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Identifying Near-Term Opportunities for Carbon Capture and Sequestration (CCS) in China

The full issue paper on CCS potential in China will be available later in the fall at **www.nrdc.org/policy**.

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Beijing Gaobeidian coal power plant with a pilot carbon capture facility

To avoid the worst consequences of global warming, the world must limit average temperature increases to 2°C or less by reducing carbon emissions at least 50 percent below 1990 levels by the year 2050.[1] Since the publication of the IPCC's last synthesis report, several recent studies have further found that the committed warming as of today will exceed 2°C, even if emissions were to stop completely.[2] Achieving the urgently needed emission reductions will require efforts beyond first-resort measures such as energy efficiency, conservation, and enhancement of natural carbon sinks. Given the world's current heavy reliance on fossil fuels, nations must pursue a wide range of carbon mitigation strategies that includes Carbon Capture and Sequestration (CCS). China is well-positioned to be a global leader in the development and deployment of CCS technologies that—with broad support and engagement from the international community—can be an important tool for reducing carbon emissions as the world transitions to truly clean energy technologies.

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Carbon Capture and Sequestration Can Help Reduce Carbon Emissions Significantly

All three components of CCS technology—capture, transport, and sequestration—are commercially mature, but very few integrated large-scale projects are in operation today. Sequestering high-purity CO_2 waste streams from certain industrial facilities presents low-hanging fruit opportunities for CCS demonstration at low cost. For the technology to contribute meaningfully to emission reductions, integrated commercial projects are urgently needed to gain operational experience and drive down costs. CCS can be applied to a variety of carbon emission sources and fuels, including biomass (where net emissions could be negative), but by far the biggest need for CCS lies with coal-fired power generation. In total, CCS is estimated to be capable of contributing 15 to 55 percent of worldwide cumulative carbon emission reductions through 2100.[3]

Table 1: Summary of China's Potential CO_2 Storage Capacity (by type of storage option)[4]

	Deep saline formations ($MtCO_2$)	Oil fields by proved OOIP ($MtCO_2$)	Gas fields by proved OGIP ($MtCO_2$)	Unmineable coal seams ($MtCO_2$)
Onshore	2,288,000	4,600	4,280	12,000
Total	3,066,000	4,800	5,180	12,000

China Can Benefit from Large-Scale CCS Deployment

CCS is of particular importance for China. Although the country has made significant strides to reduce its reliance on coal by expanding capacities in hydro, wind, solar, and nuclear power, it still meets 70 percent of its energy needs from coal. By 2020, China is projected to have four times the hydropower capacity and double the wind- and solar-power capacity of the United States, but these sources will still remain small in comparison to coal consumption.[5] Even under the most aggressive policy scenario—assuming concerted action that includes restricting the development of energy-intensive industries, implementing taxation policies to encourage energy efficiency and conservation, maintaining strong government support for renewable and nuclear energy development, and achieving high efficiency standards in industrial production—coal will continue to meet nearly half of China's energy demand through 2030 and a significant portion for the foreseeable future.[6]

Fortunately, China is well-suited for widespread adoption of CCS. Costs for carbon capture are likely to be lower than in Western countries due to lower fuel, material, and labor costs.[7] Also, China's geology and the location of large CO_2 point sources relative to potential geologic sinks mostly match well. Initial assessments performed and published jointly by report authors Li and Wei of the Chinese Institute of Rock and Soil Mechanics (IRSM) with the Pacific Northwest National Laboratory (PNNL) suggest that theoretically China has sufficient deep saline formations to sequester up to 3,066 $GtCO_2$—more than 450 times China's total CO_2 emissions in 2005 (see Table 1).[8] There are 1,623 large point sources in China, each emitting more than 100,000 tCO_2 per year.[9] More than half of those large point sources are located directly above a potential geologic sink, and more than 80 percent are within 80 kilometers from such a site (see Table 2).[10]

Relatively Low-Cost CCS Opportunities Exist in China

Many existing high-purity CO_2 sources in China could be sequestered at much lower costs than that of a typical power plant CCS application. There are at least 130 Mt per year of such emissions from 185 large-scale ammonia, hydrogen, and ethylene oxide production facilities.[11] According to the same joint IRSM-PNNL research, three-quarters of those high-purity CO_2 streams are situated within 80 km of a suitable sink (see Table 2). High-purity CO_2 streams could total as high as 208 Mt per year in China once all planned ammonia, methanol, and liquid hydrocarbon production facilities come online.[12] The cost of CCS for several of these sources can be in the region of \$10 to 20 per tCO_2, lower than typical estimates for CCS power plants.[13]

In addition, China's geology offers significant CO_2-enhanced oil recovery (EOR) and enhanced gas recovery (EGR) opportunities. Two-fifths of the large point sources are located within 80 km of an oil or gas field, and these fields can store nearly 10 $GtCO_2$. EOR and EGR offer carbon sequestraton at reduced net costs due to increased oil and gas production. The estimated incremental oil production by EOR in China's 16 major onshore and 3 offshore oil basins could technically reach up to 7 billion barrels—enough to meet one quarter of China's current annual oil demand for nearly a decade.[14] Combining high concentration CO_2 sources with EOR/EGR may offer the most promising near-term CCS opportunities.

