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16. Abstract

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The Texas Urban Triangle – 17 million persons spread over 58,000 square miles – is a new urban phenomenon, a triangular megalopolis whose development is not linear and contiguous. This report gives policy makers and investors from all sectors of society the critical knowledge they need to make decisions that will shape the future of Texas.

The Texas Urban Triangle is one of the most dynamic urban regions in the nation, and to ensure it continues to flourish, we must build a future based on sustainable growth principles. Our *preliminary* findings suggest that this is not always the case. Further research needs to be conducted to obtain a complete, detailed, and comprehensive portrait. Nonetheless, even these preliminary findings are robust and point to more sustainable options for the future.

Now that this preliminary analysis has been completed, readers are invited to consider the results. The ultimate goals of the project are three-fold:

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- To determine what future research, particularly at the regional scale, is needed to provide a sound basis for public policy and private investment decisions.

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TEXAS URBAN TRIANGLE: FRAMEWORK FOR FUTURE GROWTH

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Research Report SWUTC/08/167166-1

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The students listed below were enrolled in the Sustainable Urbanism Seminar (PLAN 675) and the Applied Planning Studio (PLAN 662). They are commended for their diligent efforts, attention to detail and intellectual contributions in support of this research project.

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EXECUTIVE SUMMARY

The Sustainable Urbanism Seminar and the Applied Planning Studio of the Department of Landscape Architecture and Urban Planning of Texas A&M University is pleased to present this Executive Summary of the 150 page, full color, 11 x 17 inch Regional Analysis of the Texas Urban Triangle (available at http://swutc.tamu.edu/publications/technicalreports/167166-1full.pdf. This project came into being due to the dramatic transformation of the four core Texas metropolitan areas into an emergent megalopolis: Dallas-Fort Worth, Houston, San Antonio, and Austin. Its aims are two-fold: to provide a framework for decisions about future growth in the fastest growing region of Texas, and to spur further research into the complexities of this vast and rapidly emerging mega-region.

The Texas Urban Triangle – 17 million persons strong spread over 58,000 square miles – is a new urban phenomenon, a triangular megalopolis whose development is not linear and contiguous like prior megalopolises, such as Boston-Washington, Santa Barbara-Tijuana, and Tokyo-Osaka. These unique characteristics, along with the Triangle's rapid reshaping of the Texas landscape and economy, firmly place this project in the vanguard. This report gives policy makers and investors from all sectors of society the critical knowledge they need to make decisions that will shape the future of Texas.

What makes this urban triangle a functional mega-city region is the high and increasing degree of integration found among their metropolitan areas economies and societies. This can be evidenced by the economic, informational, and human flows among the four grand urbs of the Triangle. As long ago as 1969, geographer Donald recognized the "triangle to be the Core area of Texas". Today we can say that the Texas Urban Triangle is beginning to work as a single mega-city that rivals New York and Los Angeles. The Texas Urban Triangle is the new nucleus of Texas. Its dominance in Texas continues to grow, in part at the expense of some rural areas of the state.

The Texas Urban Triangle is one of the most dynamic urban regions in the nation, and to ensure it continues to flourish, we must build a future based on sustainable growth principles. Our *preliminary* findings suggest that currently, this is not always the case. Further research needs to be conducted to obtain a more complete, detailed, and comprehensive portrait. Nonetheless, even these preliminary findings are robust and point to more sustainable options for the future.

Over thirty Texas A&M University students and faculty from Landscape Architecture, Urban Planning, Architecture, Construction Science, Geography, Civil Engineering, and Recreation, Parks and Tourism collaborated to produce this Regional Analysis and Framework for Future Growth. The student and faculty investigators thus far have presented their findings at various national and international meetings spanning four continents.

Overview of the Current Situation

The Texas Urban Triangle is located in the heart of Texas, with the metro areas of Houston, Dallas-Fort Worth, and San Antonio composing the vertices of the Triangle. The Texas Urban Triangle's Metropolitan Statistical Areas alone had an estimated 2005 population of about 16.3 million inhabitants. In absolute terms, it has been the fastest growing region of the state for decades, with parts of the Rio Grande Valley having the fastest growth *rates*. In the year 2030, population for the counties that make up the Triangle is projected to exceed 23 million, compared to 31.8 million for the entire state. In other words, the 2030 population of the Triangle alone is projected to exceed the 2000 population of the entire state by over two million.

