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Comparing Existing Pipeline Networks with the Potential Scale of Future U.S. CO_2 Pipeline Networks

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ABSTRACT: There is growing interest regarding the potential size of a future U.S. dedicated CO_2 pipeline infrastructure if carbon dioxide capture and storage (CCS) technologies are commercially deployed on a large scale. For example, the Congressional Research Service notes in a recently published analysis, "There is an increasing perception in Congress that a national CCS program could require the construction of a substantial network of interstate CO_2 pipelines." The CRS report list a number of bills and one recently enacted public law that all call for assessments of the feasibility of creating a national CO_2 pipeline network and recommendations for the most cost-effective means of implementing a CO_2 transportation system. In trying to understand the potential scale of a future national CO_2 pipeline network, comparisons are often made to the existing pipeline networks used to deliver natural gas and liquid hydrocarbons to markets within the U.S. This paper assesses the potential scale of the CO_2 pipeline system needed under two hypothetical climate policies and compares this to the extant U.S. pipeline infrastructures used to deliver CO_2 for enhanced oil recovery (EOR), and to move natural gas and liquid hydrocarbons from areas of production and importation to markets. The data presented here suggest that the need to increase the size of the existing dedicated CO_2 pipeline system should not be seen as a significant obstacle for the commercial deployment of CCS technologies.

KEY WORDS: carbon dioxide capture and storage; pipelines, carbon management; climate change.

There is growing interest regarding the potential size of a future U.S. dedicated CO_2 pipeline infrastructure if carbon dioxide capture and storage (CCS) technologies are commercially deployed on a large scale. For example, the Congressional Research Service notes in a recently published analysis, "There is an increasing perception in Congress that a national CCS program could require the construction of a substantial network of interstate CO_2 pipelines." The CRS report list a number of bills and one recently enacted public law that all call for assessments of the feasibility of creating a national CO_2 pipeline network and recommendations for the most cost-effective means of implementing a CO_2 transportation system.[1] In trying to understand the potential scale of a future national CO_2 pipeline network, comparisons are often made to the existing pipeline networks used to deliver natural gas and liquid hydrocarbons to markets within the U.S. This paper assesses the potential scale of the CO_2 pipeline system needed under two hypothetical climate policies and compares this to the extant U.S. pipeline infrastructures used to deliver CO_2 for enhanced oil recovery (EOR), and to move natural gas and liquid hydrocarbons from areas of production and importation to markets. The data presented here suggest that the need to increase the size of the existing dedicated CO_2 pipeline system should not be seen as a significant obstacle for the commercial deployment of CCS technologies.

The Current U.S. CO_2 Pipeline System

There are currently 3,900 miles of dedicated CO_2 pipelines in the U.S.[2], of varying lengths and diameters, serving enhanced oil recovery (EOR) projects. Eighty percent of the existing CO_2 pipeline infrastructure was built to deliver CO_2 into and within the Permian Basin of West Texas for the purpose of EOR (See Figure 1). The earliest pipelines were built in the 1970s in Texas, where the first CO_2-floods were initiated. Other regions with significant CO_2 pipeline infrastructure include Wyoming/Colorado, Mississippi/Louisiana, Oklahoma, and North Dakota. The largest of the existing CO_2 pipelines is the 30-inch Cortez Pipeline which was completed in 1983 and runs for slightly more than 500 miles from the McElmo Dome in Southwestern Colorado to the EOR fields in West Texas.[3]

