

CHAPTER 9: ECONOMY

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Earlier chapters have shown that elevated levels of greenhouse gases (GHGs) in the atmosphere and the resulting impacts on the earth's climate could have significant environmental impacts. This chapter focuses on the economic impacts of climate change. It begins by reviewing the latest Texas demographic and economic trends and forecasts. This is followed by a discussion of the likely economic impacts on the State of projected climate change. The next sections discuss the economics of climate change, the types of public policy that can be used to address it, and the economic impact on the United States and Texas of national climate change policy.

TEXAS POPULATION TRENDS

The 2000 census reported the population of Texas at 20.9 million. The State's January 2007 population is estimated at 23.8 million (Texas State Data Center 2007). Table 9.1 shows population projections under four alternative scenarios based on different assumptions about age, sex and race/ethnicity specific rates of net migration but using common assumptions about fertility and mortality.¹ The 0.5 scenario is recommended as the most appropriate for purposes of long-term planning. While this scenario assumes an annual rate of growth approximately 1.5 percent slower than that experienced in the 1990s, it nonetheless projects that Texas will add 14.9 million persons (a 71.5 percent increase) between 2000 and 2040, a numerical increase greater than the State's total population in 1980. (By way of comparison, the U.S. Census projects only a 50 percent increase in the U.S. population between 2000 and 2050.)

In understanding the potential impacts of climate change on the Texas economy, the key factor is not just how many Texans there will be, but how they are distributed across the state. Under the 0.5 scenario, growth is evident across a majority of Texas counties with 211 of the state's 254 counties showing population increases from 2000 to 2040.² Three areas of the state - the four major urban centers, the counties along the Texas Gulf Coast, and the counties bordering

¹ The 0.0 scenario assumes zero net migration, showing what the size and characteristics of the population will be if population change occurs only as a result of births and deaths. It is provided largely for comparison purposes and is seen as unlikely to characterize the actual patterns that will occur in the coming decades. The 0.5 scenario assumes net migration equal to one-half of the age, sex, and race/ethnicity-specific rates of net migration experienced in the 1990s. This produces a level of growth that is lower than the rate of growth of the 1990s but slightly higher than those in the 1980s (in percentage terms but not in numerical terms). The 1.0 scenario assumes that the net migration rates of the 1990s will characterize those occurring in the future. It represents the high growth alternative because it reflects the 22.8 percent growth in the state's population over this decade. The 2000-2004 projection scenario assumes that the 2000-2004 rates of net migration will prevail from 2000 through 2040. Since the post-2000 population trends featured reduced levels of net migration, the overall population growth under this scenario is less than in the 1.0 scenario.

² This is a marked departure from the pattern of growth experienced from 2000-2004. If these years are used as the basis for projecting future population, 116 counties would lose population, concentrating population in suburban and some central city counties. On the other hand, rural counties and some metropolitan counties especially those in the Panhandle and West Texas would lose population.

on Mexico - are especially important to an understanding of the economic impacts of climate change.

Table 9.1. Texas Population in 2000 and Projections of Population from 2010 to 2040 under Alternative Assumptions of Age, Sex and Race/Ethnicity-Specific Net Migration

Year	Population (millions)				% Change			
	0.0 Scenario	0.5 Scenario	1990-2000 Scenario	2000-2004 Scenario	0.0 Scenario	0.5 Scenario	1990-2000 Scenario	2000-2004 Scenario
2000	20.9	20.9	20.9	20.9				
2010	22.8	24.3	26.1	25.1	9.4	16.7	25.0	20.4
2020	24.3	28.0	32.7	30.3	6.7	15.1	25.6	20.5
2030	25.5	31.8	41.1	36.3	4.6	13.7	25.6	20.1
2040	26.1	35.8	51.7	43.6	2.5	12.3	25.8	20.0
Change 2000-2040	5.2	14.9	30.8	22.7	25.1	71.5	148.0	109.0

Notes: 0.0 Scenario assumes no net migration
 0.5 Scenario assumes net migration equals one-half of that experienced from 1990-2000 – Center recommends using this Scenario for planning purposes.
 1990-2000 Scenario assumes net migration equal to that experienced from 1990-2000
 2000-2004 Scenario assumes net migration equal to that experienced from 2000-2004

Source: Texas State Data Center and Office of the State Demographer, <http://txsdc.utsa.edu>

The four largest metropolitan areas in Texas (Austin-Round Rock, Dallas-Fort Worth-Arlington, Houston-Sugar Land-Baytown, and San Antonio) had a population of 12.8 million in 2000, representing nearly 59 percent of the state’s population. By 2007, their estimated population had risen 19.5 percent to about 15.3 million. These urban areas are projected to have a population of 23.7 million by 2040 (0.5 scenario) and would be home for two out of every three Texans.

The transportation sector is responsible for a sizeable portion of the greenhouse gas (GHG) emissions in Texas. The number of Texans residing in urban areas is a significant indicator of the potential for these emissions. The U.S. Office of Management and Budget defines an Urbanized Area (UZA) as comprising the urban core, densely populated blocks in proximity to the urban core, and the sum of blocks containing 50,000 people or more. It can extend beyond the city limits. The state has 34 UZAs today and is expected to add four additional UZAs by 2010, when it is estimated that over three-fourths of Texans (18.1 million) will live in UZAS (Cline 2008).

The 18 counties along the Texas Gulf Coast are estimated to have added nearly 655,000 persons between 2000 and 2007, a 12.6 percent increase. Under the 0.5 scenario, their population would rise 60 percent, from 5.2 million in 2000 to a projected 8.3 million in 2040.

This would place additional pressures on coastal development that might be significantly affected by a continued rise in sea level.

The population of the 13 counties along the Texas-Mexico border is estimated to have risen about 18 percent between 2000 and 2007. Under the 0.5 scenario, their population would rise from 2.3 million in 2000 to a projected 4.1 million in 2040, a 78 percent increase. This region is the poorest in the state and has major health problems not found in other parts of the state. If, as many anticipate, climate change results in the incidence of tropical diseases moving northward, new health issues are likely to arise. This area is also dependent upon water from the Conchos and Pecos rivers that are likely to experience reduced flows due to projected climate change.

The young and the old represent special populations that are especially vulnerable to a warming climate. Historically, Texans have been younger on average than their counterparts across the nation. For example, the 2000 Census revealed a median age for Texas of 32.3 years as contrasted with a median age for the U.S. of 35.3 years. However, by 2040 the State Data Center projects the median age will rise to 37.9 years. It is forecast that the population 65 years of age and older will total 7.1 million to 8.2 million, up from 2.2 million in 2000.

THE TEXAS ECONOMY

Gross state product (GSP) is a widely used indicator of a state's economy. Like gross domestic product (GDP) for the nation, it is a measure of the total value of goods and services produced in one year. Sometimes referred to as value added, it reflects the economic returns to all employed factors of production—land, labor, capital and management. Table 9.2 shows Texas' GSP for 1990 and 2000 and projected GDP in 2030.

Historically, Texas depended on agriculture and minerals (cotton, cattle, oil and gas) to fuel its economy. Later, refining and petrochemical manufacturing became important. These industries were hit hard by the 1980's downturn in the Texas economy, as oil and gas prices plunged and the state's financial and real estate markets collapsed. By 1990, the share of the goods sector in the state's economy had fallen to about 27 percent and it is expected to remain at that level through 2030 (Texas State Comptroller 2007).

Within the goods sector, however, a second transformation has been taking place. At the height of the oil boom in the early 1980s, energy production accounted for nearly a fourth of the state's GSP (Texas Comptroller 2008). In 1990, however, agriculture and oil combined accounted for only 12 percent of Texas GSP. By 2000, the share of these two industries had fallen by 40 percent, and this trend is projected to continue. In 2030, agriculture and mining are expected to account for only 0.4 percent of the State's output. This is significant because national studies indicate the major economic impact of a changing climate over the next few decades is a reduction in agricultural output, while the major part of the cost of reducing carbon emissions would fall on energy-related activities. The other sector impacted by climate change is transportation and public utilities. Output in this sector rose strongly between 1990 and 2000, but it is projected to decline over the next two decades. By 2030, its projected share will be below the level of 1990.

