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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

Interest is growing regarding the potential size of a future U.S.-dedicated carbon dioxide (CO_2) pipeline infrastructure if carbon dioxide capture and storage (CCS) technologies are commercially deployed on a large scale within the United States. This paper assesses the potential scale of the CO_2 pipeline system needed under two hypothetical climate policies (WRE450 and WRE550 stabilization scenarios); a comparison is then made to the extant U.S. pipeline infrastructures used to deliver CO_2 for enhanced oil recovery and to move natural gas and liquid hydrocarbons from areas of production and importation to markets. The analysis reveals that between 11,000 and 23,000 additional miles of dedicated CO_2 pipeline might be needed in the United States before 2050 across these two cases. While either case represents a significant increase over the 3900 miles that comprise the existing national CO_2 pipeline infrastructure, it is important to realize that the demand for additional CO_2 pipeline capacity will unfold relatively slowly and in a geographically dispersed manner as new dedicated CCS-enabled power plants and industrial facilities are brought online. During the period 2010–2030, this analysis indicates growth in the CO_2 pipeline system on the order of a few hundred to less than 1000 miles per year. By comparison, during the period 1950–2000, the U.S. natural gas pipeline distribution system grew at rates that far exceed these growth projections for a future CO_2 pipeline network in the U.S. This analysis indicates that the need to increase the size of the existing dedicated CO_2 pipeline system should not be seen as a major obstacle for the commercial deployment of CCS technologies in the United States. While there could be issues associated with siting specific segments of a larger national CO_2 pipeline infrastructure, the sheer scale of the required infrastructure should not be seen as representing a significant impediment to U.S. deployment of CCS technologies.

***Keywords*:** carbon dioxide capture and storage; pipelines, carbon management; climate change.

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1. Introduction

Interest and concern are growing regarding the potential size of the future U.S.-dedicated carbon dioxide (CO_2) pipeline infrastructure related to large-scale deployment of carbon dioxide capture and geologic storage (CCS) technologies. For example, in early 2008, the Congressional Research Service (CRS) stated, "[t]here 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 lists a number of bills and one recently enacted public law that require assessments of the feasibility of creating a national CO_2 pipeline network as well as 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 United States. This paper assesses the potential scale of the CO_2 pipeline system needed under two hypothetical climate policies and compares these to the extant U.S. CO_2 pipeline infrastructure (See Figure 1, left-hand panel) and the interstate and intrastate natural gas transmission pipeline infrastructure (See Figure 1, right-hand panel). The analysis presented here suggests 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.

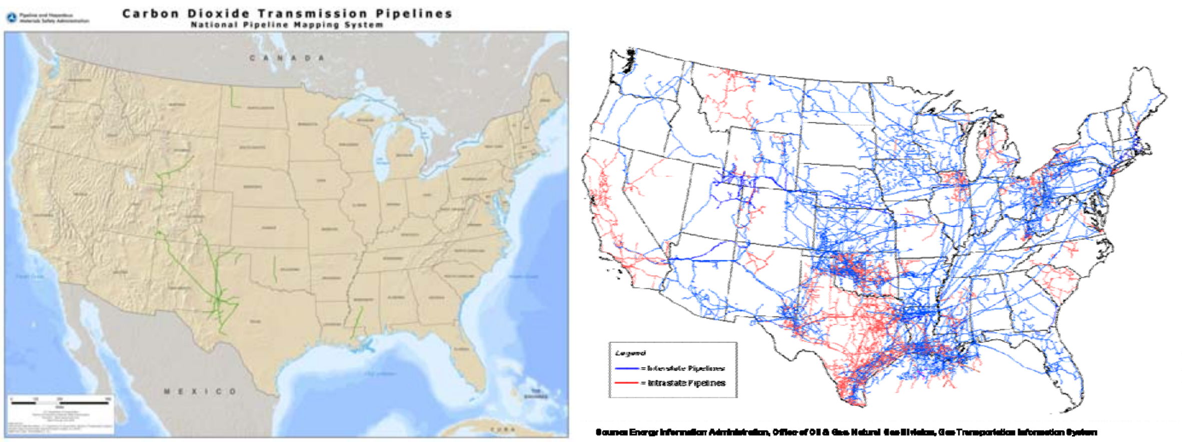

Figure 1: Existing U.S. CO_2 Pipelines (left-hand panel, [2]) and Existing U.S. Interstate and Intrastate Natural Gas Transmission Pipelines (left-hand panel, [3])

2. The Existing U.S. CO_2 Pipeline System

There are currently 3900 miles of dedicated CO_2 pipelines in the United States—of varying lengths and diameters—built primarily to serve CO_2-driven enhanced oil recovery (EOR) projects. Many of these pipelines deliver CO_2 from large natural underground accumulations, while some originate at anthropogenic sources (e.g., natural gas and syngas processing facilities). 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 CO_2-driven EOR [4]. 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 [5].