As shown in Figure 2, nearly three-quarters of this existing CO_2 pipeline infrastructure was built in the 1980s and 1990s largely driven by energy security concerns and resulting federal tax incentives designed to boost domestic oil production. In the 1980s the major impetus for development of this large CO_2 pipeline network was provided by significant changes to the Windfall Profits Tax that preferentially benefited enhanced oil recovery projects (taxed at 30%) as opposed to conventional oil production projects that were taxed at 70%. While CO_2-driven EOR oil production was a relatively minor source of domestic oil production at that time, this change in the Windfall Profits Tax was a significant incentive for the commercial development of the large natural CO_2 deposits (domes) as well as the large CO_2 pipeline infrastructure that continue to supply most of the CO_2 used for EOR in West Texas as well as in Mississippi and Louisiana.[4] These infrastructures which were being developed in the 1980s allowed for the quick adoption and expansion of the CO_2-EOR production method in the 1990s.[5]

[1] Congressional Research Service. "Pipelines for Carbon Dioxide (CO2) Control: Network Needs and Cost Uncertainties." CRS Order Code RL34316. Washington, DC. January 10, 2008.
[2] U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration, Office of Pipeline Safety, Natural Gas Transmission Pipeline Annual Mileage Database. http://ops.dot.gov/stats/stats.htm. Last updated. 07/30/2007.
[3] IPCC: Chapter 4.
[4] C. Norman. "CO_2 for EOR is Plentiful but Tied to Oil Price." Oil & Gas Journal. February 7, 1994.
[5] During the early 1980s, CO_2 floods comprised a relatively minor aspect (approximately 5%) of total U.S. EOR production (with steam flooding the most commonly applied method). However, by 1990 CO_2-driven

Figure 1: Overview of Existing US CO_2 Pipelines[6]

Since 1990, the most significant federal incentive for CO_2 EOR stems from the Section 43 tax credit for Enhanced Oil Recovery which was put in place as a result of the Gulf War and domestic concerns about energy security arising from that crisis. The Section 43 tax credit is applicable to 15% of the capital costs in starting up a qualified EOR project, capital improvements to an operational flood, and perhaps most importantly, the credit is applicable to CO_2 purchases.[7] Over the period 1994-2004, an estimated $980 to $1,500 million (in constant 2005 dollars) in tax credits related to CO_2-driven EOR have been claimed and granted by the U.S. Internal Revenue Service (IRS).[8] This estimated $980 to $1,500 million outlay is only the cost to the federal government and does not include state tax credits designed to boost domestic oil production through enhanced oil recovery.[9]

EOR accounted for approximately 15% of all EOR production. F.D. Martin. "Enhanced Oil Recovery for Independent Producers." Society of Petroleum Engineers Paper SPE/DOE 24142. 1992.

[6] Map from Oil and Gas Journal.

[7] IRS Form 8830 (http://www.irs.gov/pub/irs-pdf/f8830.pdf) describes in detail what are allowable "enhanced oil recovery costs. The Enhanced Oil Recovery Tax Credit was not available for tax years 2006 and 2007 because the price of oil was sufficiently high that the tax credit was completely phased out (please see http://www.irs.gov/irb/2007-34_IRB/ar10.html).

[8] The IRS Statement of Income "Table 21 - Returns of Active Corporations, Other Than Forms 1120-REIT, 1120-RIC, and 1120S" reports data for the cost of the Enhanced Oil Recovery tax credit for the years 1994-2004 (http://www.irs.gov/taxstats/article/0,,id=170734,00.html). As this IRS publication does not specifically break out tax credits for CO_2-driven EOR from other approved EOR methods (e.g., steam flooding), data from the Oil and Gas Journal's biennial survey of EOR production was used to compute what fraction of EOR in the U.S. is specifically CO_2-driven. The authors used this ratio to apportion the reported aggregate Section 29 tax credit expenditures into estimates for CO_2-driven EOR and all other approved methods. G. Moritis. "CO_2 injection gains momentum." Oil and Gas Journal. Volume 104 Issue 15, Apr 17, 2006.

[9] F.D. Martin (1992) lists a number of state tax incentives for CO_2-EOR and other secondary and tertiary enhanced oil recovery methods.