Table 9.2. Texas Gross State Product, 1990, 2000, and Projected 2030 (Billions of chained \$*)

Year	1990	% of Total	2000	% of Total	2030	% of Total
Agriculture	4.40	1.0	6.47	0.9	6.62	0.3
Mining (Oil and Gas)	49.27	10.7	45.18	6.2	28.20	0.1
Construction	22.51	4.9	36.88	5.1	80.80	4.1
Manufacturing	47.25	10.2	92.88	12.8	409.88	21.0
Total Goods (CY2000 dollars)	123.43	26.7	181.52	25.0	525.51	27.0
Wholesale and Retail Trade	55.68	12.1	102.0	14.0	242.7	12.5
Transportation and Utilities	23.94	5.2	53.79	7.4	90.47	4.6
Other Services**	197.77	42.8	309.35	42.5	931.53	47.9
Government	63.99	13.9	80.59	11.1	157.27	8.1
Total Services (constant 2000 dollars)	338.57	73.3	545.72	75.0	1,422.00	73.0
Total Gross Product (constant 2000 dollars)	462.00	100.0	727.23	100.0	1,947.51	100.0
Total Gross Product (current dollars)	382.04		727.23		4,178.53	

*The measure chained dollars is used to express real dollar amounts adjusted over time for inflation. Chained dollars are based on the average weights of goods and services in successive pairs of years. The measure is "chained" because the second year in each pair, with its weights, becomes the first year of the next pair. The advantage of using the chained-dollar measure (rather than expressing each year's values in constant dollars) is that it is more closely related to any given period covered and is therefore subject to less distortion over time. The measure was introduced by the Department of Commerce in 1996 and generally reflect figures computed with 2000 as the base year. Chained dollars do not sum to category totals.

**Includes information, financial activities, professional and business services, education and health services, leisure and hospitality, and other services.

Source: Susan Combs, Texas Comptroller, Fall 2007 Forecast

Economic Growth and GHG Emissions

Table 9.2 shows the growth of the state's economy in real terms. Real-dollar projections take out the influence of inflation by expressing the projected quantity of goods and services produced in constant 2000 dollars. This is important when comparing GSP growth with growth in GHG emissions or other pollutants measured in physical units. For a given level of technology, there exists a direct relationship between the amount of economic growth and environmental pollution,

including GHG emissions. More people, more economic activity, more travel, and more demand, all increasing the pressure on all environmental and natural resources.

As indicated in earlier chapters, the primary contributors to GHG emissions in Texas are manufacturing, utilities, oil and gas production, and transportation. Those sectors of the economy that contribute the least amount of GHGs are the services industries other than transportation. It is significant, therefore, that the sectors of the economy in Texas that are growing the fastest contribute the least to GHG emissions, as well as to other forms of air and water pollution. This is borne out by the trends in population, output, and CO₂ from fossil fuels for U.S. and Texas from 1990 to 2006, as well as by U.S. DOE's projections for 2020 and 2030 under the "Business as Usual" scenario, shown in Table 9.3. Although Texas exceeds the nation in emissions per capita and in emissions intensity, in both the U.S. and Texas emissions per capita and emission intensity are falling and are projected to continue to fall through 2030.

Table 9.3. Carbon Dioxide Emissions, Projected to 2030

	1990	2000	2006	BAU 2020	BAU 2030
CO ₂ Emissions* - U.S. (million metric tons)	5,069	5,865	5,890	6,384	6,851
CO ₂ Emissions* – Texas (million metric tons)	588.3	691.6	641.6**	695.4***	746.2***
U.S. Population (millions)	248.7	281.4	298.8	335.8	363.6
Texas Population (millions)	17.0	20.9	23.5	28.0	31.8
U.S. Emissions Per Capita	20.4	20.8	19.7	19.6	18.8
Texas Emissions Per Capita	34.6	33.1	27.3	24.8	23.5
U.S. GDP (billions of 2000 dollars)	7,113	9,817	11,319	15,984	20,219
Texas GSP (billions of 2000 dollars)	462	727	868	1,286	1,685
U.S. CO ₂ Intensity tons/mil. \$	713	582	520	399	339
Texas CO ₂ Intensity tons/mil. \$	1,273	951	739	541	443

BAU = "business as usual" reference case

*from fossil fuels

**estimated (using growth rate from 2004 to 2005) based on released data for 2005

***estimated by taking the proportion of U.S. emissions to Texas emission in 2006 and applying it to the U.S. projected emissions for 2020 and 2030.

Sources:

U.S. CO₂ Emissions: U.S. EIA Annual Energy Outlook 2008 Texas CO₂ Emissions (1990, 2000, 2006): U.S. EPA, CO₂ Emissions from Fossil Fuel Combustion
http://epa.gov/climatechange/emissions/state_energyCO2inv.html

U.S. Population U.S. (2020 and 2030): Census Bureau, 2004, "U.S. Interim Projections by Age, Sex, Race, and Hispanic Origin," Texas Population: U.S. Census Bureau

U.S. GDP (1990, 2000, 2006): U.S. Department of Commerce, Bureau of Economic Analysis
 Texas GSP (1990, 2000, 2006, 2020, 2030) Texas State Comptroller

ECONOMIC IMPACTS OF CLIMATE CHANGE ON TEXAS

In recent years, a number of studies analyzing the impact of climate change on a state or region have been published. These studies generally are limited to describing the types of damages that might be experienced in the context of the economic structure and demographic characteristics of a single state or region without employing an integrative model to estimate the impact on the area's overall economy.

The continued rise in global temperature may be expected to have several effects on the growth and development of the Texas economy. The primary industries directly affected by climate are those closely tied to natural resources, such as agriculture and forestry, which are sensitive to both temperature and precipitation changes, and coastal development, which is impacted by the influence of temperature change on sea levels and hurricane intensity. The energy industry, transportation infrastructure, and public health are also impacted by climate change.

Agriculture

As discussed in chapter 6, studies indicate that, while agriculture in the U.S. and Texas is sensitive to climate change, which affects land and water usages as well as crop and livestock production, the overall economic impact on the agricultural sector is likely to be small. For the nation as a whole, societal welfare increases between \$22 billion and \$29 billion depending on the climate model used in the analysis (Nordhaus 1994; Nordhaus and Boyer 2000; Jorgenson *et.al.* 2004). The gains come mostly to agricultural producers. For Texas, however, it is estimated that by 2030 producer net income will fall by \$50 million (1.1 percent) under the Canadian climate change scenario and \$503 million (10 percent) under the Hadley climate change scenario (see Table 6.3). To put these figures into perspective, the contribution of agriculture in 2030 is projected at \$6.6 billion in a total state economy of \$4.2 trillion. The warming impact will vary across regions of the State, with the Texas High Plains being especially vulnerable.

Energy

Due to its large population and energy-intensive economy, Texas leads the Nation in direct energy consumption, accounting for more than one-tenth of total U.S. energy use. However, Texas has a very different sectoral energy use mix than the nation as a whole. Industry in Texas consumes about 64 percent of the State's total end-use energy, compared to 38 percent for the nation (EIA 2008b).

The most recent assessment of the impact of climate change on energy production and consumption in the U.S. concludes that climate warming will mean reductions in total heating requirements and increases in total cooling requirements which will vary by region and season (CCSP 2007). In general, the changes imply increased demands for electricity, which supplies virtually all cooling energy services but only some heating services.

Analysis by the Electric Reliability Council of Texas (ERCOT) indicates that electricity consumption in the State is closely related to temperature (ERCOT 2006).³ Texas, like most southern states, uses more electricity for space cooling than for heating. Because capacity must be constructed to match summer peak demand for electricity, peak demand for cooling is highly sensitive to temperature increases. An increase in average temperature is likely to necessitate large increases in generating capacity, unless a greater effort is made to promote conservation through rate restructuring and improvements in the energy efficiency of buildings.

Table 9.4 presents projections of baseline and global warming-induced capacity requirements for Texas for 2000, 2030 and 2050. Projections are made under a low growth and a high growth scenario. In both scenarios, generating requirements grow much more slowly than projected economic output. The Texas State Comptroller projects that Inflation-adjusted GSP in Texas will increase at an annual rate of 3.3 percent between 2000 and 2030, while the U.S. Energy Information Administration is projecting the nation's real GDP will grow 2 percent per year over this period (Texas Comptroller 2008, EIA 2008a). The low growth scenario assumes that electric generation in the State will increase only 1.5 percent per year between 2000 and 2050. This is quite conservative given that in 2006 net generation capacity had already jumped a third since 2000 (Texas Comptroller 2008). The high growth scenario assumes that electric generating requirements will grow 2.1 percent per year between 2000 and 2050, the rate of growth actually experienced between 1990 and 2006. The increase in peak demand for electricity due to climate change is assumed to be 20 percent. This is the low end of the estimate of a 20–30 percent increase in capacity above the baseline for the southern region of the United States (Linder et.al. 1987, Smith and Tirpak 1990) and slightly higher than a more recent estimate of a 17 percent increase in peak electricity demand in California (Miller et.al. 2008).⁴

Given these assumptions, it is estimated that the cumulative cost of construction of the additional, climate change-induced generating capacity needed between the years 2000 and 2050 will range from \$21 billion to \$45 billion under the alternative scenarios. These construction costs are in constant dollars, and therefore do not include the effects of inflation. Average construction costs per kilowatt of capacity were estimated for both scenarios, using projected costs for new generating facilities in constant 2003 \$/KWH (OECD 2005). It is assumed under the high scenario that the current fuel mix will continue unchanged. This gives a weighted cost of a generating unit of \$1,050 made up of a composite fuel source consisting of 49 percent gas, 37 percent coal, 10 percent nuclear, and 4 percent hydroelectric, wind, and other renewables. The low growth scenario reflects adjustments in the fuel mix as a consequence of tighter regulation of GHG emissions. It gives a weighted cost of a generating unit of \$1,032 comprised of 15 percent nuclear, 60 percent natural gas, 20 percent coal, and 5 percent renewables.

