequestration sites in Kansas and Texas, the researchers found the overall change in chemistry was not harmful. The team also recommended that potential sequestration sites be subject to careful study before use since variability in sediment composition could make a difference.

PNNL research, study, development and testing of CCUS technologies have been significant and diverse. The lab continues to be a valuable scientific resource and facility for substantial further development of these technologies.

PNNL's progress in CCUS technologies has been complemented by Washington's research universities. The University of Washington and Washington State University have developed programs and pursued research centered on clean energy and renewable biofuels.

University of Washington

The UW's Clean Energy Institute (CEI) program is aimed at advancing next-generation solar energy and electrical energy storage materials, devices and systems. The program also studies the integration of such technology into the power grid. CEI produces training programs for students, acts as a regional resource for research and market translation, partners with industry groups or other institutions, recruits students and faculty to campus and invests in increased research and education activities. Governor Inslee's leadership and formative energy has been fundamental to initiating and implementing these programs at UW.

The Northwest National Marine Renewable Energy Center (NNMREC) is a partnership between the University of Washington, Oregon State University, and the University of Alaska Fairbanks. It is supported by a range of federal and non-federal sponsors. NNMREC is an integrated, standardized test center for U.S. and international developers of wave and tidal energy. The center tests devices and processes for effective use of wave and tidal energy technologies. Test results support improved forecasting of the wave energy resource, and ultimately seek to increase reliability and survivability of marine energy systems.

NNMREC also evaluates potential ecosystem and human dimensions impacts of using this form of energy. Evaluations focus on the compatibility of marine energy technologies with ocean and coastal environments and coastal users.

Washington State University

WSU is home to a wide range of clean tech initiatives, seeking new solutions to address the threats of energy supply, climate change, pollution and resource depletion. University researchers are exploring how to produce clean-burning, cost-competitive biofuels to replace fossil fuels, and studying necessary steps to transition to these alternatives. Other areas of study include preserving resources in the built environment, the "smart grid" management of shared resources, and improving materials for the infrastructure.

The Paccar Environmental Technology Building (PETB), currently under construction, will provide a hub for these interdisciplinary efforts. PETB will house a wide range of research and education activities designed to help reduce the region's dependence on foreign oil, minimize carbon footprints, and improve air and water quality.

Construction of the PETB incorporates renewable materials and technologies developed at WSU, including wood composites, recycled concrete and pervious pavement. The PETB will also incorporate water capture and re-use, heat recovery, individual control of air quality factors, maximized daylighting, optimal siting and incorporation into its landscape. Once completed, it will be the greenest building on the WSU Pullman campus.

State of Washington/China Collaboration

Washington state recently entered into an agreement with the Chinese Academy of Sciences to cooperate on project and investment opportunities in the development of clean and low-carbon energy technologies. Potential projects on which the partners will collaborate include two gas-to-methanol plants at the Ports of Kalama and Tacoma, with each involving an estimated investment of \$1 billion.

The proposed plants would convert natural gas to methanol and export the methanol to Asia for use in olefin production. Olefin is used in such consumer goods as plastic containers, cell phones and carpet fibers. The cleaner-burning methanol would reduce reliance on coal and petroleum in producing olefin, thereby reducing carbon emissions. According to NW Innovation Works, the company proposing the gas-to-methanol projects, replacing oil and coal with olefin derived from methane made from natural gas reduces carbon emissions by as much as 70 percent.

This latest development complements work being done by the Washington State China Relations Council as part of the U.S. Clean Energy Research Center's Advanced Coal Technology Consortium (CERC-ACTC). CERC-ACTC is implementing a five-year Joint Work Plan to significantly advance technology for clean coal, including CCUS, in both China and the United States.

Summit Power Group

Summit Power Group, headquartered in Seattle, develops projects across a broad spectrum of energy technologies. Summit's Carbon Capture division focuses on CCUS projects, including the production of value-added industrial products such as CO₂ for Enhanced Oil Recovery (EOR), urea for fertilizer, and ammonia.

Summit's projects include the Texas Clean Energy Project (TCEP), a 90 percent carbon capture coal gasification project. This project represents nearly \$3 billion in investment. It is one of the highest-profile USDOE-supported clean coal projects. The TCEP facility will incorporate CCUS technology in a first-of-its-kind commercial clean coal power plant. TCEP is projected to capture more than 2.5 million tons per year of CO₂ to be sold into EOR markets.

Summit is also developing the Caledonia Clean Energy Project, a new project in the United Kingdom. The Caledonia plant will capture CO₂ and sequester it in a subsea saline formation in the North Sea. There are other Summit Carbon Capture projects under development that are not yet public.