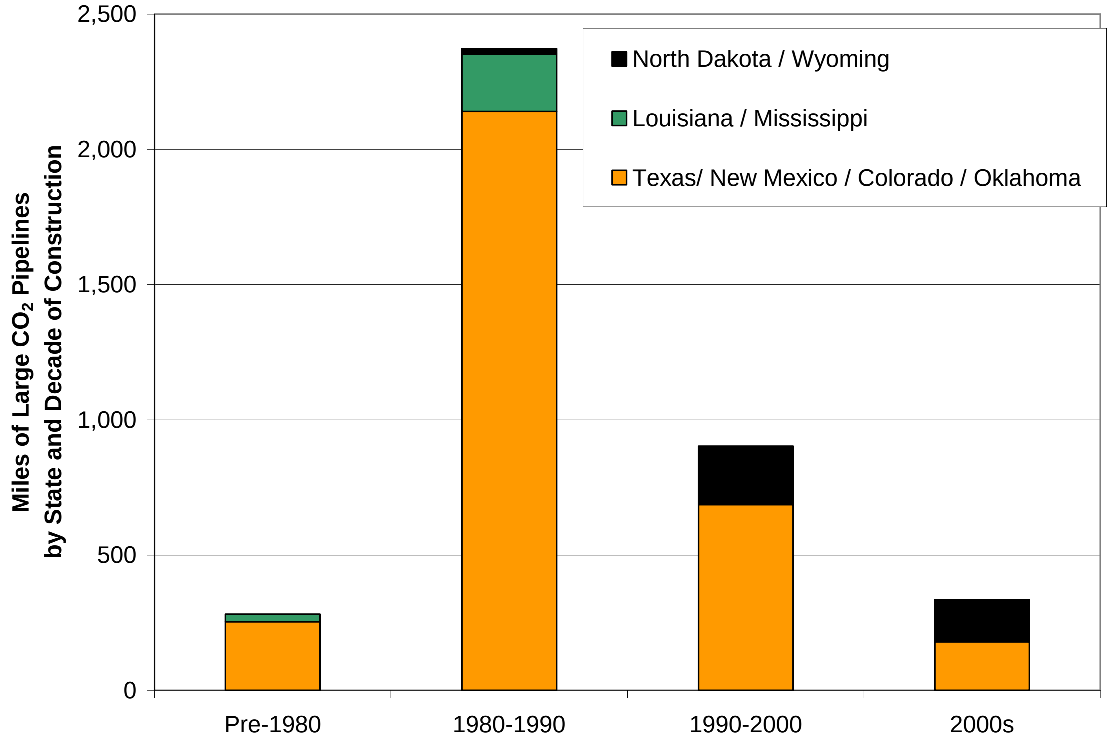

Figure 2: Build-out of Existing U.S. CO_2 Pipelines by Region

Drivers for an Expanded U.S. CO_2 Pipeline System

While the existing pipelines built to deliver CO_2 to ageing oilfields for EOR will provide a useful starting point for a larger system for CCS deployment, a key determinant that will govern the necessary size of a future U.S. CO_2 pipeline network is the proximity of each large industrial facility that will utilize CCS technologies (e.g., power plants, refineries) to suitable deep geologic storage reservoirs. For the U.S., because of the numerous large and geographically well-distributed deep geologic CO_2 storage reservoirs, fully 95% of the largest CO_2 point sources lie within 50 miles of a potential storage reservoir.[10] It is therefore difficult to envision the need for long transcontinental CO_2 pipelines at the scale routinely built and operated to move oil and natural gas from relatively isolated pockets of production or import (e.g., Alaska, Gulf Coast) to distant and disperse markets.