³ Daily loads are U-shaped reaching a minimum at about 65°F. The hot-side slopes are similar across the regions, ranging from 0.82 kWh per degree to 1.05 kWh per degree. These slopes are amplified above 80 degrees by an additive slope of 0.57 kWh per degree, but are muted beyond 85 degrees by an additive slope of -0.15 kWh per degree. Cold-side slopes across regions are also strong, ranging from 0.66 kWh per degree below 60 degrees to 1.39 kWh per degree. These slopes are amplified below 50 degrees by an additive slope of 1.09 kWh per degree.

⁴ The increase in peak demand relates not only to average increases in temperature, but also to projected increases in the incidence of extreme-heat-events caused by climate change.

Table 9.4. Potential Impacts of Climate Change on Texas Electric Utility Capacity

	2000	2030		2050	
		Low 1.5%/yr	High GSP 2.1%/yr	Low GSP 1.5%/yr.	High GSP 2.1%/yr.
Baseline Capacity (MW) ^a	76,000	102,436	141,770	159,999	214,833
Baseline plus 20% for Global Warming (MW) ^a	76,000	122,923	170,124	191,998	257,800
Global Warming Requirements (MW)		20,487	28,354	31,999	42,967
Cumulative Cost for Additional Capacity (\$billions) ^c		21.1	30.0	33.0	45.1

^aERCOT, 2006.

^bLinder *et.al*, 1987; Smith and Tirpak, 1990, Miller *et.al.*, 2008.

^cOECD, 2005. Assumes \$1,050/MW for the High Case and \$1,032/MW for the Low Case (2003 dollars).

Electric utility annual costs of operations are estimated to be about 20 percent of cumulative capacity cost (Linder *et.al* 1987). Using this estimate, Texas' utility sector operating costs in response to global warming could range near \$9 billion per year to cover variable costs, depreciation and other fixed costs. Generating capacity is required to meet peak—i.e., summer—demand. Thus, a warmer summer accompanied by a warmer winter will have the effect of increasing the excess capacity during nonpeak periods. This increase in excess capacity and change in the distribution of seasonal demand during the year adds to the cost of operation.⁵

Increases in energy costs, such as those experienced in 2008, add to the attractiveness of increasing energy-efficiency. Price increases spur the development of more advanced technologies, such as more efficient generating and transmission systems. Investment in improved insulation, more efficient air conditioners, alternative construction designs, and other methods of reducing cooling costs may also be stimulated by rising temperatures and increased electricity costs.

Climate warming also will impact energy production and supply if extreme weather events become more intense. In addition, temperature increases reduce overall thermoelectric power generation efficiencies and may impact facility siting decisions. Most of these impacts are thought to be modest, however (CCSP 2007).

Indirectly, climate change is likely to affect the investment behavior of some energy institutions, as well as energy technology, R&D investments, and energy resource and technology choices. Indirect effects also include impacts of climate change on other countries in

⁵ Getting the additional power to market would also require significant investment in new transmission capacity. For example, a recent study completed by ERCOT on the potential costs to build transmission lines to West and Northwest Texas to transport electricity generated from wind power estimated that it would cost between \$3 and \$6 billion depending on the amount and capacity of transmission lines built (ERCOT 2008).

ways that affect U.S. energy conditions through their participation in global and hemispheric energy markets. Climate change concerns could interact with some driving forces behind policies focused on U.S. energy security. Given the prominence of the State in energy production, such impacts would likely be significant for Texas energy producers. However, given the current state of knowledge, it is not possible to quantify these indirect impacts (CCSP 2007).

Coastal Development

Texas has over 367 miles of coastline and more than 3,300 miles of Bay Shore, all of which provide a wide range of essential goods and services. These include overlapping and often competing uses, such as recreation and tourism, coastal development, commercial fisheries, aquaculture, biodiversity, marine biotechnology, navigation and mineral resources.

While the 18 counties bordering the Gulf of Mexico constitute only 7.2 percent of land in the State they account for nearly a quarter of its population. These areas become more crowded every year. As noted earlier, it is projected that the State's coastal population will jump 60 percent by 2040. This growth, as well as increased income and wealth, will place rapidly increasing demands on coastal and marine resources for both economic benefits and aesthetic enjoyment.

The Gulf coast is vital to the State's economy. It is estimated that about 70 percent of the State's industrial base, commerce and jobs are located within 100 miles of the coastline (Texas General Land Office 1995). More than half of the nation's chemical and petroleum production is located on the Texas coast, and the State leads the nation in marine commerce with 10 deep-draft ports (three of the top 10 in the nation based on total cargo tonnage). More than 66 million short tons of cargo with a commercial value of more than \$25 billion move along the 420 mile Texas portion of the Intercoastal Waterway each year. Texas' commercial fishing fleets bring in more than \$170 million of fish and shellfish annually (Texas General Land Office 2005).

In addition to direct economic benefits, coastal and marine ecosystems, like all ecosystems, have characteristic properties or processes that directly or indirectly benefit human populations (National Assessment Synthesis Team 2000, Ch. 16). The value per acre of estuaries, tidal marshes, coral reefs and coastal oceans has been estimated at \$9,240, \$4,043, \$2,459, and \$1,640, respectively (Constanza et.al. 1997).⁶ Ecosystem valuation is difficult and fraught with uncertainties. But the magnitude of these estimates and the degree to which coastal and marine ecosystems are viewed as among the most valuable to society, serve to emphasize their economic importance.

Increasing population and related land use changes have led to major reductions in coastal wetlands (Moulton et. al. 1997). The Texas coast may be the most vulnerable region in the nation. Sea level rise especially impacts Texas because of its low lying coast, increasing incidence of subsidence, and high erosion rates due to reduced sedimentation and greater flushing rates. The sea level is projected to rise an additional 19 inches by 2100, with a possible

⁶The Constanza study examined the economic value of sixteen biomes, or ecosystem types, and seventeen of their key goods and services, including nutrient cycling, disturbance regulation, waste treatment, food production, raw materials, refuges for commercially and recreationally important species, genetic resources, and opportunities for recreational and cultural activities.

range of 5 to 37 inches along most of the US coastline (National Assessment Synthesis Team 2000, Ch. 16).

Storm Impacts on Infrastructure

As demands on coastal and marine resources increase and as coastal areas become more developed, the vulnerability of human settlements to hurricanes, storm surges and flooding events also increases (IPCC 2007b). Climate models indicate that rising global temperatures may cause significant increases in storm intensity. Industry, energy and transportation works are sensitive to weather extremes that exceed their safety margins. Costs of these impacts can be high. For example, power outages in the U.S. cost the economy \$30 billion to \$130 billion annually (EPRI 2003, LaCommare and Eto 2004). From 1994 to 2004, fourteen U.S. utilities experienced 81 other major storms, which cost an average of \$49 million per storm, with the highest single storm impact of \$890 million (EEI 2005).

Texas is especially vulnerable because it borders on the Gulf of Mexico. The hurricanes crossing Florida in the summer of 2004 resulted in direct system restoration costs of \$1.4 billion to the four Florida public utilities (EEI 2005). The impacts of Hurricanes Katrina, Rita and Wilma in 2005 and Ivan in 2004 demonstrated that the Gulf of Mexico offshore oil and natural gas platforms and pipelines, petroleum refineries and supporting infrastructure can be seriously harmed by major hurricanes, which can produce national-level impacts, and require recovery times stretching to months or longer (EEA 2005, EIA 2005, Levitan and Associates Inc. 2005, RMS 2005). Hurricane Ike devastated the upper Texas coast in the summer of 2008. The total damages it caused are yet to be determined but the damage from wind and the storm surge is estimated at \$6-\$16 billion dollars. This estimate does not include the cost of extensive inland flooding (Walsh 2008).

THE ECONOMICS OF CLIMATE CHANGE

Economics has an important role to play in helping us understand climate change and in developing effective public policies to address it. Economics can explain why markets have difficulty dealing with the threat of climate change. It can also assist policymakers in balancing the magnitude of the damages from projected climate change against the costs of actions to reduce GHG emissions.

Climate Change Results from Market Failure

Man uses the atmosphere as a resource to absorb wastes (GHGs) that result from growing crops, raising animals for food and fiber, and heating, cooling and running machines with fossil fuels. As long as these emissions don't exceed the carrying capacity of the resource, they do not accumulate over time in the atmosphere. However, since no one has property rights to the atmosphere, the cost of dumping wastes into it is essentially zero. This can lead to over use and result in a build-up over time of GHGs in the atmosphere to critical levels.