Beyond Washington State

The DOE sponsors and co-funds a network of seven Regional Carbon Sequestration Partnerships to help develop the technology, infrastructure, and regulations to implement large-scale CO₂ storage. Washington participates in two of these partnerships.

Regional Partnerships

West Coast Carbon Sequestration Partnership

The West Coast Carbon Sequestration Partnership is known as WESTCARB, and includes Alaska, Arizona, California, Hawaii, Oregon, Nevada, Washington and the province of British Columbia. It is a collaborative project involving more than 90 public agencies, private companies, nonprofits, universities and research labs. WESTCARB explores the best regional opportunities to reduce or eliminate CO₂ emissions.

WESTCARB identifies major stationary sources of CO₂, such as power plants, oil refineries and cement plants. It then assesses CO₂ capture technologies that could be applied at these facilities, and determines the potential for using CO₂ commercially and/or storing it in geologic formations.

Big Sky Carbon Sequestration Partnership

The Big Sky Carbon Sequestration Partnership (BSCSP) is part of Montana State University's Energy Research Institute. BSCSP encompasses Montana, Wyoming, Idaho, South Dakota, Eastern Washington and Oregon. The partnership brings together representatives from these states, including universities, national laboratories and the private sector, to pursue regional collaboration on carbon sequestration efforts.

BSCSP researches and develops new approaches for geologic carbon storage in the Big Sky region. The partnerships work includes paper studies, field-based research, computer modeling, data analysis, small-scale pilot projects and large-scale demonstration projects. BSCSP has created a robust outreach and education program to improve public understanding of carbon storage technologies.

University of Wyoming

The Carbon Management Institute (CMI) at the University of Wyoming is one of several Centers of Excellence within the university's School of Energy Resources, whose funding sources include Arch Coal. CMI is actively engaged in CCUS research projects and cooperative initiatives. This work encompasses initial site characterization, facility design and demonstration, legal and regulatory

issues, and other challenges. Part of CMI's mission is to supply regulators, legislators and other stakeholders with the best science and information available on CCUS. Over the next decade or more, CMI will be integrally involved in the implementation of CO₂ utilization in Wyoming.

The University of Wyoming's Ruckelshaus Institute works to advance the understanding and resolution of complex environmental and natural resources challenges. The Institute conducts and publishes relevant research and promotes collaborative decision-making. As part of this mission, the Institute is engaged in the Energy Mitigation Initiative. This initiative focuses specifically on mitigating impacts to wildlife from energy development.

Wyoming Infrastructure Authority

The Wyoming Infrastructure Authority (WIA) was created by the Wyoming state Legislature to "diversify and expand the state's economy by adding value to Wyoming's energy resources and infrastructure for the benefit of Wyoming and the region."

The WIA's strategic plan calls for methodical study, development and implementation of CCUS technology in Wyoming. Earlier this year, the Wyoming Legislature also granted WIA the ability to issue up to \$1 billion in bonds to finance infrastructure projects outside of the state.

Wyoming Integrated Test Center

Wyoming is also developing a new test facility sited at an existing coal-fired plant in the state. The facility's test bays will allow entities to validate the commercial readiness of processes for carbon capture and utilization of CO₂. The test bays will be connected to the flue gas of the host coal-fired facility. During the 2014 legislative session, \$15 million was appropriated for the center to be designed and constructed.

West Virginia University

West Virginia University is the leader of a U.S.-China Energy Center CCUS project being conducted in collaboration with two Chinese companies and four Chinese universities. The goal is to evaluate resources and planning for two pilot-demonstration CCUS projects in China. WVU team members will describe and quantify the geologic, environmental and economic challenges to successful development of large-scale CCUS in China.

The first of the two Chinese companies involved in the project is Shenhua Group. Shenhua has developed the world's first modern direct coal liquefaction facility in Inner Mongolia. The plant is in full operation and produces significant amounts of CO₂. The company's goal is to permanently store

much of this CO₂ in geologic formations in the Ordos Basin.

Shanxi International Energy is the second company involved in the project. Shanxi plans to build two oxy-fueled facilities for integrated electricity generation coupled with distributed heating and cooling in Shanxi Province, China. The completed facility will produce about four million tons of high purity CO₂. West Virginia University and the China University of Geosciences have developed a prefeasibility evaluation of potential options for CO₂ geologic storage and industrial utilization.

Washington University in St. Louis, Missouri

The Washington University in St. Louis' Consortium for Clean Coal Utilization is a center for research in advanced coal and carbon capture technologies. The establishment of the Consortium was made possible through commitments from three lead sponsors, including Arch Coal. Funding goes to support a variety of research projects, advanced research facilities, and outreach activities relating to the clean utilization of coal. The research projects are led by Washington University faculty in collaboration with faculty from partner universities.