The region composed of the Texas Urban Triangle has a celebrated cultural history based on the open range and the cowboy, and more recently on oil. It sports many traditions from the blues in the Navasota area, Czech, German, and Spanish-Mexican heritage in its southern part, and cotton plantations in the northeast. In addition, there are many large military bases throughout the Triangle and its immediately adjacent territory. Culturally, the region possesses a demographic mix and colorful history that combines Mexican, Cajun, Southwest, Plains, Western, and Texan cultures.

This diverse heritage, commanding central location in the continent, and robust economy serve as a great reservoir from which to draw as the Texas Urban Triangle continues to grow. Regional infrastructures and facilities of all types are essential to assure this growth and attract new residents and businesses. For example, the Trans Texas Corridor initiative is the latest effort, among several over the last decades, to forge partnerships in attempts to provide high speed rail. It has spurred the imagination, plus major planning efforts to better connect the region with its state, national, and international environs. With the Texas Urban Triangle as the new spatial launching pad into the global arena, Texas can think big.

Yet challenges abound in the region, notably water supply and distribution, the conversion of prime farm and ranch lands to exurban sprawl, metropolitan traffic congestion and air and water pollution, urban poverty, land subsidence, and high per capita rates of energy consumption. For example, aquifer levels have dropped over 800 feet in the Dallas area, and 400 feet in the Houston area in less than a century. In Houston, the accompanying subsidence has damaged buildings, increased flooding, jeopardized numerous hazardous and toxic waste facilities, and exposed the metropolis to much greater risk in the face of hurricanes and global warming. Ozone and other airborne pollutant levels exceed limits, which are not only injurious to health and the economy, but place at risk billions of dollars of federal transportation funding.

It is the ***patterns*** of growth – its location, densities, uses, and suitability to its underlying ecological constraints – that cause or worsen many of these less than desirable conditions. Furthermore, growth occurs at a pace that outstrips the fiscal and infrastructural capacity to support it to the quality levels and standard of living to which we have become accustomed. How many children attend classes in trailers, or are forced into double shifts at hours that are inconvenient or even burdensome, much less conducive to good learning? To solve these and other growth-related problems, and to correct these inequities, Texas once again will have to

think big to accommodate the amount of growth anticipated over the next decades and to direct it into more sustainable patterns.

Principal Findings and Challenges for the Future Growth

As Texas continues to grow steadily, growth in the Triangle is expected to be even faster. Population in the Triangle is projected to increase 57% between 2000 and 2030, above the 42% increase for the rest of the state. The Texas Urban Triangle is projected to account for 8,407,000 of the state's 10,979,000 new inhabitants, or 77% of all Texas's growth. The attendant impacts of growth – new homes, new jobs and businesses, new transportation and infrastructure networks, less farm and ranch lands, and more pollution – are easy to predict based on past experience. How we handle this new growth will determine to a large degree whether we continue to prosper and enjoy a high quality of life.

This report is intended to support future growth policy, investments, and planning for Texas, the Texas Triangle mega-city region, and the region's metropolitan areas. A key implication of this work is to guide *regional design* using regional scale infrastructure systems, especially transportation, telecommunications, energy, and "green" networks. Just as cities cannot exist without urban infrastructure, the great Texas mega-city of the future cannot function without regional infrastructures.

Our analysis reveals that two issues will dominate the Texan landscape and imagination over the next decades: water and energy. Water sustains all life on this planet, of course. Nothing could be more fundamental, and given the collision course of water usage rates and growth rates in Texas and elsewhere, nothing could be more critical. Our report also has much to say about water, not only its usage, but the impacts of its use, and the disparities among its sources and end-users. Nothing besides energy could be more critical.

Energy powers the economy and every aspect of daily life. It is also the fuel of hope that enables Texans to strive unfettered for a better tomorrow. Energy, more precisely oil and gas, is as much a part of the contemporary Texas consciousness as the cowboy, cattle drives, and the open range were in the 19th century. Today we can add solar, wind, and other renewable sources to new generation nuclear power to attain a diverse energy portfolio. For good reasons, energy and water are considered "critical infrastructures".