Promising Opportunities for CCS Pilots in China

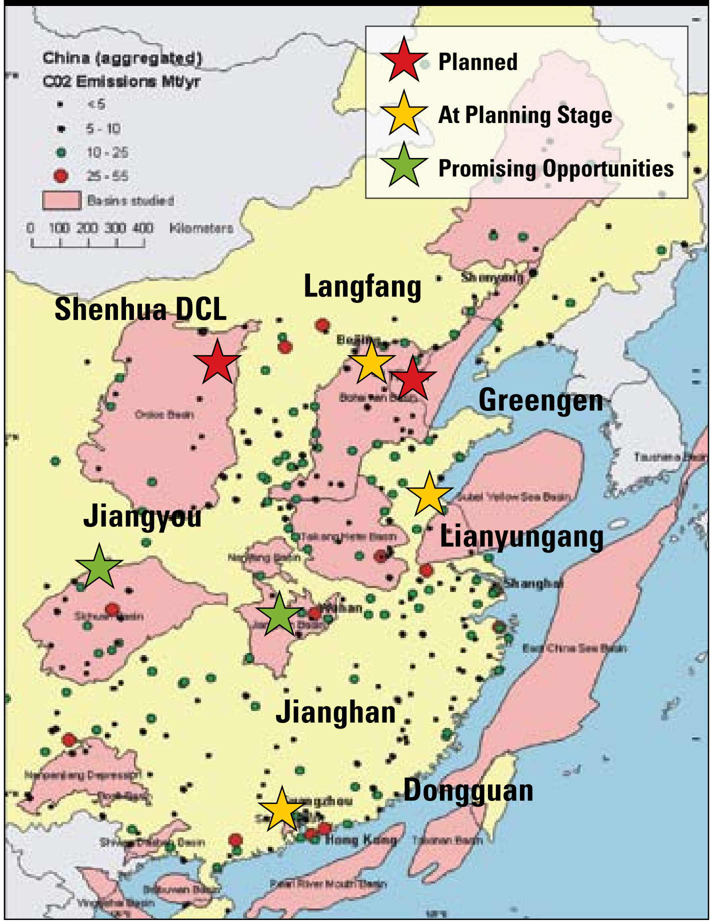
We profile two oil and gas basins in China that show promising EOR/EGR opportunities from using high concentration CO_2 sources or integrated sequestration of waste gas streams. We also discuss four Integrated Gasification Combined Cycle (IGCC) projects and one direct coal liquefaction project under construction or in planning stage. All of these projects plan to feature CCS (see Figure 1).

Table 2: Distance of CO_2 Sources from Nearest Storage Reservoir (by source and reservoir type)[15]

	All CO_2 Sources	High-Purity CO_2 Sources Only	All CO_2 Sources	High-Purity CO_2 Sources Only
	All Reservoir Types		Oil/Gas Fields Only*	
0 km	54%	45%	-	-
80 km	83%	75%	39%	46%
160 km	91%	92%	65%	62%

* Due to lack of reliable data on oil/gas field boundaries, our analysis modeled oil/gas field reservoirs as points rather than areas. As a result, these figures represent conservative estimates.

Figure 1: Locations of Promising CCS Opportunities



The depleted oil fields in the Jianghan Basin and the Jiangyou depleted gas field in the Sichuan Basin have favorable geology for CO_2 sequestration. They are also close to several large and/or inexpensive sources of CO_2. The combined benefits of short distance between sources and sinks and the potential EOR/EGR revenues make these areas promising near-term CCS candidates in China.

China's largest coal producer, the Shenhua Group, has a joint U.S.-China project that aims to collect high-purity CO_2 from a direct coal liquefaction facility in the Ordos Basin of Inner Mongolia and is slated to reach operational status in 2010/11, with an aim to eventually sequester 2.9 Mt of pure CO_2 per year, most likely in a nearby saline aquifer.

The GreenGen project led by China's largest power producer, the Huaneng Group, will be China's first commercial-scale IGCC facility that includes carbon capture technology. The aim is to capture and sequester 25,000 to 30,000 tCO_2 per year starting in 2012-2013, with a higher target set for 2017. Greengen's 250 MW IGCC plant is currently under construction in the Bohai Basin in Tianjin.