Economics defines an externality as occurring when a decision by one party causes costs or benefits to a third party. If participants in an economic transaction do not bear all of the costs or reap all of the benefit of the transaction, too much or too little of the good may be produced and consumed in terms of the overall cost or benefit to society. For example, emitting GHGs in

the process of producing electricity can harm people around the world, if it adds to the atmospheric concentration of these gases causing global temperatures to rise and other climatic change. The “social cost of carbon” is the present value of additional economic damages now and in the future caused by an additional ton of GHG emissions.⁷

Because it is the sum of all the GHGs emitted around the earth that matters (i.e., the damage is not related significantly to the location and timing of emissions), the atmosphere may be thought of as a global public good. A public good has two principal characteristics: it is difficult to prevent people from using the good without paying for it (consumption is non-excludable) and the incremental costs of allowing more users is near zero (consumption is nonrival). As a resource the atmosphere satisfies both conditions. Market institutions do not function properly when a resource has these characteristics. As a result, the resource may not be efficiently used.

It is customary to look to government to solve the problems posed by the existence of public goods. The solution most commonly proposed for projected climate change is for governments to take action to reduce GHG emissions sufficiently to restore the atmosphere to a sustainable level of GHG concentration. The key to effective public policies to address climate change is to internalize the externality caused by GHG emissions. In practice, this will require that the market price of carbon be increased, which will raise the prices of fossil fuels and the products of fossil fuels. This will transmit the social costs of GHG emissions to the everyday decisions of billions of people and firms.

Because the causes and consequences of climate change are global, effective mitigation policies require extensive cooperation among countries. This is crucial because, even though the industrialized world today accounts for the largest portion of GHG emissions, developing countries such as China, India and Brazil are rapidly joining their ranks and will soon become the largest emitters. In the absence of mitigation policies, it is estimated that two-thirds to three-quarters of the projected increase in global CO₂ emissions will occur in developing countries (IPCC 2007b).

Even though climate change affects all nations, some may be reluctant to reduce greenhouse gases voluntarily, realizing that they cannot be prevented from enjoying a better climate whether they contribute to it or not (i.e. free-riding). The incentive to free ride is likely to be much higher in developing countries where long-term global climate change may take a back seat to more pressing concerns such as clean water, a stable food supply and economic growth. In addition, countries differ significantly in the extent to which they are contributing to global climate change and the degree to which they will be impacted by it.

Even if international cooperation is achieved, there is no guarantee that governments, individually or collectively, will efficiently allocate climate resources. Governments tend to represent coalitions of private and public interests that often engage in what economists term rent seeking behavior – attempting to redirect the economy’s resources to their own advantage (e.g. ethanol mandates). The necessity of acting through voluntary international coalitions compounds this problem.

⁷A ton of CO₂ makes the same contribution to climate change regardless of the location of emissions in the world. For emissions of other GHGs, they will generally have different radiative forcings and different atmospheric lifetimes; however, their global warming potential (GWP) can be converted to “equivalent” CO₂ units conventionally expressed as metric tons of CO₂-e (IPCC 2001). One metric ton is equal to 1,000 kilograms or 1.1 short tons (2,000 pounds).

PUBLIC POLICIES TO COMBAT GHG EMISSIONS

Traditionally, U.S. environmental policy has relied on regulation and direct controls. A typical example is enacting mandates and providing incentives to switch to non-fossil fuel alternatives, such as Renewable Fuels Standards (RFS), e.g., corn-based ethanol for vehicles, and Renewable Portfolio Standards (RPS), e.g., wind power for electricity generation (both are discussed in chapter 8). This category also includes measures aimed at reducing energy consumption, such as mandated energy efficiency standards for home appliances and motor vehicle efficiency requirements for cars and trucks, often referred to as corporate average fuel economy (CAFÉ) standards. Many of these measures have been justified on a variety of non-climate change grounds, including energy security and air pollution control.

The political attractiveness of direct controls stems from the fact that they do not explicitly convey the costs they impose. They are a form of hidden taxes. Unfortunately, this also means that they do not provide consumers and producers information about the social costs of their decisions, making them less likely to be effective in mitigating global climate change (Nordhaus 2007, Parry and Pizer 2007). Research indicates that these approaches are also much more costly. One study found that limiting U.S. GHG emissions through traditional regulatory approaches could be ten times higher than achieving the same result through a pricing policy (Pizer *et.al.* 2006). Research has also shown that gasoline and carbon taxes offer a much less expensive way to attain a given transportation emissions target than fuel economy standards (Austin and Dinan 2005, Aldy and Pizer 2008).

It has been observed that “Emissions reductions are equally valuable wherever they occur, but they are not equally costly” (Kopp and Pizer 2007). A cost-effective climate change policy would seek to achieve emission reductions at the lowest possible cost. For this reason, economists generally favor addressing climate change through the use of incentive-based policies, either singly or in combination, that increase the price of carbon emissions through fees or taxes, or restrict overall quantities of emissions through a system of cap and trade (Yohe 1992, Newell and Stavens 2003, GAO 2008). Setting a price on CO₂ emissions sends a clear signal to everyone engaged in emissions-producing activities – including both direct emitters and downstream consumers of emissions-producing products- about the social value of cutting emissions. Simultaneously, higher carbon prices provide incentives for research and development in low-carbon products and processes that can replace current technologies (Nordhaus 2007).

Almost a century ago, the English economist, Arthur Pigou, proposed taxing goods that were the source of a negative externality so as to accurately reflect the cost of the goods' production to society, thereby internalizing these costs (Pigou 1912, 1920). A tax on a negative externality is termed a Pigouvian tax and should equal the marginal damage costs. A number of European and Scandinavian countries have adopted some form of a carbon tax and Costa Rica and Brazil are considering carbon taxes (Aldy and Pizer 2008). The Clinton Administration proposed, but was unsuccessful in getting enacted, a Btu tax. Two carbon tax bills (Stark H.R. 2069 and Larson H.R. 3416) were introduced in the 110th Congress.

The major advantage of a carbon tax is that it provides certainty as to the cost of using carbon thereby facilitating long-term investments in carbon-saving technologies. The major drawback is that it may not result in limiting GHG atmospheric concentrations to targeted

levels.⁸ The Stark proposal (H.R. 2069) seeks to combine near-term price certainty with a long-term emissions target, calling for a tax that rises continually until U.S. CO₂ emissions fall to 80 percent below 1990 values.

The current debate in Congress about policies to reduce GHG emissions, however, has focused more on a cap and trade program than a carbon tax. Under a cap and trade program, GHG-emitting entities are identified as the points of responsibility for emissions. Emissions allowances (actually entries in an electronic bookkeeping system) are distributed such that the total is equal to the national cap, and covered entities must surrender allowances equal to their emissions, or the emissions that result from their activities. Market trading in these allowances establishes a price on emissions that in turn creates economic incentives for cost-effective abatement (MIT 2007).

A cap and trade program ensures that targeted GHG concentration levels will be reached, but the cost of achieving these levels is not known with certainty. A hybrid policy coupling a cap and trade program with an emissions price constraint (“safety valve”) is garnering support among economists as providing both certainty and greater cost control (GAO 2008).

However achieved, restricting GHG emissions also would tend to reduce emissions of some conventional pollutants as well, yielding a variety of ancillary benefits, such as improvements in health from better quality air and water. Those additional benefits would partly offset the costs of greenhouse gas regulations (CBO 2003).

Economists also express support for mitigating climate change by public investment in invention, innovation, and education (which may be thought of as public goods as opposed to public “bads,” i.e., negative externalities (GAO 2008)). There is general agreement that new low-carbon technologies and processes will be required if climate change is to be effectively addressed. Through direct government funding or the use of tax credits, basic science as well as research and development can be encouraged.

Kyoto – A Global Approach Addressing Climate Change

International cooperation on the issue of climate change began with the creation of the Intergovernmental Panel on Climate Change (IPCC) in 1988 and came to fruition with the Kyoto Protocol (draft treaty) in 1997 (discussed in more detail in chapter 8). Kyoto is a cap and trade system that imposes national limits on the emissions of developed countries, requiring them on average to reduce their emissions 5.2 percent below their 1990 baseline over the 2008 to 2012 period. Developing nations are encouraged to reduce their GHG emissions, but not obligated to do so. Kyoto created a framework and a set of rules for a global carbon market. It has resulted in the creation of several such markets, termed exchange trading schemes, with varying degrees of linkages among them.⁹ Kyoto also led to the creation of a mechanism that regulated entities to use carbon credits (offsets) based on emission reduction projects.

⁸ The degree of emission abatement achieved will also vary year-to-year with the state of the economy (Parry and Pizer 2007).

⁹ The European Union Emission Trading Scheme (EU ETS) is the largest multinational GHG exchange-traded emission allowances program in the world. It currently is the world’s only mandatory carbon trading program. Phase one (2005-2007) began in January 2005 with 25 of the 27 EU countries participating. Phase II (2008-2012) links the ETS to other countries participating in the Kyoto trading system. It is estimated that worldwide global trade in emission allowances amounted to \$30 billion in 2008 and trade is projected to have reached \$56 billion in 2007 (Sjardin 2008).