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TABLE OF CONTENTS

LIST OF FIGURES

TEXAS URBAN TRIANGLE

Framework for future growth

QUICK FACTS

		Texas	Texas Urban Triangle
The Environment	Total Area (sq. miles)	268,581	58,410
	Land (sq. miles)	261,767	56,173
	Water (sq. miles)	56,173	2,237
	Highest Point	Guadalupe Peak (8,749 ft.)	Midway, Kerr County (2,396 ft.)
	Lowest Point	Gulf of Mexico (0 ft.)	Gulf of Mexico (0 ft.)
	Longest Distance North-South	801 miles	362 miles
	Longest Distance East-West	773 miles	315 miles
The People	Total population April 2000 Census:	20,851,820	14,664,613
	Total population estimate July 2006:	23,508,000	16,149,000 (MSA's only)
	Population projection (2030) TXOSD:	31,831,000	23,120,000
	Population Density (2000):	29.98/sq. km.	91.92/sq. km.
Most populated (2000)	metropolitan area:	Dallas – 5,346,119	Dallas – 5,346,119
	county:	Harris – 3,400,578	Harris – 3,400,578
	incorporated city/town:	Houston – 1,953,631	Houston – 1,953,631
Most populated (2006 estimate)	metropolitan area:	Dallas – 6,004,000	Dallas – 6,004,000
	county:	Harris – 3,886,000	Harris – 3,886,000
	incorporated city/town:	Houston – 2,144,000	Houston – 2,144,000
Least populated (2000)	micropolitan area:	Andrews – 13,004	Mineral Wells – 27,026
	county:	Loving – 69	Delta – 5,327
	incorporated city/town:	Los Ybanez – 32	Dayton Lakes – 101
Establishments	total (2002):	481,850	349,450
	average size (2002):	16.5 employees	17.8 employees
Employment	total (2002):	7,937,492	6,227,400
	top metro (2002):	DFW – 2,546,007	DFW – 2,546,007
	top county (2002):	Harris – 1,654,636	Harris – 1,654,636
	Annual payroll (2002): million	$275,084	$233,038
	Retail Sales (2003): billion	$281.80	$212.50
	Employment (2030):		14,145,056 (projected)
Infrastructure	Highway Miles (2004):	189,745 miles	71,231 miles
	top county:	Harris – 4,740 miles	4,740 miles
	bottom county:	Loving – 67 miles	Somervell – 190 miles
Road-related expenditures (2004)	state/contracted maintenance:	$1,122,090,877	$520,790,822
	state construction:	$4,449,810,426	$3,075,251,119
Vehicles registered (2004)	Vehicle miles driven per day:	449,486,854	304,518,992
Railroads	miles operated (2003):	14,049	n/a
	Amtrak passengers (2004):	267,568	222,706
Seaports	total tonnage (2003):	473,941,000	413,390,000
	foreign imports:	281,985,000	229,077,000
	foreign exports:	62,300,000	52,862,000
Airports	number of commercial airports:	28	11
	passenger enplanements:	60,226,460	56,376,167
Solid waste	tons of hazardous waste (1995):	146,770,659	112,992,174
Brownfields	number of Superfund sites (2003):	76	43

QUALITY OF FARMLANDS

According to the U.S. Department of Agriculture, soils should be classified as prime farmland if "…they meet or posses the best combination of physical and chemical characteristics for producing food, feed, fiber, oilseed, and certain economic or production criteria" (USDA 2007). Over the last decades urban sprawl and economic growth have been causing undue pressure on prime farmlands by introducing competition for other uses. The largest concentrations of prime farmlands in the Texas Triangle are found along the I-35 corridor, and to a lesser extent the I-10 corridor, within commuting distance to Dallas, Austin and Houston. This means most of prime farmlands are increasingly as valuable developable lands (NRCA 2007).

The contribution of agriculture for the value of rural lands in Texas is minimal around the larger urban areas of the Texas Urban Triangle, and especially around and beyond its western fringe, in more scenic hill and forest areas, generally on higher ground (and consequently less polluted). This is apparent in the eastern side of the Edwards Plateau and the divide between the Red River basin and the Trinity and Brazos basins. It is also clear around Houston, reflecting the contrast between the western residential side and the eastern industrial side, and along the I-10 and I-45 corridors.