The China Power Investment Corporation has proposed to build an IGCC facility in Langfang (Beijing area) aiming to capture 8 percent of the CO_2 from the syngas produced by two 488 MWe IGCC units. An oilfield is only one kilometer away from the facility site, making sequestration through EOR a prime possibility for this project. The project is awaiting the government's final approval.

In addition, two other large IGCC projects have been proposed and are seeking government approval, one in Dongguan of Guangdong Province and the other in Lianyungang of Jiangsu Province. The former, planning for four 200 MW IGCC units, will be situated 100 km from two depleted oil fields. The latter, aiming to eventually build 1200 MW of IGCC capacity, is in a coastal city 200 km north of the Subei oil field. Both projects have expressed interest in combined CCS and EOR.

International Cooperation Around CCS in China is Crucial for Success

The ample near-term opportunities for CCS in China are ideal for international and domestic firms to collaborate on specific demonstration projects to gain valuable field experience. Such partnerships—inter-governmental, business-to-business, or multi-stakeholder—could accelerate learning, reduce costs, help develop best practices, and share knowledge and expertise across countries. In particular, international expertise is stronger than that of China in three technical areas: subsurface geological engineering, long-term monitoring and verification, and long-distance CO_2 transportation infrastructure.[16] Given the United States' extensive CO_2 EOR infrastructure and experience—the world's first CO_2 EOR project was launched in Texas nearly four decades ago—the United States is well-positioned to play a key role in CCS in China.

International collaboration may also take place in joint technology research and development (R&D). China has already begun its own CCS research, notably by Tsinghua University, Zhejiang University, several institutes in the Chinese Academy of Sciences, and research institutes of China National Petroleum Corp and the Huaneng Group. Chinese companies, such as the Huaneng Group and the ENN Group, have developed proprietary coal gasification technologies and are already collaborating with Australia and the United States. International partnerships in R&D with China could help further accelerate global CCS development to the benefit of all parties.

The international community could also provide recommendations to China on developing a regulatory system to ensure the safety and effectiveness of CCS projects. Currently, no explicit CCS regulations exist in China, but more than a dozen different laws and regulations that can affect CCS projects exist and are administered by various government agencies. A clear and regularly updated regulatory framework that addresses energy policy and enforcement issues (e.g., environmental health, safety, and efficacy) in a technologically neutral manner is essential to ensure safe CCS development in China.

In the Chinese context, this regulatory framework will likely consist of a unique mix of regulations and multi-year plans, and will require various ministries and stakeholders to work together. Australia, the European Union, and the United States have experience in addressing many of the regulatory issues China now faces, and the latter two have already launched efforts to share their regulatory experiences with China.[17] This is also an area where international NGOs can make substantial contributions.[18] Exchanges between Chinese and international regulators on audits of regulated power plants and industrial facilities could help Chinese policymakers strengthen regulatory enforcement capabilities with regard to CCS.

Increased Funding and Collaboration is Needed to Jump-Start a CCS Industry in China

More substantial funding from both the Chinese government and international sources is critical in order to deploy and improve CCS technologies and thus reduce the costs involved. Three main areas are in need of major support: large, integrated projects to test commercial-scale technologies, gain experience, identify regulatory issues, and train human resources; research into offshore basins for carbon sequestration to meet the sequestration needs of China's heavily-industrialized eastern and southern coastal regions that lack sufficient onshore storage capacity; and detailed subsurface geological assessments of China's major onshore sedimentary basins to refine current methodologies and produce more accurate estimates. Here, the government can play a critical role in requiring state-owned oil and gas companies to collaborate and share information, while international companies and governments can provide funding and key technical support to Chinese institutions.

To develop a CCS industry in China that is also capable of exporting technology and expertise, further policy and economic drivers are needed in the form of direct regulations, carbon taxes, emissions control subsidies, or even a carbon cap-and-trade system. Incentive systems might be established in law as with the renewable energy and energy efficiency laws, but might also be set by government directive or regulation as has recently been the case with programs for new technology vehicles and for solar installation. To be successful, a number of different ministries and stakeholders will need to coalesce to develop a shared understanding for how China might enable CCS development. International experience with many of these concepts, such as the European Union's Emission Trading Scheme, can prove invaluable in helping Chinese leaders implement effective policies. Eventually, international trading of CCS-related carbon permits may offer revenues while lowering compliance costs.

Addressing China's Emissions Dilemma Will Serve Other Nations

China will need a portfolio of mitigation measures, including CCS, to reduce its carbon footprint. Many low-hanging fruit opportunities exist in the field of CCS, but tapping them will depend on the extent to which governments, international institutions and corporations engage in meaningful and prompt financing, capacity building, technology and knowledge transfer agreements. Such agreements are not only important in themselves, but can pave the way to broader pacts on emission reductions. The benefits would be substantial, for China, the cooperating countries, and the rest of the world.