As part of the recently completed Fourth Assessment Report of the IPCC, mitigation costs were estimated for a range of GHG stabilization targets ranging from 445 to 710 parts per million (ppm) CO₂-equivalent in 2050 (IPCC 2007c). Based on a review of econometric models, the IPCC estimated that the result of attaining these goals would range from a positive GDP gain of 1 percent for the least ambitious target to a negative GDP loss of 5.5 percent for the most ambitious goal of stabilizing global GHG concentrations below 535 ppm (IPC 2007c). The wide variability in results reflects the continued high level of uncertainty of both climate and econometric models.

These cost estimates are likely to be optimistic because the IPCC scenarios assume that mitigation (cap and trade) policies are introduced in a globally coordinated fashion such that the marginal cost of GHG abatement measures is equalized across all regions and countries (Peace and Weyant (2008). Any reduction or restriction in the number of participating countries or regions would increase both the carbon permit price and the economic cost associated with achieving a given stabilization target.

U.S. Climate Change Policy

The 1990 Clean Air Act Acid Rain Program included a cap and trade policy to limit SO₂ emissions. Since 1990, SO₂ emissions have dropped 40 percent (Coile 2007). The EPA estimates that by 2010, the overall costs of complying with the program for businesses and consumers will be \$1 billion to \$2 billion a year, only one-fourth of what was originally predicted (EPA 2006). One study estimates that in 2010, the Acid Rain Program's annual benefits will be approximately \$122 billion (2000\$), at an annual cost of about \$3 billion - a 40-to-1 benefit-to-cost ratio (Chesnut and Mills 2005).¹⁰

States and regions have developed their own initiatives to use a cap and trade approach to restrict CO₂ emissions (Litz 2008). California was the first to enact such a comprehensive statute in 2006. Through similar legislation, Hawaii, Minnesota, New Jersey, Oregon and Washington also have established GHG emissions targets. As noted in chapter 8, governors in many other states have issued executive orders or plans setting statewide, economy-wide GHG reduction targets. Although for the most part these orders and plans do not have the full force of state law, they provide impetus for significant action to reduce emissions. At the regional level, in 2003, New York State attained commitments from nine other Northeast states to form a cap and trade CO₂ emissions program for power generators (Regional Greenhouse Gas Initiative 2003). This program is due to launch on January 1, 2009 with the aim to reduce the carbon "budget" of each state's electricity generation sector to 10 percent below their 2009 allowances by 2018.¹¹

These actions at the state and regional levels are already causing companies to view climate change as a serious business issue. But they also create uncertainty and the potential for

¹⁰Unfortunately, the future of the SO₂ cap and trade policy was cast into doubt by a by a recent (7/8/08) federal court decision which invalidated the regulation. The effect was potentially to make worthless \$15-\$20 billion dollars of allowances. The decision highlighted one problem with regulated solutions to problems – the risk that the courts or a future Congress could change the rules of the game (Dizard 2008).

¹¹ The number of permits being auctioned off for 2009 would actually allow more emissions than the plants are expected to emit. Emissions have been dropping, in part because power plants have switched to using natural gas as its price has fallen (Ball 2008).

firms to suffer, if their competitors located in other areas do not face such constraints. This increases the political pressure for nationwide action to reduce carbon emissions.

In addressing climate change, the United States has:

- Implemented programs to support research development and deployment of new technologies that reduce GHG emissions and improve energy efficiency (e.g. the DOE's Climate Change Technology Program – CCTP);
- invested in research to improve our understanding of climate change (e.g., the Climate Change Science Program - CCSP); and
- introduced voluntary programs that provide technical assistance, education and information-sharing (e.g., EPA's Climate Leaders Program) designed to encourage both public and private sector entities to curb their GHG emissions (GAO 2008).

In addition, some programs that were intended to achieve other goals, such as pollution reduction, energy independence and the limitation of soil erosion, also discourage emissions or encourage the removal of greenhouse gases from the atmosphere. However, other programs have opposing effects (CBO 2003).

THE ECONOMIC IMPACT OF A NATIONAL CAP AND TRADE POLICY

It appears increasingly likely that the United States will enact some type of cap and trade program to limit future emissions of CO₂. There were twelve proposals for mandatory climate legislation introduced in the 109th Congress, and the first session of the 110th Congress is considering almost an equal number of bills that include provisions for a cap and trade system in combination with initiatives to promote the development and adoption of low-carbon technologies (Lieberman and Beach 2007, Aldy and Pizer 2008). One of these bills, S.2191 (Lieberman/Warner) was passed by the Senate Environment and Public Works Committee but not enacted. Any U.S. system likely will be a negotiated compromise among current proposals. Moreover, the economic impacts of any climate change program also will depend on activities in other countries through the influence of trade in energy, non-energy goods and emissions allowances.

There have been a number of public and privately-sponsored studies assessing the potential economic impacts of U.S. cap and trade climate legislation (MIT 2007, MIT 2008, CRA International 2007, Murray and Ross 2007, EIA 2008c, ICF International 2007, ICF International 2008, Kopp and Pizer 2007, Aldy and Pizer 2008, EPA 2008). These studies differ in terms of their focus, assumptions and timeframes. Nonetheless, it is possible to draw some general conclusions about the likely economic impacts of a national cap and trade policy.

Coverage and Scope

More than 80 percent of GHG emissions occur as a byproduct of fossil fuel combustion (coal, oil and natural gas) with the remaining 20 percent coming from fugitive emissions of nitrous oxide and methane from agriculture, and industrial releases of fluorinated gases and nitrous oxides (EPA 2008). Economic research suggests that a cost-effective cap and trade program should

exploit emission abatement opportunities among as many sources as possible.¹² Nonetheless, pending legislation addresses primarily the emissions that come from fossil fuel combustion (termed economywide controls).

While it is possible to design a cap and trade program to be applied downstream, e.g. to residences or gasoline stations, most of the pending bills focus entirely or primarily on upstream, e.g. mine mouth or refinery gate, regulation. Regulation at or near the point of fossil fuel production would involve modest monitoring costs since only 2,000 to 3,000 facilities would need to be covered to control all fossil fuel CO₂ emissions (Stavins 2007, Hall 2007). It should be noted that even if the focus of the program is upstream, 90 percent or more of the higher carbon price would be passed forward to consumers (Lasky 2003).

Emission Reductions

Pending cap and trade proposals would result in substantial emissions reductions across the economy. For example, under S. 2191 total U.S. GHG emissions (including capped and uncapped sectors) are projected to be approximately 27 percent lower than Reference Case emissions in 2030 and 44 percent lower in 2050. Other bills set 2050 emissions reduction targets of 60-80 percent below 1990 levels (Lieberman and Beach 2007).

The basic assumption underlying cap and trade proposals is that by setting stringent CO₂ emissions targets starting in 2012, the switch by utilities away from coal to other fuels, especially natural gas, will occur sooner rather than later. If, as is commonly assumed, clean coal and carbon capture and storage (CCS) technologies become commercially viable after 2025, utilities are expected to turn once more to fossil fuels. But with reduced demand and CCS in place, CO₂ emissions will continue to fall. By mid-century (2045) it is forecast that 90 percent of CO₂ emissions from the electricity sector will be captured through CCS technologies.¹³ Thereafter additional reductions must come from other sectors, where abatement comes at a higher cost.

Impact on Prices and Output

Fossil energy “demand” (or consumer) prices all rise once the GHG allowance price is incorporated.¹⁴ However, “supply” (or producer) prices may fall in response to reduced demand. For example, in 2030 under S. 2191 the final demand price for petroleum is about 9 percent higher than the Reference Case, but the market supply price declines by only about 4 percent. Electricity prices are expected to rise substantially, as utilities transition to decarbonized

¹² One study concluded that compliance costs were cut in half when non-CO₂ gases were included in mitigation policies (Weyant et.al. 2006). Studies of U.S. mitigation costs reached similar conclusions (EIA 2005).

¹³ The electricity sector is responsible for 40% of our CO₂ emissions, but it expected to provide two-thirds to three-quarters of the emissions reductions that would be achieved during the first couple of decades of a cap and trade program (Burtraw 2008).

¹⁴ Under S. 2191, allowance prices are projected at \$29 to \$40/t CO₂e in 2015, \$61 to \$83/tCO₂e in 2030, and \$159 to \$220/tCO₂e in 2050. Using an alternative reference scenario incorporating more favorable assumptions regarding technology results in lower allowance prices in 2030 and 2050 (\$46 to \$73/tCO₂e and \$121 to \$193/CO₂e, respectively.) Allowance prices projected by other studies are a little higher, but generally consistent with the results from the EPA study.

generation. The price per kilowatt hour (kWh) is projected to rise over time increasing 18 percent above the reference case in 2015, 30 percent above in 2030, and 27 percent above in 2050.