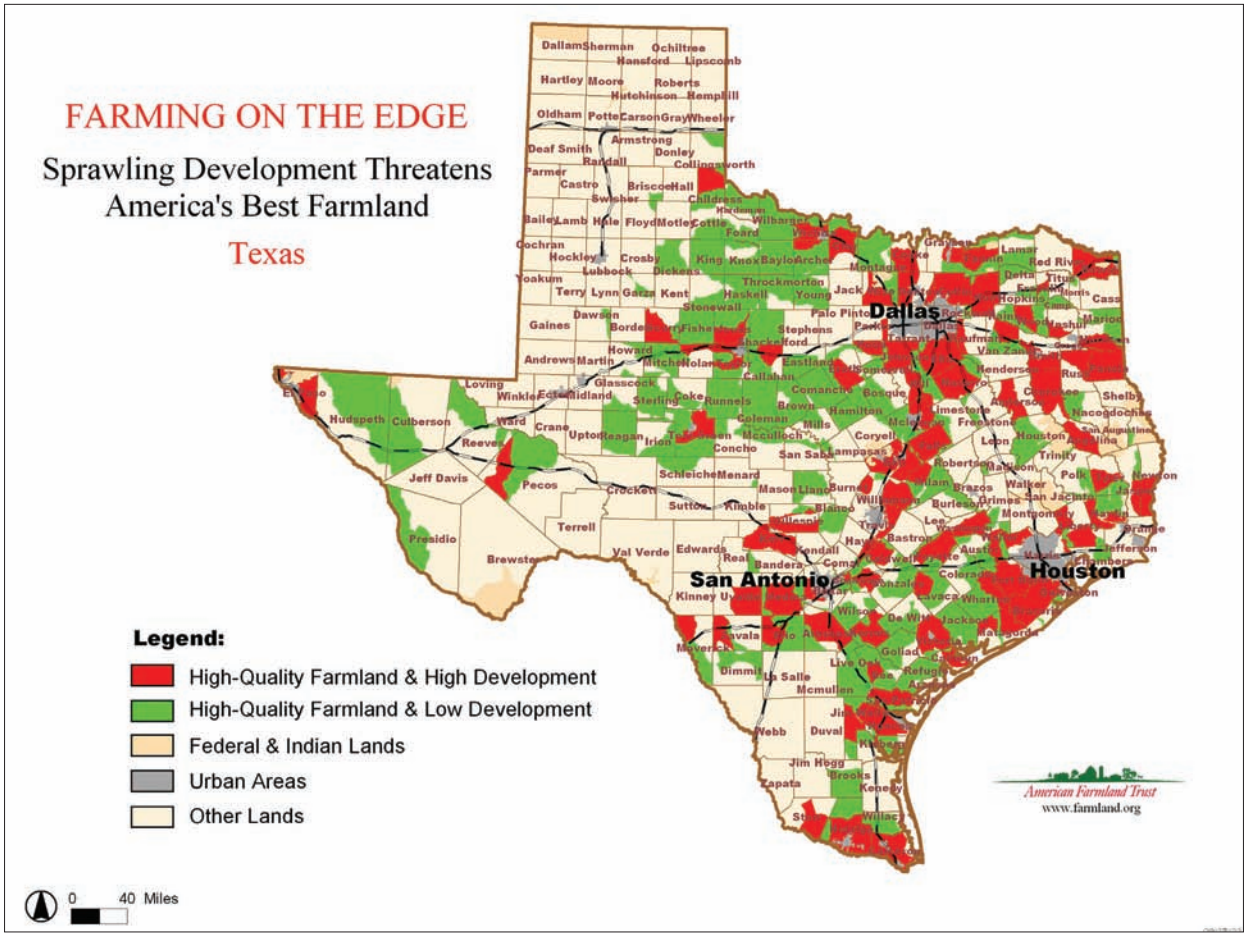

Figure 1. High-quality farmland and urban development.
Source: American Farmland Trust.

CURRENT ISSUES IN WATER AVAILABILITY

Across the Texas Urban Triangle, water availability has declined while use increased. According to the last State Water Plan (TWDB, 2007a), and if no measures are taken, the water available in times of drought (with the existing contracts and permits) will decrease by 3.3 million acre-feet, while the estimated need for additional water under the same conditions will increase by 5.1 million acre-feet. The fact that some major water sources like the Colorado River and the Trinity and the Balcones (BFZ) Aquifers are already used at capacity documents the need to conserve water – reduce demand – and to better manage existing water resources.

AQUIFERS

In Texas, groundwater remains a crucial natural resource and a basic commodity. Groundwater exists beneath the earth's surface, and is usually recharged by precipitation and percolation. Water penetrates permeable rocks such as sandstones, fractured limestone, unconsolidated sand, and gravel, and may feed wells and springs at some distance.

The Texas Urban Triangle is characterized by a coastal upland aquifer system that underlies an area of 50,000 square miles. It consists primarily of unconsolidated deposits of early tertiary age rock formations that yield large quantities of water (TWDB 2007a).

The principal aquifer type in the Texas Urban Triangle is unconsolidated sand and gravel. This makes the aquifers susceptible to contamination due to their high permeability and hydraulic conductivity (ISU 2007).

There are several major and minor aquifers in the Texas Urban Triangle. The Texas Water Development Board (TWDB) identifies nine major and twenty minor aquifers underlying about 81 percent of the state's area.