Nearly three-fourths 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 was provided by significant changes to the Windfall Profits Tax that preferentially benefited EOR projects (taxed at 30 percent) over conventional oil production (taxed at 70 percent).

During the relatively short period of 1980–1985, major U.S. oil companies paid over $88.5 billion (in constant 2005 dollars) in Windfall Profits Taxes [6]. 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 construction of the CO_2 pipeline infrastructure that continues to supply most of the CO_2 used for EOR in West Texas, Mississippi, and Louisiana [7]. 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 [8].[2]

Since 1990, the most significant federal incentive for CO_2-driven EOR stems from the Section 43 Enhanced Oil Recovery Tax Credit, which was enacted as a result of the Gulf War and renewed domestic concerns about energy security. The Section 43 tax credit can be applied to 15 percent of the capital costs in starting up a qualified EOR project and capital improvements to an operational flood. Perhaps most importantly, the credit is applicable to CO_2 purchases (IRS 2005 [9] describes allowable costs in detail). Over the period 1994–2005,[3] an estimated $1.3 to $1.9 billion (in constant 2005 dollars) in tax credits related to CO_2-driven EOR have been granted by the U.S. Internal Revenue Service.[4] This estimated $1.3 to $1.9 billion outlay is only the cost to the federal government and does not include state tax credits designed to boost domestic oil production through EOR.[5]

3. Drivers for an Expanded U.S. CO_2 Pipeline Infrastructure

The existing pipelines built to deliver CO_2 to aging oilfields for EOR may provide a starting point for an expanded national CO_2 pipeline system. Nonetheless, a key determinant governing 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 United States—because of the numerous large and geographically well-distributed deep geologic CO_2 storage reservoirs—fully 95 percent 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 dispersed markets.

However, the overriding determinant of the extent of future growth of the nation's pipeline-based CO_2 transportation infrastructure will be the stringency and rate of implementation of future climate policy coupled with the cost competitiveness of CCS-derived emission reductions. Although many potential climate policies are debated in the United States, this analysis will focus on the impact of hypothetical future U.S. climate policies that follow the WRE450 and WRE550 stabilization pathways [11]. Since their original publication, these WRE pathways have become widely used benchmarks of requirements to stabilize atmospheric concentrations of greenhouse gases in an economically efficient manner [12]. The WRE450 and WRE550 climate policies are also useful for the present analysis as the range of costs of complying with these hypothetical policies bound much of the proposed climate legislation actively being considered in the U.S. Congress [13]. Thus, these WRE pathways can shed light on the potential scale of CCS deployment within the United States. The marginal cost of reducing greenhouse gas emissions is represented here as a price on CO_2 emissions to the atmosphere. This carbon permit price rises rapidly in the WRE450 case, reaching $29/ton$CO_2$ by 2020, $64/ton$CO_2$ by 2035, and $140/ton CO_2 by 2050. In the WRE550 case, carbon permit prices increase more slowly, but these prices are still sufficient to send a powerful

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[2] 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 EOR accounted for approximately 15% of all EOR production[8].

[3] 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 (See IRS 2007 [15] for further details).

[4] 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 1994-2005 (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), historical data from the Oil and Gas Journal's biennial EOR Survey were used to compute what fraction of EOR in the U.S. is specifically CO_2-driven for each reported year [17]. The authors used these ratios to apportion the reported aggregate Section 29 tax credit expenditures into estimates for CO_2-driven EOR and all other approved methods, over this time period.

[5] Martin [8] lists a number of state tax incentives for CO_2-EOR and other secondary and tertiary enhanced oil recovery methods.

signal to the economy to begin decarbonising: \$5/tonCO_2 by 2020, \$10/tonCO_2 by 2035, and \$21/ton CO_2 by 2050. In both cases, carbon permit prices continue to increase after 2050, and investment decisions made before 2050 take this into account (CO_2 permit prices taken from Edmonds et al. [14]).