Alabama

National Carbon Capture Center

The National Carbon Capture Center (NCCC) works on the development of cost-effective CO₂ capture technologies for coal-fired power generation. It is sponsored by the DOE, and funded by several companies, including Arch Coal. The NCCC provides a world-class test facility and a highly specialized staff to test developers' technologies for extended periods under commercially representative conditions with coal-derived flue gas and syngas. The goal of the center is to help accelerate development of cost-effective CO₂ capture technologies that enable coal-based power plants to achieve near-zero emissions.

The NCCC tests and evaluates technologies that include CO₂ capture solvents, mass-transfer devices, low cost water-gas shift reactors, scaled-up membrane technologies, and improved means of CO₂ compression. The two main areas of research are gasification/pre-combustion CO₂ capture and post-combustion CO₂ capture.

Canada

In Canada, SaskPower's Boundary Dam Unit 3 (BD3) is the world's first coal-based power plant to be fully retrofitted with CCUS. The facility came online in late 2014 and is demonstrating the promise of generating electricity while capturing in excess of 90 percent of its CO₂ emissions for delivery via pipeline into a nearby EOR operation.

In its operations to date, the performance of BD3 has exceeded expectations for both efficiency and the quality of its CO₂. The plant is outputting more than 9 percent above its designed capacity. In addition, it is producing 99 percent pure CO₂. This is 4 percent more concentrated product than originally projected, making it more valuable to the EOR operation.

The International Energy Agency has noted BD3's achievement, as well as similar efforts around the world:

A significant milestone for CCS was reached with the opening of the first commercial-scale coal-fired power plant with CO₂ capture in October 2014. Further projects are being built in the United States, Canada, Australia, Saudi Arabia and the United Arab Emirates . . . Given the importance of CCS in a low-carbon future, there will need to be a substantial increase in investment in R&D, storage resources, and projects now to ensure it is widely available in the coming decades.

In a report to the DOE earlier this year, the National Coal Council, a DOE-appointed industry research and reporting group observed: "As of November, 2014, there are 13 large scale CCS projects in operation around the world, with another nine under construction. There are also 19 projects in the early planning stage and 14 in advanced planning. North America and the U.S. dominate in terms of project numbers and investment levels, followed by China . . ."

China

China Huaneng Group is currently developing Green Gen, a coal-fueled power plant equipped with the latest CCUS technology. It is projected that the plant will be capable of capturing 80 percent of its CO₂, which will be used offshore for EOR.

Supercritical Coal Plants

An area of great promise lies in improving the efficiency of conventional coal plants. Advances in materials and designs have led to the deployment worldwide of supercritical and ultra-supercritical boilers that operate at higher temperatures and pressures. These more extreme steam conditions result in greater thermodynamic efficiency (40-45 percent) and the utilization of less coal and lower CO₂ emissions to generate an equivalent amount of electricity than existing, widely deployed subcritical units (30-35 percent efficiency).

There are also design concepts for advanced ultra-supercritical plants that obtain additional improvements in efficiency. With innovations in material sciences and fabrication techniques, ultra-supercritical plants will yield even more thermally efficient plants with lower CO₂ emissions.

The World Coal Association (WCA) reports:

A range of advanced coal combustion technologies have been developed to improve the efficiency of coal-fired power generation. New, more efficient coal-fired combustion technologies reduce emissions of CO₂, as well as pollutants such as NO_x, SO_x and particulates.

Improving efficiency levels increases the amount of energy that can be extracted from a single unit of coal. Increases in the efficiency of electricity generation are essential in tackling climate change. A 1 percentage point improvement in the efficiency of a conventional pulverised coal combustion plant results in a 2-3 percent reduction in CO₂ emissions.

WCA has estimated that if high-efficiency, low-emission coal-fired plants are deployed worldwide to replace the fleet of existing plants, greenhouse gas emissions from the entire power sector can be reduced by around 20 percent. This is described by Stephen Pacala and Robert Socolow, co-directors of Princeton University's Carbon Mitigation Initiative, as one of the possible substantial "wedges" in achieving sufficient carbon reduction to mitigate climate change.

Japan

Japan has a strong energy research and development program supported by the Japanese government. The program pursues energy efficiency measures to both increase the country's energy security and reduce CO₂ emissions. New clean coal technologies are being explored in the power sector in an effort to improve environmental performance.

Japan is making significant reductions in fuel consumption through the replacement of old and energy-inefficient thermal power plants with the latest high-efficiency power generation. Upgrades to Japan's Isogo Thermal Power Station coal-fired plant, for example, successfully doubled output while reducing emissions by 17 percent.