Of the nearly 8.9 million acre-feet of groundwater Texas consumed in 1990, almost 95 percent came from nine major aquifers. The remaining five percent was drawn from 20 minor aquifers (TWDB 1993b).

Five major aquifers –Gulf Coast, Carrizo-Wilcox, Trinity, Edwards-Trinity (Plateau) and the Edwards-Balcones Fault Zone – supply water to different portions of the Texas Urban Triangle. According to the TWDB they had, in 2000 and under drought conditions, a total availability of 4.7 millions AFY, which represented 31% of the state total. Note that all of them extend beyond the Triangle, also providing water to other areas (TWDB, 2007a).

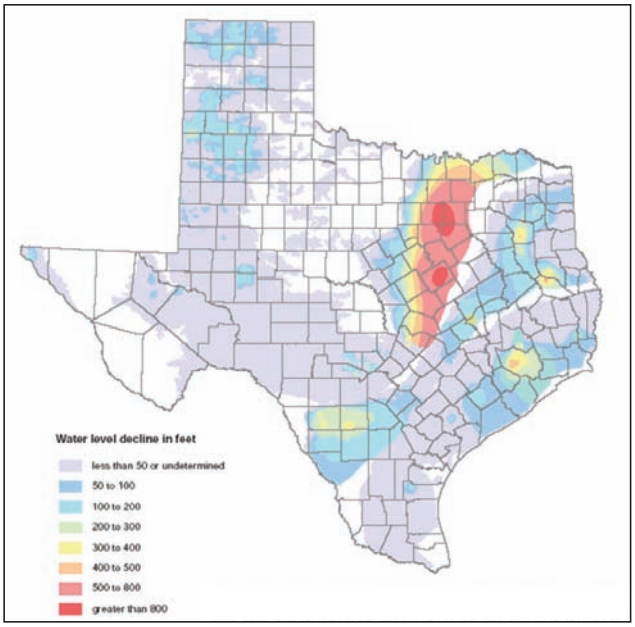

Figure 2. Estimated total water level declines in major aquifers.
Source: 2007 State Water Plan.

PLUMMETING AQUIFER LEVELS

The continuous extraction of water above recharge levels has provoked important drops in the water levels in several aquifers. Especially grave is the Trinity, whose **water level dropped more than 500 feet between** Austin and Sherman. Most severe were the drops in the areas of Dallas-Fort Worth and Waco, where water is now more than 800 feet below the average level before the beginning of mass pumping. Now these areas rely almost exclusively on surface water.

Other aquifers in the Triangle also suffered major drops. They are especially noticeable in the Gulf Coast Aquifer in Houston, and the Carrizo-Wilcox Aquifer close to Tyler, Lufkin and College Station-Bryan; all where water levels already **dropped by more than 300 feet**. See Figure 2.