1 IPCC, 2007: Climate Change 2007: Synthesis Report, Intergovernmental Panel on Climate Change, New York. November 2007, available at: www.ipcc.ch/ipccreports/ar4-syr.htm.; see also International Climate Change Task Force, 2005: Meeting the Climate Challenge, London, available at: www.americanprogress.org/kf/climatechallenge.pdf; ETH Zurich, 2009: Climate Change: Halving Carbon Dioxide Emissions by 2050 Could Stabilize Global Warming, Science Daily, 4 May, Rockville, US, available at: www.sciencedaily.com/releases/2009/05/090502092019.htm.

2 E.g., see Matthews, H. Damon and Ken Caldeira, 2008: Stabilizing Climate Requires Near-Zero Emissions, *Geophysical Research Letters*, 35; Solomon, Susan, Glan-Kasper Plattner, Reto Knuttl, and Pierre Friedlingstein, 2008: Irreversible Climate Change Due to Carbon Dioxide Emissions, *Proceedings of the National Academy of Sciences*, 106(6), 1704-1709.

3 IPCC, 2005: IPCC Special Report on Carbon Dioxide Capture and Storage, Cambridge University Press, Cambridge, UK, available at: www.ipcc.ch/ipccreports/srccs.htm.

4 Data taken from Li, X. et al., 2009: CO_2 Point Emission and Geological Storage Capacity in China, *Energy Procedia*, 1(1), 2793-2800; Dahowski, R.T. et al., 2009: A Preliminary Cost Curve Assessment of Carbon Dioxide Capture and Storage Potential in China, *Energy Procedia*, 1(1), 2849-56; and Liu, Y. et al., 2005: Preliminary Estimation of CO_2 Storage Capacity of Coalbeds in China, *Chinese Journal of Rock Mechanics and Engineering* (in Chinese), 24(16), 2947-52."

5 By 2020, China aims to have in place 300 GW of hydro, 150 GW of wind, and 20 GW of solar power capacity. For comparison, the U.S. Energy Information Administration suggests that by 2020 the US will have ~78 GW of hydropower capacity, along with ~67 GW of wind and ~12 GW of solar. Zheng, Lifei and Lijun Mao, 2009; US EIA, 2009a: Annual Energy Outlook 2009, US Department of Energy Energy Information Administration, Washington DC, available at: www.eia.doe.gov/oiaf/servicerpt/stimulus/aeostim.html.

6 Jiang, Kejun et al., 2008: China's Energy Demand and CO_2 Emissions Scenarios in 2050" (Chinese), *Advances in Climate Change Research*, 4(5).

7 Zhao, L.F., 2009: CO_2 Capture Cost Analysis in the Coal Chemical Industry (Chinese), unpublished manuscript; US DOE, 2007: Cost and Performance Baseline for Fossil Energy Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity, US Department of Energy National Energy Technology Laboratory, Pittsburgh, available at: www.netl.doe.gov/energy-analyses/pubs/Bituminous%20Baseline_Final%20Report.pdf

8 Dahowski, R.T. et al., 2009; Li, X. et al., 2009.

9 Li, X. et al., 2009.

10 Dahowski, R.T. et al., 2009; Li, X. et al., 2009.

11 Estimated by report authors Li and Wei based on data from Li, X. et al., 2009.

12 Work in progress by Z. Zheng, E.D. Larson, Z. Li, G. Liu and R.H. Williams via personal communication.

13 Ibid.

14 See Dahowski, R.T. et al., 2009 for more information on the potential for enhanced CO_2-driven oil and gas recovery potential in China. China consumed 2.9 billion barrels of oil in 2008; see BP, 2009: Statistical Review of Global Energy 2009, London.

15 Total number of large point sources and source-sink matching for all sources taken from Dahowski, R.T. et al., 2009 and Li, X. et al., 2009; GIS-based proximity analysis for high-concentration CO_2 sources was done by report authors Li and Wei.

16 Friedmann, Julio, 2009: Personal Interview, Beijing; Sung, S. Ming, 2009: Personal Interview, Beijing; Li, Xiaochun, 2009: Personal Interview, Beijing.

17 The U.S. has launched the "Building Regulatory Capacity in China – Guidelines for Safe and Effective Carbon Capture and Storage" project, while the EU has launched the "Support to Regulatory Activities for Carbon Capture and Storage" (STRATCO2) project; E3G and Germanwatch, 2009: Carbon Capture and Storage in China, Berlin, Germany, available at: www.germanwatch.org/klima/ccs-china.pdf.

18 E.g., see the WRI-Tsinghua Guidelines Project. WRI, 2009: Ensuring Safe Carbon Capture and Storage in China, World Resources Institute, Washington DC, available at: www.wri.org/stories/2009/03/ensuringsafe-carbon-capture-and-storage-china.