The costs of a cap and trade program by 2050 when compared to 2005 generally are estimated to be 1-2 percent of national income – roughly comparable to the estimated costs of all other environmental policies combined (Aldy and Pizer 2008, MIT 2207, MIT 2008, EPA 2008). However, more stringent emissions targets or cost-ineffective policy implementation could substantially increase abatement costs.

Given its dominant position as an energy-intensive state, it might be expected that cap and trade legislation would place more of an economic burden on Texas than on other states. An EPA study looked at one model's estimates of the longer-term (i.e. to 2050) economic impact of S.2191 for five regions. Texas was included in the Plains Regions, along with Oklahoma, Kansas, Nebraska, North and South Dakota and Minnesota. GSP and consumption are projected to fall less than 3 percent throughout the 2030-2050 time frame in all regions other the Plains region, which is forecast to experience a 3.8 percent reduction in GSP by 2050. Texas accounts for more than 38 percent of the Plains region's economic output. It also accounts for 47 percent of the region's consumption of coal, 42 percent of its use of natural gas, 75 percent of its petroleum consumption, and 62 percent of its retail electricity sales (EIA 2008b). Thus, the economic impact on Texas might be expected to be more severe than for the region as a whole.

Cost Containment

Concern about the uncertainty regarding the costs of implementing a cap and trade program has generated interest in including mechanisms to contain these costs. Cost-containment is likely to be more important in the short-run as the economy adjusts to carbon constraints than in the longer-run when with broader global efforts stabilizing GHG atmospheric concentrations at a specific level may take precedence (Kopp and Pizer 2007).

Some proposals allow regulated entities to shift their obligations across periods, banking emission units for future use and/or borrowing by shifting deficits forward. This can improve near-term cost certainty by limiting allowance price volatility. These provisions are usually phased out over time.

Another approach to cost containment would establish a price cap, termed a “safety valve” provision, where the government agrees to sell allowances in unlimited amounts at a fixed price to guard against price spikes that may sharply raise compliance costs or threaten the survival of the system itself. The Lieberman-Warner Bill (S. 2191) delegates authority for managing price and emission uncertainty to an independent board. Other legislation seeks to contain costs by including specific limits on allowance prices, which gradually increase over time.

One feature of a cap and trade program that potentially can limit costs is to permit offsets under which projects that reduce GHG emissions relative to some agreed upon baseline are granted credits equal to the volume of reductions. These credits can be sold into a cap and trade program. Linking a cap and trade program to outside systems has two advantages. First, it enables domestic producers use offsets to take advantage of the relatively low cost emission reductions available in other countries or in domestic sectors (e.g. agriculture) that are not covered by the program. Second, it offers a cost-effective means of achieving emissions reductions in developing countries where political and institutional constraints make a full-

fledged emissions trading program an unlikely possibility. But there are a host of difficulties in implementing such a system, not the least of which is high transaction costs due to the need to validate the effectiveness of the offset projects. Nonetheless, most pending cap and trade proposals contain provisions permitting use of domestic offsets and international credits to achieve their net emission reduction targets. The offsets and credits are gradually reduced over time.

Allowance Allocation

Capping emissions creates a new commodity, an allowance - the right to emit CO₂. These allowances would have substantial value, estimated to be as much as \$100 billion to \$370 billion annually depending on the scope and stringency of the program (MIT 2007, CBO 2007, EIA 2007). For the first few decades under a cap and trade program, the value of emission allowances would substantially exceed the value of the resources actually used to achieve emissions reductions. It is not surprising that recent research indicates that the method used to allocate these allowances is one of the most important features of a cap and trade program affecting both its overall efficiency and equity (CBO 2007, Kopp and Pizer 2007, Burtraw *et al.* 2008).

A cap and trade program causes losses to workers and investors in the fossil fuel parts of the energy sector (e.g., coal producers) and in energy-intensive industries whose output would be expected to decline. If the government gives allowances at no charge to businesses in the energy supply chain (e.g. fossil energy extraction, processing, power generation and energy-intensive manufacturing) who are directly harmed (the approach taken in the sulfur dioxide program and that used by the EU since 2005 in its cap and trade program), then this value would essentially go to these firms and their shareholders (about 10 percent to overseas firms and shareholders).¹⁵ This would result in substantial windfall profits, since the value they would receive would far outweigh the costs they would bear. The cost of the cap would ultimately be borne by consumers.¹⁶ In addition, since state-level CO₂ emissions per capita vary by a factor of ten, free allocation could also exacerbate regional inequalities (Aldy 2007).

One estimate is that no more than about 15 percent of emission allowances would need to be freely distributed to avoid equity losses in the most vulnerable industries (Goulder 2001). Other studies suggest a 50 percent free allocation initially, with a phase out over time to zero (Stavins 2007, NCEP 2007). In either case, the government could sell (i.e., auction off) a substantial majority of emissions allowances, and use the resulting revenues to address concerns about regressivity and efficiency.

Even with an auction, downstream consumers would bear most of the cost of a cap and trade program. Moreover, the cost burden would fall disproportionately on lower income households, since energy constitutes a much larger portion of their budgets than those of higher

¹⁵ Some proposals expand the free allocation beyond direct emitters to include a broader set of firms, as well as states, funds and quasi-governmental corporations that support climate-related activities (Aldy and Pizer 2008).

¹⁶ An exception would be electricity customers in regions of the country under cost-of-service regulation. They can expect to benefit from free allocation through reductions in electricity prices because regulators in those regions will apply the value of the allowances to offset other changes in costs in the wholesale power market (Burtraw and Palmer 2008).

income households.¹⁷ Returning revenues received from selling allowances directly back to citizens, sometimes termed lump sum recycling, would substantially reduce the regressivity of the program and result in a dramatic improvement in the well-being of poor households (Burtraw *et.al.* 2008).

Alternatively, some economists have suggested using allowances auction revenues to lower existing taxes on income, labor and capital. Reductions in these distortionary taxes could promote greater labor force participation and capital accumulation. This could substantially lower the costs of a cap and trade program depending on the percent of revenues recycled (Goulder 2002).

Congress could use allowance auction revenues to provide support for other climate-related activities. The Regional Greenhouse Gas Initiative allocates some of the revenues from the allowance auction to programs aimed at increasing energy efficiency and related demand side management programs. Some of the cap and trade bills pending before Congress propose setting aside revenues to aid low-income households and to help workers in fossil fuel industries to transition into alternative employment. Others use revenues to promote climate-friendly technologies, especially carbon capture and sequestration, as well as more research in climate change and adaptation.

Efficiency-Equity Tradeoff

A public policy can be evaluated in terms of its efficiency. In simple terms, economic efficiency is achieved when a given result is achieved at the lowest possible cost. Another measure used to evaluate a public policy is equity defined as the distributional burden across households. If the costs imposed by a public policy fall disproportionately on lower income households, it is said to be regressive. If the costs are borne disproportionately by higher income households, the policy is said to be progressive. In many instances, equity and efficiency are tradeoffs in the sense that an improvement in efficiency may come at the expense of a reduction in equity.

In economic terms, welfare is defined as consumer surplus - the aggregate amount that consumers benefit by being able to purchase a product for a price that is less than they would be willing to pay. Implementation of a cap and trade program raises the price of fossil fuels and products, such as electricity, that are made from fossil fuels. Consumers who were willing to pay to buy these products at the initial price now find that they either have to pay more or consume less. This results in a decrease in consumer surplus and a decline in economic welfare.

Changes in consumer surplus, however, do not account for ancillary effects from changes in employment and income that also occur when the price of a product rises. A cap and trade program will shift economic activity away from relatively energy-intensive sectors of the economy to those that are less energy-intensive. This shift likely would lead to unemployment for displaced workers and may force some workers to accept jobs with lower wages. To the extent that lower-wage workers are employed by energy-intensive industries or in regions, such

¹⁷Nationally, direct expenditure on energy represents 25.5 percent of annual income among households in the lowest-income quintile, but only 3.6 percent for households in the highest income quintile (Burtraw *et.al.* 2008). It has been estimated that the wealthiest 20 percent of Americans would enjoy higher disposable income under a cap and trade or emissions tax program, while the poorest 80 percent would experience lower disposable income (Parry 2004).

as Texas, that would experience a reduction in economic activity, these employment and income aspects could be regressive.

Of course, a cap and trade program also creates benefits in terms of lessening damages from climate change. In developing and assessing public policies, economists prefer to balance the costs and benefits of proposed actions. However, it is much more difficult to estimate the economic impacts of projected climate change than it is to estimate the cost of policies to avoid such impacts. This is because the effects of climate change are location-specific and are generally thought to occur gradually over long periods of time (i.e., centuries). At the national and global levels, climate change models yield a wide range of possible temperature and other climate changes that are likely to occur over broad geographic areas that generally do not reflect political boundaries. For local and regional analysis, there is a dearth of data at the level of detail needed to make an accurate impact assessment. Since there are sizeable differences between economic sectors in terms of their vulnerability to climate change, comprehensive integrative models are needed to assess impacts in terms of the entire economy. Three additional problems make it especially difficult to estimate the present value of damages from projected climate change.