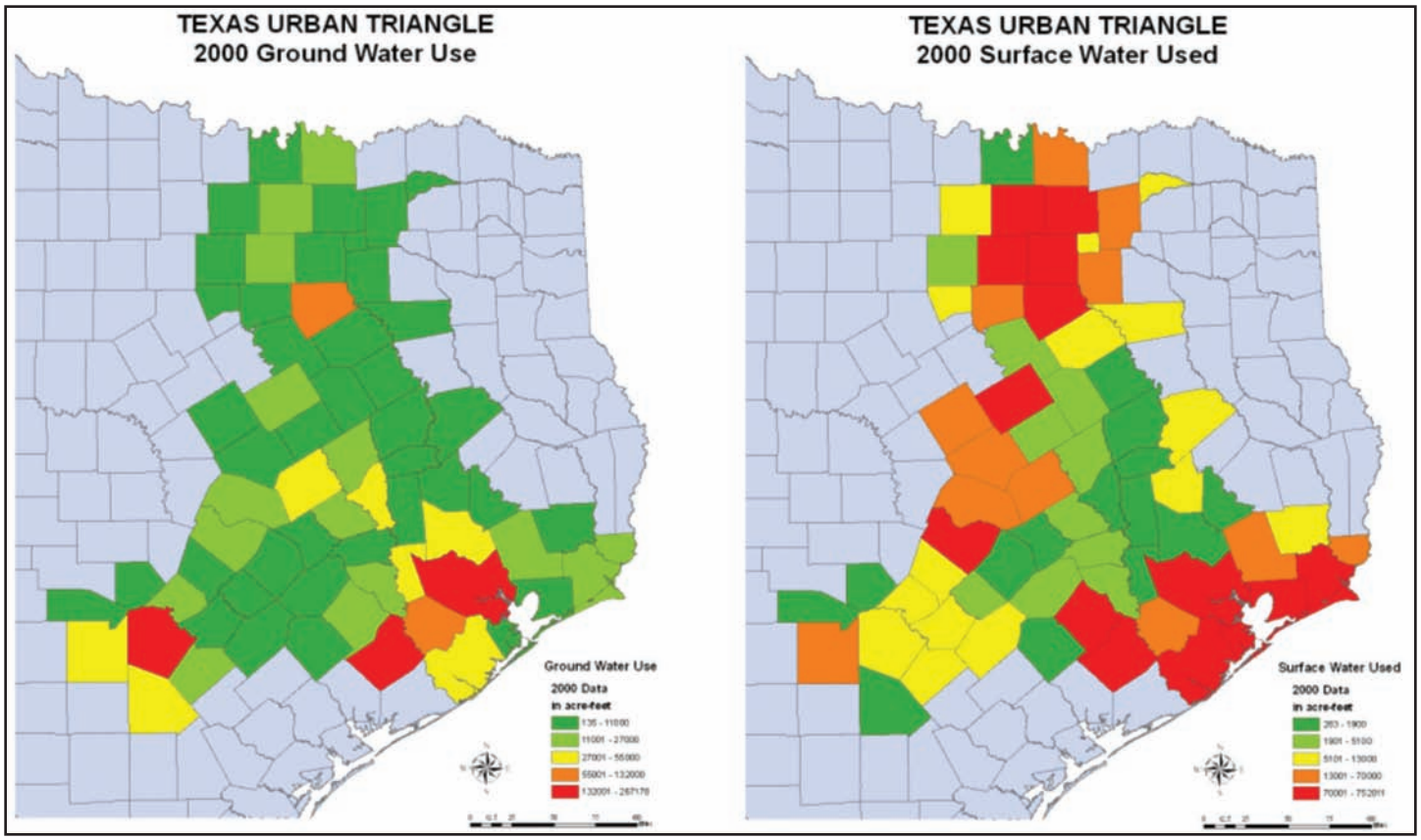

Figure 3. Ground and Surface water use by county in the Texas Urban Triangle, 2000.
Source: TWDB.

Comparing the 2000 county patterns of water use in the Texas Urban Triangle, several major differences stand out (see Figure 3):

- overall there was a major contrast between urban (more populated) and high-consumption counties at the Triangle vertices, and more rural (less populated) and low-consumption counties in the core;
- high groundwater use was more localized in a few counties, most of them in the southern section of the Triangle; among the top consumers were Harris and Bexar counties, where the cities of Houston and San Antonio are located;
- surface water use was more widespread, but generally higher in (more populated) urban counties, especially in the Dallas-Fort Worth and Houston-Beaumont areas, and lower in the core of the Triangle; and
- the major exception to the urban/rural dichotomy was found in the rice-producing area west of Houston, where both Wharton and Colorado counties were large water consumers.