Figure 2 illustrates the resulting commercial adoption of CCS technologies by the U.S. electric utility sector in response to these two hypothetical climate policies. Figure 3 shows the resulting CO_2 pipeline infrastructure requirements under each scenario.

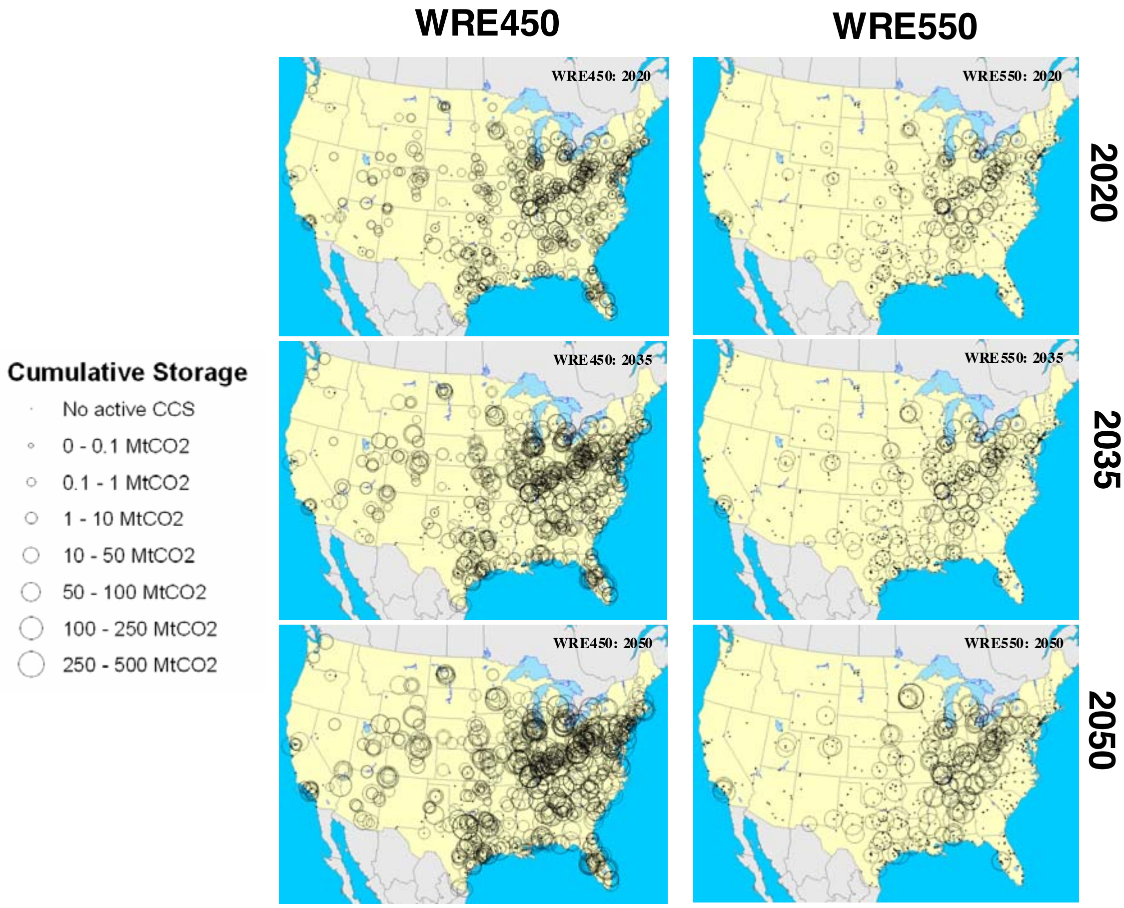

Figure 2: U.S. electric utility deployment of CCS-enabled generation systems under WRE450 and WRE550 hypothetical climate policies (Figure from Dooley et al. [15])

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

4.1. WRE450

In the more-stringent WRE450 stabilization case, up to 23,000 miles of dedicated CO_2 pipelines must be built and operated in the U.S. between 2010 and 2050. If implemented, a hypothetical stabilization policy such as this could result in approximately 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 (See Dooley et al. [14] for more details on these scenarios). It is important to realize that the projected 23,000 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, only about 25 percent of the total projected 23,000 miles of CO_2 pipeline must be built before 2030 under this hypothetical WRE450 scenario.