- Projected economic damages from climate change are quite modest initially, begin to become somewhat significant at mid-century, and increase in severity as we reach the end of the century and beyond. But when these longer term damages are discounted to the present in a cost-benefit analysis they become much less significant (Sheraga and Sussman 1998, Nordhaus 2007).¹⁸
- There is a high degree of scientific uncertainty with regard to the magnitude of climate change (Heal and Kristrom 2002, Newell and Pizer 2001). To further complicate the analysis, one or more possible highly undesirable outcomes from climate change may be irreversible and the possibility exists that there might be abrupt and catastrophic changes in climate (IPCC 2007a). In light of the variability surrounding future climate paths it remains difficult to assign probability estimates to possible climate scenarios.¹⁹
- There are many impacts of climate change that cannot be easily expressed in monetary terms (Howarth and Monahan 1996). Efforts by economists to find ways of valuing non-market resources have not been successful in garnering widespread acceptance.

Integrated Assessment models project both the costs of policies to limit GHG emissions and the benefits of such action (largely defined in terms of avoided damages). One of the most prominent integrated assessments uses the DICE model developed by William Nordhaus (Nordhaus 1994, Nordhaus and Boyer 2000). The latest projections using this model indicate the

¹⁸ The Nordhaus study imposed a discount rate that gradually declined from over 4 percent today to under 3 percent in 100 years. This led the model to assign a present value of about \$25 billion—one-fortieth the future value—to a trillion dollars of damages a century from now. Some economists support using a much lower discount rate for assessing long-term damages (Cline 1992).

¹⁹ The range of possible outcomes in terms of temperature and precipitation can not be expressed in a single number. Nor does averaging them help. For example, assume that 99 times out of 100 the right number is -1. But one in a hundred times the right number is -51. The average, -1.50, is not a useful representation of the actual situation. In cost-benefit terms, one would not be willing to spend \$2 to avoid a \$1.50 outcome. But one might be willing to spend much more than \$2 to ensure that the -\$51 outcome does not occur.

net present value global benefit of an “optimal” GHG emissions reduction policy is \$3 trillion relative to no controls (Nordhaus 2007). This total involves \$2 trillion in projected abatement costs and \$5 trillion of reduced climatic damages. An estimated \$17 trillion in damages would remain but additional abatement would cost more than the additional reduction in damages (i.e., be “non-optimal”).

The U.S. General Accountability Office (GAO) recently convened a panel of experts to consider the economics of policy options to address climate change (GAO 2008). All of the 18 panelists agreed that Congress should consider using a market-based mechanism to establish a price on GHG emissions. Most panelists preferred either a tax on emissions or a hybrid policy that incorporates a cap and trade program with a safety value provision under which the government would sell additional emissions permits if the permit price rose above a specified level. A majority recommended additional actions as part of a portfolio to address climate change, including investment in research and development of low-emission technologies.

GAO noted that 14 of the 18 panelists were at least “moderately certain” that the benefits of their recommended portfolio of actions would outweigh the costs. But the panel rated estimates of costs as more useful than estimates of benefits for informing congressional decision-making. In other words, the panelists rejected making the decision to limit carbon emissions on a cost-benefit basis (reflecting concerns about the major issues discussed above in determining benefits). Instead, they emphasized the role of economics in helping determine the least-cost means of accomplishing whatever level of carbon emissions is established.

Quantifying the Efficiency-Equity Tradeoff

A recent study evaluating the short-term (i.e. to 2015) effects of a national CO₂ cap and trade program on households in eleven regions, one of which is Texas, finds that the incidence (the distribution of costs) depend critically on how the program distributes the value created by placing a price on CO₂ emissions (Burtraw et.al. 2008).²⁰ Ten alternative policies for allocating allowances were evaluated. The equity (i.e. consumer surplus or welfare) impacts of each policy were estimated and sorted into annual income deciles, corresponding to the effects that would occur in 2015 from policies enacted in 2008. All of the scenarios assume a constant level of emissions reductions of 3.13 metric tons of CO₂ per capita and that the government retains for its own use 35 percent of the allowance value in order to offset its own increases in costs at the state and federal level. The efficiency of each policy is reflected in the projected cost (\$ per ton of CO₂) of allowances.

The results are summarized in Table 9.5. It can be seen that average households experience losses in welfare ranging from 1.2 percent to 2.0 percent in Texas and 1.21 percent to 1.60 percent nationwide. The largest welfare loss results from free allocation of allowances to emitters. On average, Texas fares better than the nation under some policies and worse under other policies. But the differences are relatively small.

²⁰ The analysis would be equally valid for distributing the revenues from a carbon tax.

Table 9.5. Impact of Cap and Trade Alternatives (Changes in welfare*)

Allowance Policy	Texas		Nation		Allowance Price
	Loss of welfare for bottom 2 deciles (%)	Average loss of welfare (%)	Loss of welfare for bottom 2 deciles (%)	Average Loss of welfare (%)	
Cap & taxable dividend	-3.80**	1.42	-1.97	1.39	\$41.52
Cap and tax exempt dividend	-0.59	1.40	0.62	1.36	\$41.52
Reducing income tax	8.67	1.59	8.00	1.36	\$41.52
Reducing payroll tax	-5.09	1.49	5.17	1.36	\$41.52
Expanding Earned Income Tax Credit	-6.00	1.27	-2.76	1.36	\$42.52
Excluding transportation	-1.72	1.39	-0.03	1.43	\$43.25
Excluding home heating	-2.81	1.60	-1.59	1.41	\$42.80
Free allocation to electricity customers	-3.78	1.50	-1.68	1.57	\$46.95
Invest in efficiency	-3.50	1.20	-1.81	1.21	\$37.20
Free allocation to emitters	7.24	2.00	6.15	1.60	\$45.65

*In economic terms, welfare is defined as consumer surplus, which is the aggregate amount that consumers benefit by being able to purchase a product for a price that is less than they would be willing to pay. An increase in the price of fossil fuels and products that are made from fossil fuels leads to a reduction in consumer surplus. It should be noted, however, that this measure ignores the employment and income effects of these higher prices, as well as the benefits obtained from reducing economic damages from climate change.

**Negative numbers reflect gains in welfare.

Source: Burtraw *et.al.* 2008.

The results for the bottom two income deciles, however, tell a quite different story. In Texas, poorer households experience losses in welfare of 8.67 percent when revenues from sales of allowances are used to reduce income taxes and 7.24 percent when the allowances are given free of charge to emitters. Households across the nation experience smaller, but similar losses, from these two policies. But lower income households in Texas experience gains in welfare under all other allocation policies. The highest gains (6 percent) result from using allowance revenues to expand the Earned Income Tax Credit (EITC). This also represents the highest gain for the bottom two deciles in the nation, although the gain is estimated at only 2.76 percent.

The allowance price needed to achieve the target level of emissions is highest when allowances are given free to electricity emitters (\$46.95) or to all emitters (\$45.65). These higher allowance prices reflect a more costly (less efficient) policy. On the other hand, using revenues from sales of allowances to invest in energy efficiency and carbon saving technologies results in a reduction in the allowance price (\$37.20) while still providing some equity gains (3.51 percent for the poorest Texas households and 1.81 percent for the nation's poorest households).

These results clearly demonstrate the equity-efficiency tradeoffs facing those who design cap and trade policies. For both Texas and the nation, free allocation of allowances provide neither equity nor efficiency gains. The largest gains in equity come from using allowance sales revenues to expand the Earned Income Tax Credit. But these gains come at the cost of a modest loss in efficiency (i.e. an allowance price of \$42.52). Using revenues from allowance sales to invest in improving efficiency offers strong equity and efficiency gains.

Cap and Trade Increases the Importance of Non-Fossil Fuel Alternatives

A number of engineering studies and other analyses have identified ample opportunities to improve energy efficiency at relatively low cost. From an economic perspective, however, such opportunities would exist only if there were persistent market failures. While these cannot be completely ruled out, there is a good deal of evidence that consumers and firms respond relatively quickly to perceived economic opportunities. For example, as oil prices soared in 2008, sales of fuel-inefficient cars plunged and transit ridership rose (*Financial Times* 2008). A higher price for carbon would likely spur efforts to improve energy efficiency.