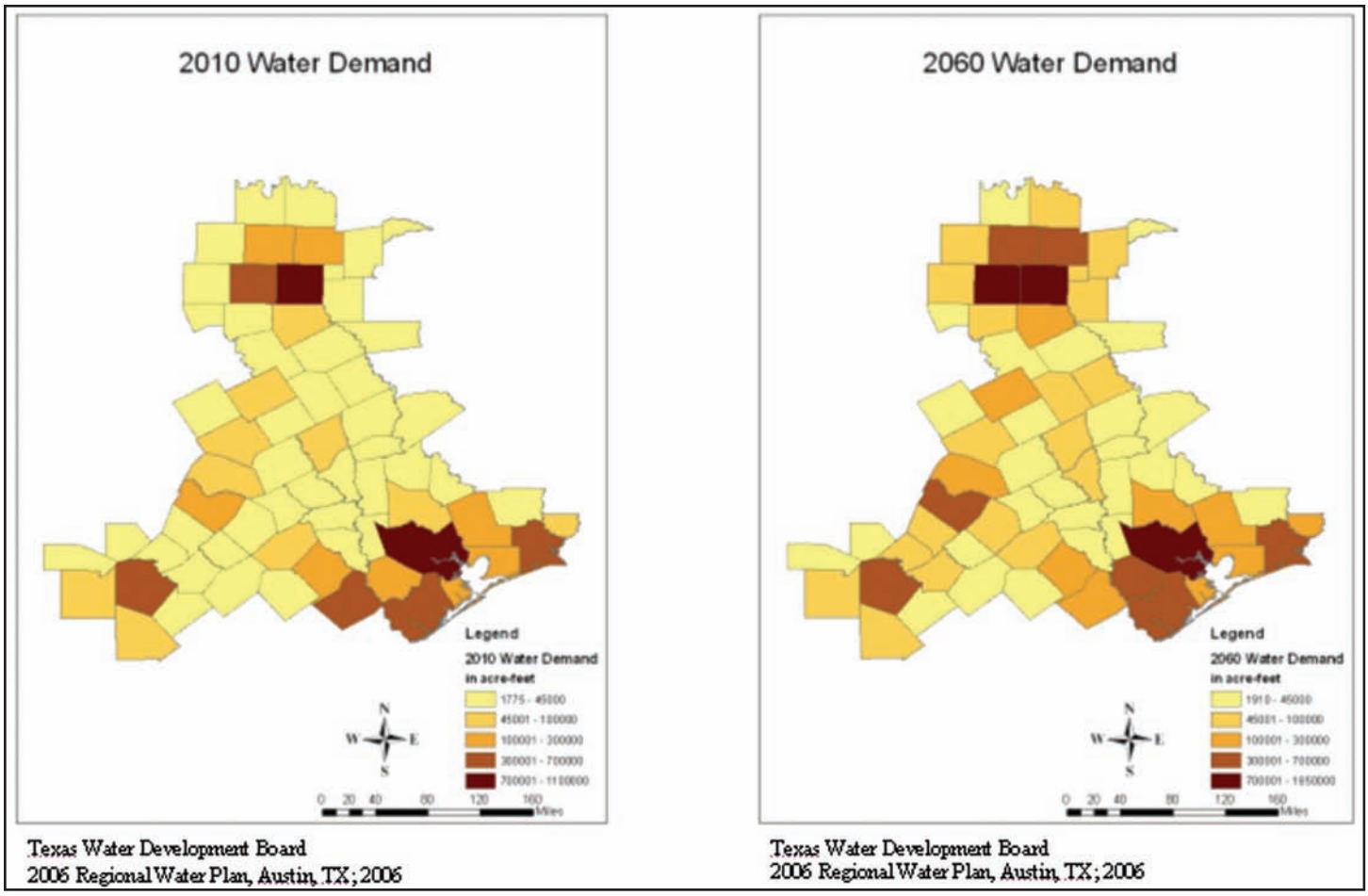

Figure 4. Total projected water demand in Texas, 2010-2060.
Source: TWDB.

WATER DEMAND

The share of water demands state-wide met by groundwater and surface water has changed over time. Groundwater use has dropped from 70 percent of all water used in 1974 to 55 percent in 1991. In absolute terms, the state's consumption of groundwater has gone from more than 12 million acre-feet to about 9 million acre-feet in 11 years. Reliance on groundwater should continue to decline for two reasons: first, the decline of overall agricultural acreage (and the acres dropped were almost all irrigated by groundwater); and second, many of the large municipalities are converting to surface water or mixing groundwater with surface water (TWDB 1991). For example, Houston is gradually switching from underground sources because of subsidence problems. Other places are switching because of the increasing salinity - and declining quality - of its groundwater resources. Though this trend is expected to continue, groundwater will nevertheless continue to supply most of the water for large, arid areas of the state (TWDB 1990).

TORNADOS, STORMS AND HURRICANES

Given the size and complexity of the Texas Urban Triangle, every area is exposed to some type of hazard. Much of the focus on weather-related hazards within Texas, and more specifically the Texas Urban Triangle, is on the high-risk/high probability of tornados, storms and hurricanes. Frequency of and exposure to these types of hazards within the Texas Urban Triangle were identified in order to discuss their impact on population growth patterns; measures of exposure and vulnerability can be used in suitability analyses to identify areas more or less appropriate for development (Bright 1997).