According to a June 2015 Reuters news report, the Japanese government plans to tighten regulations to bring the average fuel-efficiency of coal-fired plants across the country up to the level of ultra-supercritical plants.

South Korea

Supercritical coal plants have successfully reduced emissions at locations around the world. In South Korea, for example, supercritical coal-fired plants at Samcheok, Yonghungdo, Hadong, Dangjin and elsewhere have earned the country regard as a clean coal technology pioneer. The IEA concluded in a 2012 analysis of the globally installed coal-fired power plant fleet: "Among the ten countries with the largest coal-fired power generation worldwide, the fleet in Korea has one of the largest shares of super or ultra-supercritical coal power generation in a single country. In addition, it is among the three countries with the youngest installed fleet and the largest share of large generation units that is currently operating."

Conclusion: Pragmatism and Progress

An impressive array of good work is underway in Washington state, across the West and globally as nations struggle to meet the challenge of providing cleaner and cost-effective energy while meeting identified priorities for economic growth, energy security and poverty reduction through meeting basic electric needs. Washington's work at Battelle PNNL, the efforts of the private sector, and the research at UW and WSU are helping make progress across all of these fronts.

The global reality is that coal and other fossil fuels will be dominant energy sources for several more decades. Developed countries depend on them for economic well-being. Developing nations depend on them to provide the life- and health-improving benefits of basic electricity. These are simple facts acknowledged by many established authorities and leaders. Among these authorities is former U.S. Secretary of Energy Steven Chu, who observed in 2009:

"Overwhelming scientific evidence shows that CO₂ emissions from fossil fuels have caused the climate to change, and a dramatic reduction of these emissions is essential to reduce the risk of future devastating effects. On the other hand, access to energy is the basis of much of the current and future prosperity of the world. Eighty percent of this energy is derived from fossil fuel. The world has abundant fossil fuel reserves, particularly coal. The United States possesses one-quarter of the known coal supply, and the United States, Russia, China, and India account for two-thirds of the reserves. Coal accounts for roughly 25 percent of the world energy supply and 40 percent of the carbon emissions. It is highly unlikely that any of these countries will turn their back on coal any time soon, and for this reason, the capture and storage of CO₂ emissions from fossil fuel power plants must be aggressively pursued."

The past offers useful perspectives in approaching today's climate and energy challenges. During the 1960s, it became clear in the U.S. that auto emissions posed a significant and growing respiratory health risk. Eliminating automobiles was an obvious theoretical solution—but it was clearly not an option most Americans and the rest of the world would embrace. Cars were viewed as essential to daily life, work and commerce, and sought after by growing populations in the world's developed and developing nations. Viable alternatives to conventional auto engines were relatively undeveloped and still decades away.

Attention turned to the emissions themselves. Through increasingly rigorous standards and intense technological effort, auto emissions were reduced and air quality was steadily and significantly improved. Japan, Germany and the U.S. were given credit for substantial leadership in developing technology to generate cleaner emissions. Meanwhile, longer-term alternatives to conventionally fueled automobile transportation have continued to evolve and progress.

The goal of cleaner air was broadly shared and critically important. But the key to achieving it was found in the pragmatic understanding that citizens and consumers around the globe would continue

to choose cars for the foreseeable future. By focusing directly on reducing emissions and increasing fuel efficiency, more immediate, successful solutions were developed.

The world finds itself in a similar situation relative to coal. Coal is an accessible, abundant and reliable fuel source, and many sovereign nations have developed growth strategies based on its use. Knowledgeable and responsible energy planners, economists and humanitarians agree that this dependence is a reality that will not change for decades to come.

But the world can and is focusing on reducing emissions and increasing fuel efficiency. This is the most direct path to minimizing the contribution of coal usage to climate change while providing affordable electricity to fuel the economic growth that lifts families out of poverty. Current research, development and experience show that both of these goals can be achieved. Since 1970, the regulated pollutants (NO_x, SO_x, particulate) from coal plant emissions have been reduced nearly 90 percent. The same can be accomplished to reduce CO₂ emissions.

Strong progress is being made in Washington state, across the U.S. and around the world on advanced coal technologies and more efficient consumption of coal. Such progress shows a viable, sustainable path to the significant CO₂ reductions required to address climate change. What is needed now is to accelerate and intensify these efforts with a broad-based and inclusive approach involving the latest in technology advancements. As policymakers, businesses, scientists and the public continue to join in this endeavor, more substantial progress will be made.

Washington state is already a part of this effort. Perhaps more importantly, it is well-positioned to become a leader in helping turn the energy future dilemma into an opportunity to effectively address climate change.