Beginning with the 1978 Energy Tax Act, the United States has used financial incentives to promote renewable energy. The Energy Policy Act (EPACT) of 1992 established a ten-year 15 cents per kWh inflation-adjusted production tax credit (PTC) for tax-paying privately and investor-owned wind projects and closed-loop biomass plants.²¹ EPACT also created a Renewable Energy Production Incentive (REPI) for electricity generated from biomass, geothermal, wind, and solar from tax-exempt publicly owned utilities and rural cooperatives. Unlike the PTC, the funding available through REPI is subject to annual congressional appropriations, thereby making the availability and level of the credit uncertain.²²

CO₂-emitting fossil fuels accounted for about 85 percent of total U.S. energy consumption in 2006. The remainder was divided between nuclear electric power (8 percent) and renewable energy (7 percent). Most of the renewable energy came from hydroelectric power (42 percent), wood (31 percent), and biofuels (11 percent) with solar/photovoltaic (1 percent), wind (4 percent), geothermal (5 percent), and waste (6 percent) making up the remainder (EIA 2008b). Projections by the federal Energy Information Agency for 2030 indicate that renewable energy incentive programs are expected to have a modest impact. The fossil fuel share of consumption is projected to decline from 85 percent in 2006 to 82.4 percent in 2030

²¹While EPACT significantly improved the economics of wind power, net metering programs, implemented at the state level, have been more beneficial to the installation of solar photovoltaic generation. These programs are designed for small electricity customers (residential or small commercial) who produce their own power to bank power on the grid in times of surplus and draw down from the grid in times of need (Texas Comptroller 2008).

²²The incentive expired in 1999, but has since been renewed twice, in 1999 and 2001, before its expiration at the end of 2003. Late in 2004, it was extended again through 2005. This latest extension increased the number of renewable technologies that are covered by the incentive.

while the non-fossil fuel share rises to 17.6 percent. Within non-fossil fuels, the share of consumption accounted for by nuclear power is expected to remain relatively constant, while the share from hydropower drops to from 2.9 percent to 2.5 percent. Most of the increase in non-fossil fuel consumption occurs in biomass, which jumps from 2.5 percent to 4.7 percent. While other renewable energy sources (including wind and solar) are projected to increase 4.4 percent annually, they are projected to provide only about 2.1 percent of total energy consumption in 2030.

Since the introduction of a cap and trade policy substantially increases the cost of using fossil fuels, it might be expected that it would result in an increase in the share of U.S. energy consumption of non-fossil fuels. The cap and trade program proposed under S. 2191 would primarily impact the fuel mix used in generating electricity, since it is expected to have only a minor impact on the transportation sector (about one-third of carbon dioxide emissions).²³

Under the S. 2191 Reference case (“business as usual”), electricity consumption, including both purchases from electric power producers and on-site generation, is projected to increase at an average annual rate of 1.15 percent between 2006 and 2050 (EIA 2008a).²⁴ The share of electricity generated by CO₂-emitting fossil fuels steadily rises, while the share of nuclear and other renewable resources declines. Adoption of the proposed cap and trade program would reverse these trends. Although natural gas is substituted for coal in the early years (to 2030), coal regains market share in the later years (2030-2050) due to the introduction of commercially viable CCS technology. Nonetheless, the share of electricity generation from fossil fuels is forecast to fall to 53.6 percent by 2030, as the share of nuclear energy rises to nearly 30 percent and other non-fossil sources climb to 16.6 percent. Even with carbon sequestration, the share of fossil fuels in electricity generation is expected to continue to decline, dropping to 38.5 percent by 2050 as the shares of nuclear and other renewables climb to 36.6 percent and 24.9 percent, respectively.

There are many uncertainties that affect the impacts of proposed cap and trade programs. These include the degree to which new nuclear power and biomass projects are technically, socially and politically feasible and whether or not commercially viable carbon capture and storage technology will be available at a large scale (EPA 2008). Under assumptions that limit the growth of nuclear, biomass and carbon capture and storage technologies, electricity prices in 2030 under S. 2191 are projected to be 79 percent higher in 2030 and 98 percent higher in 2050 than under the Reference Scenario. This would spur development of electricity generation from renewable resources. But higher prices would also reduce the overall demand for electricity, projected to be 7 percent lower in 2030 and 14 percent lower in 2050 than under the cap and trade program with unconstrained nuclear, biomass and CCS technology. As a result, the share of renewable resources would actually decline to 11.6 percent in 2030 and 10.5 percent in 2050 compared to the cap and trade program projections with no constraints (16.6 percent and 24.9 percent).

²³ This is because of the relatively modest indirect price signal an upstream cap and trade program sends to the transportation sector. The price signal provided by S2191, -- about a \$0.53 per gallon increase in the price of gasoline in 2030 (about a \$1.40 increase in 2050) -- is high enough to cause large changes in the demand for transportation or changes in how transportation services are provided (EPA 2008).

²⁴ By comparison, electricity consumption grew by annual rates of 4.2 percent, 2.6 percent and 2.3 percent in the 1970s, 1980s and 1990s, respectively.

One study estimates that it would be technically feasible to rely on wind energy to generate one-fifth of U.S. electrical energy (DOE 2008). The primary stumbling block would be the huge investment (\$60 billion between now and 2030 under optimistic assumptions) required to refigure the nation's electric grid to bring wind energy generated in remote areas to urban markets. Another obstacle is the variability of the availability of wind power over the 24-hour day and seasonally. Finally, large wind power and transmission projects may face serious political and environmental opposition. These obstacles are more likely to be overcome under a cap and trade program with constrained development of nuclear, biomass and CCS technology.

A recent report emphasizes the potential of solar energy, long derided as being uneconomical (Lorenz et.al. 2008). Over the last 20 years, the cost of manufacturing and installing a photovoltaic solar-power system has fallen 20 percent with every doubling of installed capacity. Meanwhile, the cost of generating electricity from conventional sources, such as natural gas, has been rising. As a result, solar power has been edging closer to being cost competitive in some markets. Within three to seven years, it is projected that unsubsidized solar power could cost no more to end customers in markets, such as California and Texas, than electricity generated by fossil fuels. By 2020, it is estimated that global installed solar capacity might be 20 to 40 times its level today and account for 3-6 percent of installed generation capacity (1.5 percent to 3 percent of output). As with wind energy, solar power must overcome a number of obstacles to gain market share. Foremost among them are choosing among competing technologies, and developing appropriate regulatory policies to provide incentives that encourage production in the short-run but that phase out as solar power reaches grid parity with other power generation sources.

Texas may have many opportunities to develop new industries under a cap and trade program. Texas leads the nation in non-hydropower renewable energy potential with a large amount of wind generation capacity and high levels of direct solar radiation capable of supporting solar power generation (EIA 2008b)²⁵. Due to its large agricultural and forestry sectors, Texas also has an abundance of biomass energy resources. Texas already is a major nuclear power generating state. Two nuclear plants, Comanche Peak and South Texas Project, are among the largest in the nation and account for nearly one-eighth of total net electricity generation.

Although renewable energy sources contribute minimally to the state's power grid accounting for only 3 percent of total net electricity generation, Texas leads the nation in wind-powered generation capacity, accounting for 27 percent of the U.S. total. Currently, there are over 2,000 wind turbines in West Texas alone. Improvements in wind generation technology and reductions in development costs are leading to construction of substantial new wind-generation capacity (Texas Comptroller 2008). The State's pulp and paper industry uses the biomass energy from wood to generate the electricity, heat and steam it uses on site. Texas also is the largest producer of biodiesel transportation fuel in the U.S., but is only a minor producer of ethanol (EIA 2008b).

²⁵Although Texas is not known as a major hydropower state, substantial untapped potential exists in several river basins, including the Colorado River of Texas and the Lower Red River (EIA 2008b). However, the importance of managing Texas water as a scarce resource is likely to outweigh the relatively tiny amount of power it could add to the state's electricity grid.(Texas Comptroller 2008).

CONCLUSIONS

Projected climate change over the next century is likely to have only a small measurable impact on the Texas economy. Many of the potential impacts involve problems that are already recognized. Texas needs to address issues such as sea level rise and coastal erosion, air quality in its major urban centers, over-reliance on coal for electricity generation, dwindling availability of water including the conflict between agricultural and urban use, and water quality. Effectively addressing these issues will go a long way towards mitigating the impact of climate change on the State.

If, as appears increasingly likely, the nation adopts some form of cap and trade legislation to reduce GHG emissions, market forces will bring about significant changes in the State's energy mix. The average economic impact of these changes as well as the impact on the State's poorest households will depend to a significant degree on the specifics of the policy, especially on whether the allowances are distributed without charge or auctioned off. In addition, cap and trade policies that permit the use of domestic and international offsets, allow banking and borrowing of allowances, provide assistance for transition to emission-saving technologies, and contain a safety value to limit costs will reduce, but not eliminate, the relatively higher economic burden placed on the State.

Texas also is in a unique position to benefit from expanded use of non-fossil fuel sources for electricity production. The nuclear power industry in the State is well established. While Texas is leading the way in converting wind energy into electricity, much untapped potential remains. The State is also rich in solar and biomass resources.

Looking to mid-century, it is clear that the cost to Texas of a national cap and trade policy would likely exceed any possible measurable benefit in terms of avoided damages. But over a longer time frame, if the harmful impacts of climate damage continue to increase the cost-benefit balance might shift. But time is not on our side. Texas would benefit economically by taking stronger actions today to address climate change impacts at the State level, and by supporting the adoption of cost-effective, equitable policies at the national level to limit GHG emissions and encourage the use of non-fossil fuel alternatives.

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