However, the overriding determinant of extent of the U.S. CO_2 transportation infrastructure will be the stringency and rate of implementation of future climate policy. Most climate policies currently being debated within the U.S. exhibit costs that are bounded by those associated with implementing WRE450 and WRE550 stabilization pathways. Figure 3 shows the projected cost of CO_2 emissions permits under these hypothetical WRE450 and WRE550 stabilization scenarios.[11] Figure 4 illustrates the resulting commercial adoption of CCS technologies by the

[10] JJ Dooley, CL Davidson, RT Dahowski, MA Wise, N Gupta, SH Kim, EL Malone. 2006. *Carbon Dioxide Capture and Geologic Storage: A Key Component of a Global Energy Technology Strategy to Address Climate Change.* Joint Global Change Research Institute, Battelle Pacific Northwest Division. PNWD-3602. College Park, MD.

[11] Projected CO_2 permit prices taken from JA Edmonds, MA Wise, JJ Dooley, SH Kim, SJ Smith, PJ Runci, LE Clarke, EL Malone, and GM Stokes. 2007. *Global Energy Technology Strategy Addressing*

U.S. electric utility sector in response to these two hypothetical climate policies,[12] while Figure 5 shows the resulting CO_2 pipeline infrastructure requirements.

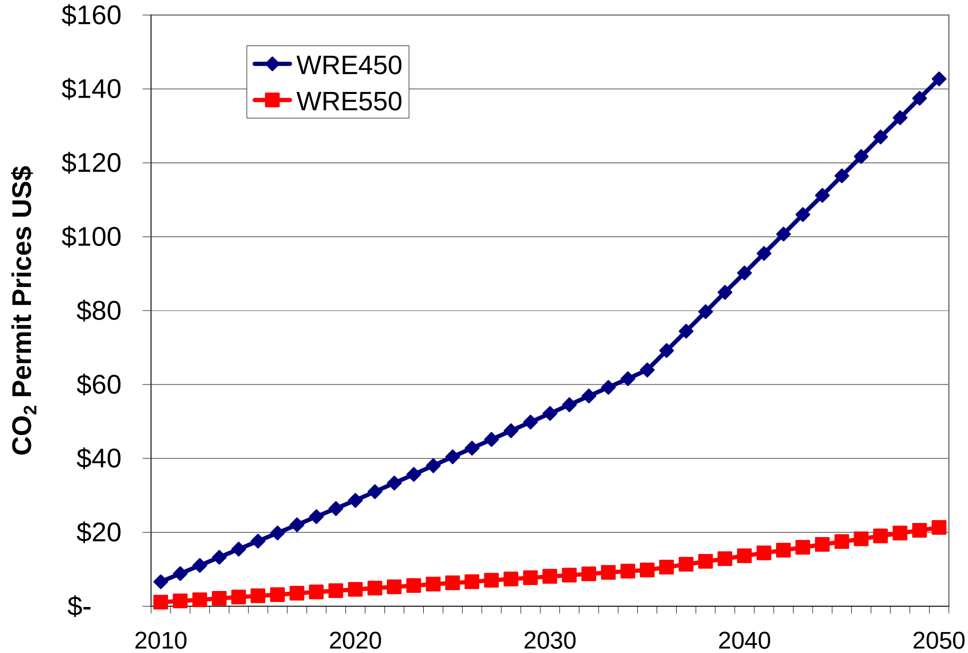

Figure 3: Projected CO_2 permit prices for WRE450 and WRE550 stabilization scenarios

Estimating the Scale of a Future U.S. CO_2 Pipeline System

In the more stringent WRE450 stabilization case, as much as 120,000 miles of dedicated CO_2 pipelines would need to be built and operated in the U.S. between 2010 and 2050. If implemented, a hypothetical stabilization policy such as this would result in perhaps 54 $GtCO_2$ of CO_2 being captured and stored in deep geologic reservoirs by 2050. Adoption of CCS technologies at this pace and on this scale (along with continued expansion of renewables and nuclear power) would result in a nearly complete decarbonization of the U.S. electricity sector by the middle of this century.[13] It is important to realize that the projected 120,000 miles of new CO_2 pipeline would be built incrementally over time as the commercial deployment of CCS systems accelerates in response to the rising CO_2 permit price. Thus approximately only 25% of the total projected 120,000 miles of CO_2 pipeline would need to be built before 2030 under this hypothetical WRE450 scenario.