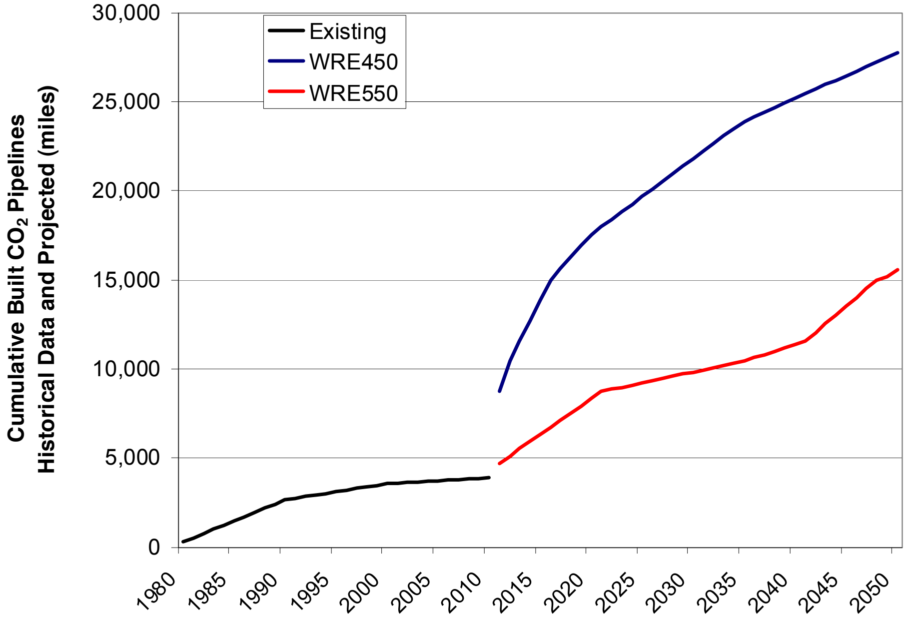

Figure 3: Projected commercial adoption of CCS technologies by the U.S. electric utility sector in response to WRE450 and WRE550 climate stabilization policies

4.2. WRE550

In the less-stringent WRE550 stabilization case, an estimated 11,000 miles of dedicated CO_2 pipeline must be added to the existing CO_2 pipeline system 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 U.S. economy under the WRE550 scenario equates approximately to a doubling of the current CO_2 pipeline system. Table 1 summarizes key data on the build-out of the national CO_2 pipeline system under the hypothetical WRE450 and WRE550 climate policies.

5. Discussion

While the size of these future CO_2 pipeline infrastructures may seem large, it is important to put the potential demand for CO_2 pipelines in some context. Since 1950, more than 270,000 miles of large inter- and intrastate natural gas pipeline were constructed in the United States to move natural gas from areas of production and/or importation to markets across the country (see Figure 1, left-hand panel).[6] This is an intentionally narrow accounting of the size of the nation's total liquid and natural gas hydrocarbon pipeline distribution system and is

[6] All data presented here on existing U.S. pipeline infrastructures are derived from USDOT [4].

intended to account only for those aspects of the pipeline infrastructure that would be most analogous to those used for CO_2 transport.[7]

Table 1: Summary Statistics of potential build-out of the U.S. CO_2 pipeline system 2010–2050 in response to WRE450 and WRE550 climate stabilization policies

	WRE 450 Stabilization	**WRE 550 Stabilization**
Average annual number of power plants adopting CCS 2010–2030	~ dozen per year	1–3 per year
CCS Adoption by high-purity CO_2 point sources 2010–2030[8]	(nearly) all high-purity CO_2 point sources decarbonized within 10 years	(relatively) slower adoption of CCS by high-purity CO_2 point sources
Average growth in CO_2 pipelines 2010–2030	<900 miles/year	~ 300 miles/year
Average source-sink pipeline length	Tens of miles	Tens of miles
CO_2 Pipelines in Operation 2030	~22,000 miles	<10,000 miles (i.e., approximately a doubling of the existing CO_2 pipeline system)
CO_2 Pipelines in Operation 2050	~28,000 miles	~16,000 miles

Since 1950, the U.S. economy has developed and maintained a natural gas pipeline transmission system that is *significantly* larger than the total amount of CO_2 pipeline that must 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. economy, as measured by its gross domestic product (GDP), has grown and is expected to continue growing in the future. Between 1950 and 2000, the 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 exists today or that might exist between now and mid-century, more than 100,000 miles of these large natural gas transmission pipelines were built without disruption of the nation's energy infrastructure or macroeconomy.