Climate Change: Phase 2 Findings from an International Public-Private Sponsored Research Program. Joint Global Change Research Institute, Battelle Pacific Northwest Division, College Park, MD.

[12] From JJ Dooley, CL Davidson, MA Wise, RT Dahowski. "Accelerated Adoption of Carbon Dioxide Capture and Storage within the United States Electric Utility Industry: the Impact of Stabilizing at 450 ppmv and 550 ppmv." In, ES Rubin, DW Keith and CF Gilboy (Eds.), *Greenhouse Gas Control Technologies*, *Volume I* (pp. 891-899). Elsevier Science, 2005.

[13] These and subsequent projections of the commercial deployment of CCS technologies under WRE450 and WRE550 scenarios are taken from Dooley, Davidson, Wise and Dahowski 2005.

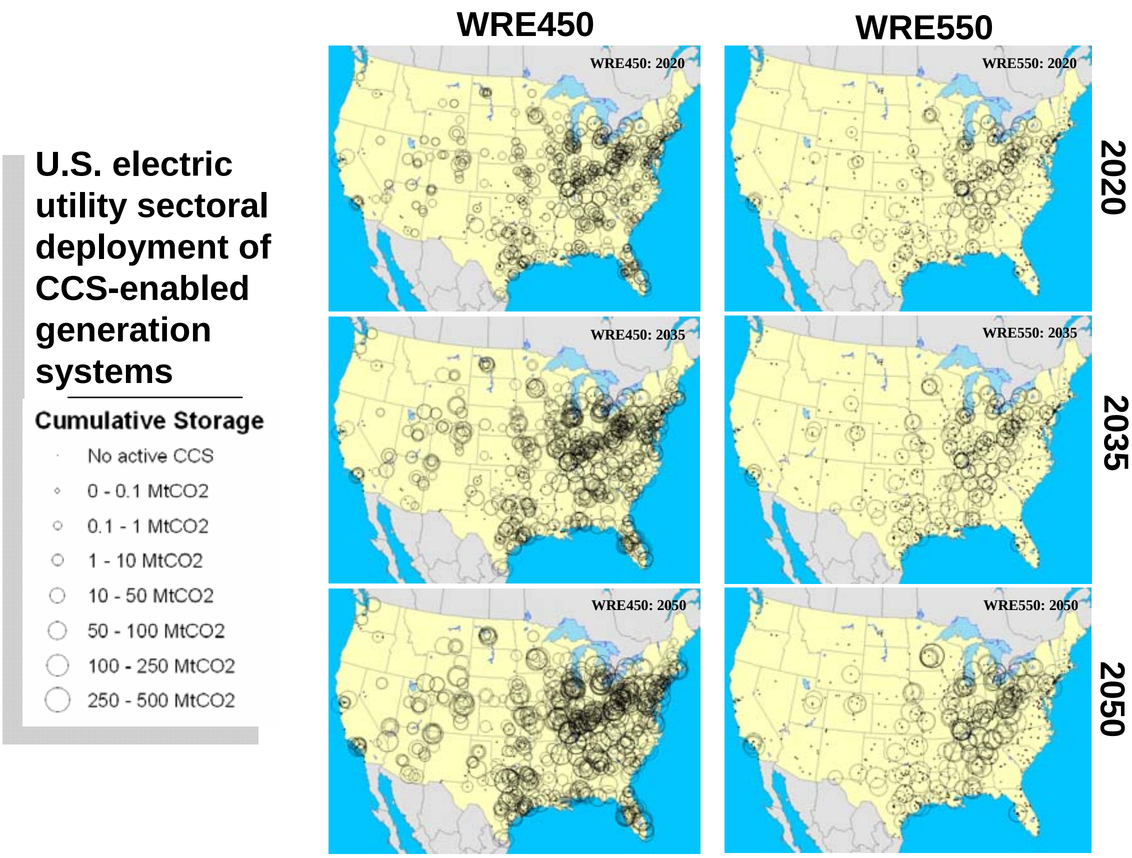

Figure 4: Projected commercial adoption of CCS technologies by the U.S. electric utility sector in response to WRE450 and WRE550 climate stabilization policies

In the less stringent WRE550 stabilization case, an estimated 12,000 miles of dedicated CO_2 pipeline would need to be built and operated in the U.S. between 2010 and 2050. While less stringent than the WRE450 scenario, this hypothetical climate policy results in significant reductions in greenhouse gas emissions – due in part to significant commercial adoption of CCS technologies across the U.S. economy. For example, in this WRE550 scenario, the U.S. electric power sector's adoption of CCS technologies could result in approximately 19 $GtCO_2$ being stored in deep geologic formations by 2050. Again, this build-up of the CO_2 pipeline network unfolds over time in response to the escalating price of CO_2 emissions permits. In the near term (2010-2030), the growth in the CO_2 pipeline infrastructure across the entire U.S. economy under the WRE550 scenario equates to an approximate doubling of the extant CO_2 pipeline system.

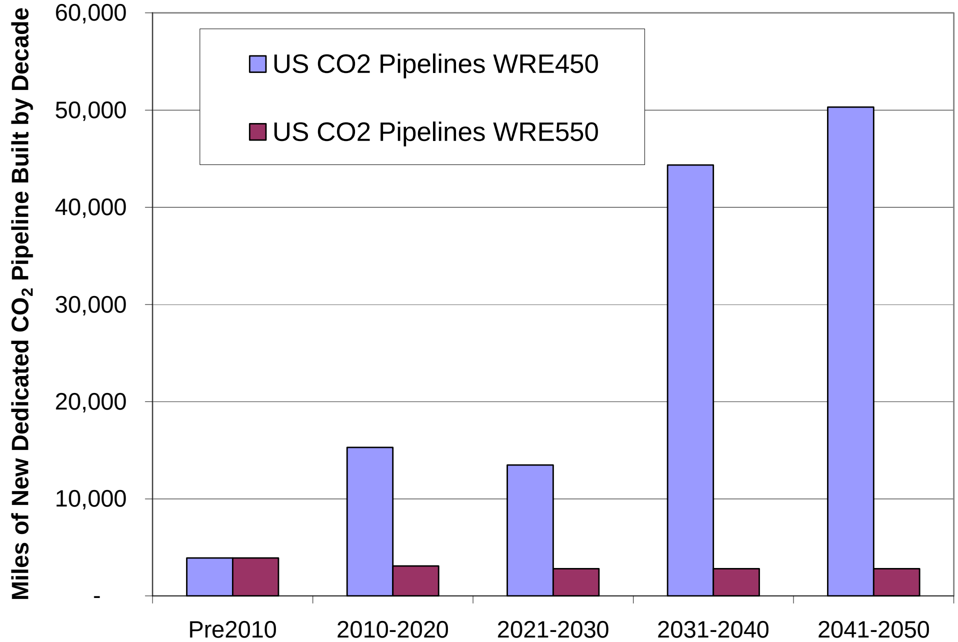

Figure 5: Projected U.S. CO_2 pipeline growth in response to WRE450 and WRE550 stabilization scenarios

Discussion

While the size of these future CO_2 pipeline infrastructures may seem large, it is important to put this potential demand for CO_2 pipelines in some context. Since 1950, more than 400,000 miles of pipeline have been constructed in the U.S. to move liquid hydrocarbons and natural gas from areas of production and/or importation to distant markets where these fuels are distributed to final end-users (see Figures 6 and 7).[14] This estimate of 400,000 miles accounts for only the large inter- and intrastate natural gas transmission and major liquid hydrocarbon pipeline networks. It is an intentionally narrow accounting of the size of the nation's total liquid and natural gas hydrocarbon pipeline distribution system and is intended to only account for significant pipeline infrastructures that would be most analogous to those used for CO_2 transport.[15]

[14] All data presented here on the size of the existing U.S. natural gas and liquid hydrocarbon pipeline infrastructures are derived from data contained in the U.S. Department of Transportation Natural Gas Transmission Pipeline Annual Mileage Database (2007).