In both the WRE450 and WRE550 cases modelled here (Figure 4), a handful to a dozen large power plants and other industrial facilities are expected to adopt CCS systems each year, demanding between a few hundred and a few thousand miles of new pipeline constructed per year. Given the scale of the existing natural gas transmission pipeline network and given that much of it was built in a relatively short period during a time that the U.S. economy was significantly smaller, the cost burden imposed by the need to build a CO_2 pipeline infrastructure should not pose a significant barrier for the commercial deployment of CCS systems in the United States.

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[7] This estimate does not include the more than 900,000 miles of natural gas distribution pipeline mains built since 1950 that 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).

[8] There are approximately 350 "high purity" stationary CO_2 point sources in the U.S. These tend to be smaller facilities and therefore they account for only about 6% of the emissions from large stationary CO_2 point sources (large is defined here as more than 100,000 tonsCO_2/year). These high purity CO_2 point sources include natural gas processing, ethanol, ammonia, ethylene oxide facilities). See Dooley et. al. 2007 for further details.

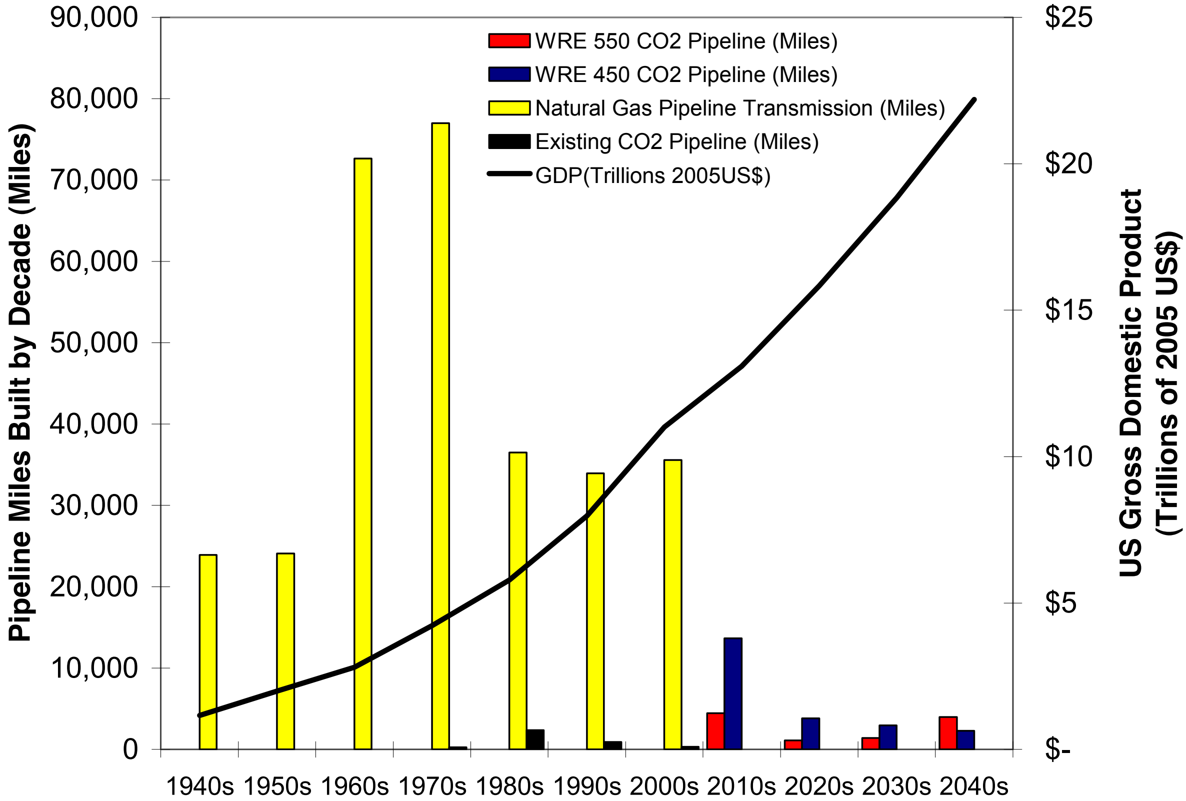

Figure 4: Growth in selected U.S. pipeline systems since 1950 as well as projections of growth in a dedicated CO_2 pipeline system between 2010–2050 as well as U.S. GDP 1950–2050

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