[15] This estimate does not include the more than 900,000 miles of natural gas distribution pipeline mains used to move natural gas from these large transmission lines into communities nor does it include smaller natural gas pipelines that would be needed to move natural gas "the last mile" to its final point of consumption (e.g., a home, factory, or commercial building), built since 1950.

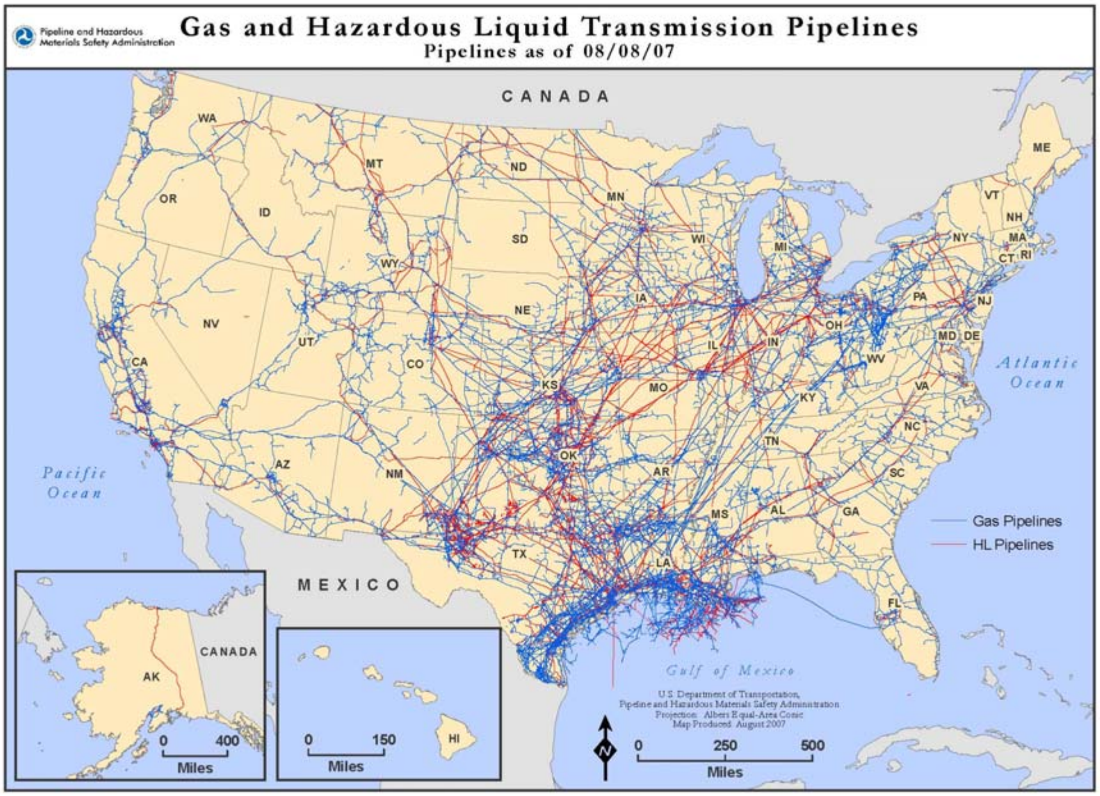

Figure 6: Existing Natural Gas and Liquid Pipelines in the US[16]

Thus, over the course of the past 50 years, the U.S. economy was able to develop and maintain a transmission pipeline system for moving hydrocarbons that is *significantly* larger than the total amount of CO_2 pipeline that would need to be built in the 40-year period 2010-2050 under the more stringent WRE450 case. It is also important to note that the U.S. GDP has grown and is expected to continue doing so in the future. Between 1950 and 2000, U.S. GDP grew from $2 to $11 trillion dollars (in constant 2005 US$). Between 2010 and 2050, the U.S. GDP is projected to double from approximately $13 to $26 trillion (in constant 2005 US$). In this regard it is particularly noteworthy that in both the 1950s and 1960s, with a much smaller economy than that which exists today or that which might exist between now and mid-century, more than 100,000 miles of these large hydrocarbon and natural gas transmission pipelines were built.

[16] Map from the U.S. Department of Transportation's National Pipeline Mapping System. http://www.npms.phmsa.dot.gov/Documents/NPMS_Pipelines.pdf

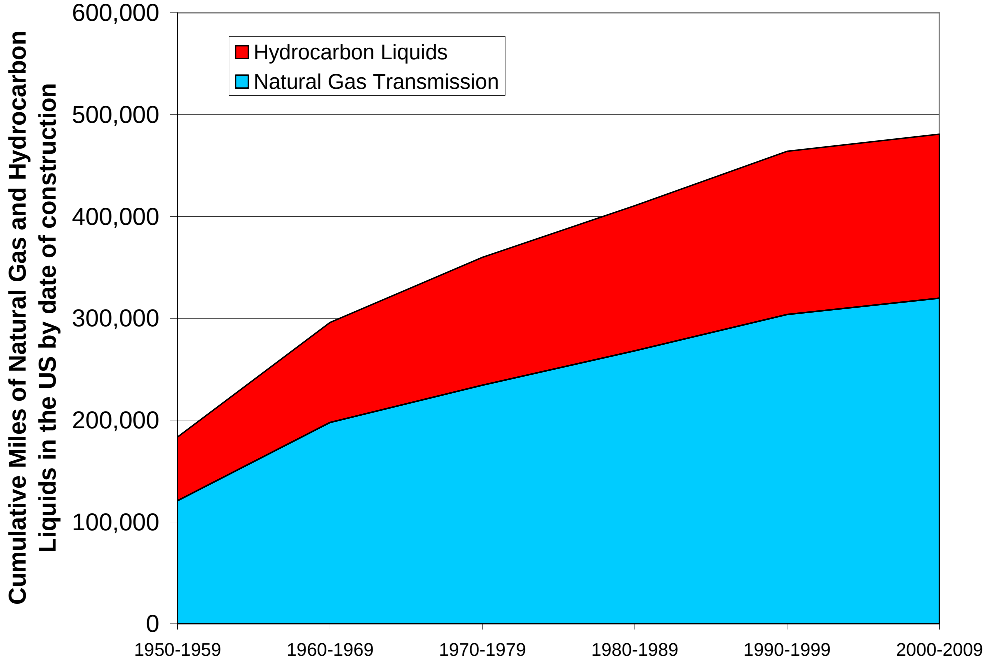

Figure 7: Cumulative growth in selected U.S. natural gas and liquid hydrocarbon pipeline transmission infrastructures since 1950

In both the WRE450 and WRE550 cases modeled here, the demand for new CO_2 pipeline between now and 2030 equates to a few hundred miles to less than a couple of thousand miles per year as a handful (for the WRE550 case) to a dozen (for the WRE450 case) large power plants and other industrial facilities adopt CCS systems each year. Given the scale of the existing hydrocarbon transmission pipeline network and given that much of it was built in a relatively short period many decades ago when the U.S. economy was significantly smaller, it is does not appear that the cost burden imposed by the need to build a CO_2 pipeline infrastructure should pose a significant barrier for the commercial deployment of CCS systems in the U.S.