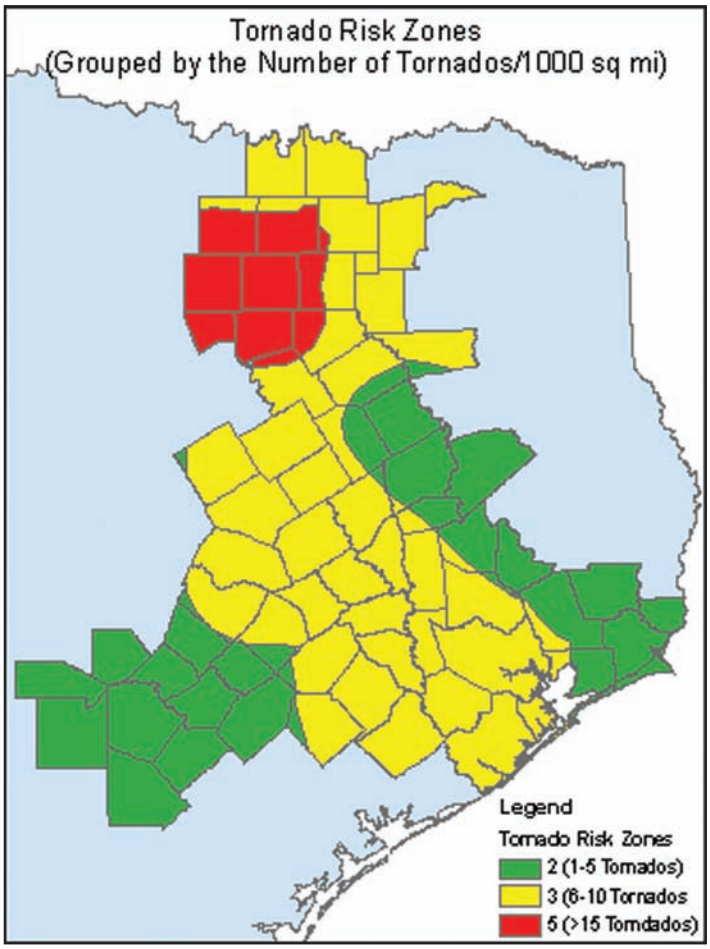

Figure 5. Tornado risk zones in the Texas Urban Triangle.
Source: THMP.

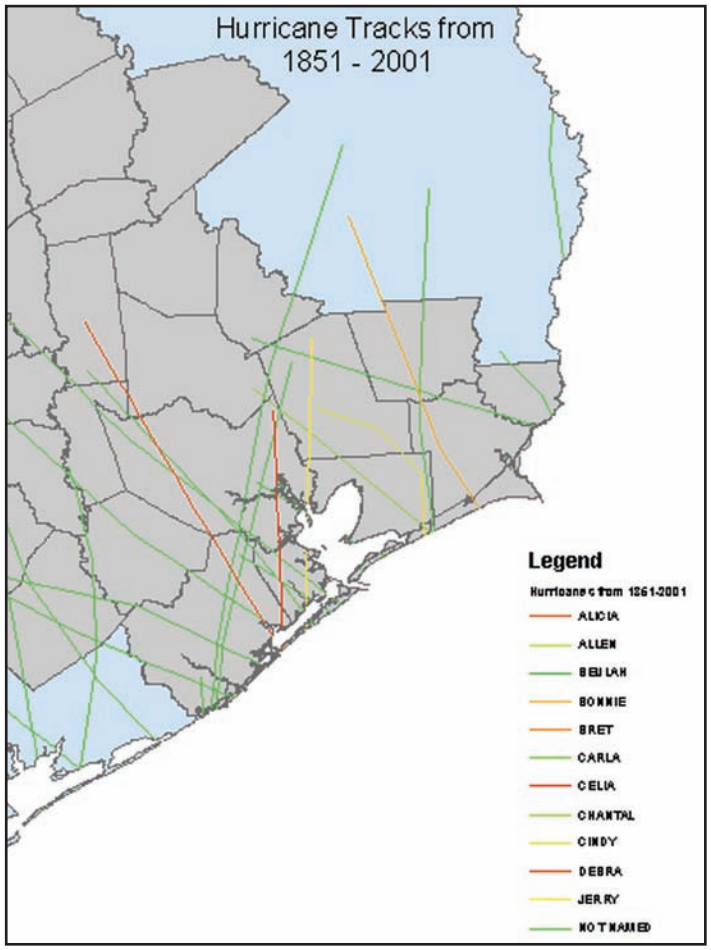

Figure 6. Hurricane tracks, 1851-2001.
Source: NOAA.

LAND SUBSIDENCE

Land subsidence along the Gulf Coast has been proven to be a serious environmental hazard. This is due population, infrastructure and hazardous facilities located in the area, especially considering the amount of population and physical infrastructure located in the area. Counties in the metropolitan Houston have been the most severely affected. Land subsidence compounds the effect of sea level rise in the future. The problem has been associated with excessive water pumpage from aquifers in unconsolidated sediments. When average rates of annual aquifer recharge are less than average pumpage rates the soil tends to compact and sink (Kesmarek et al., 2005).

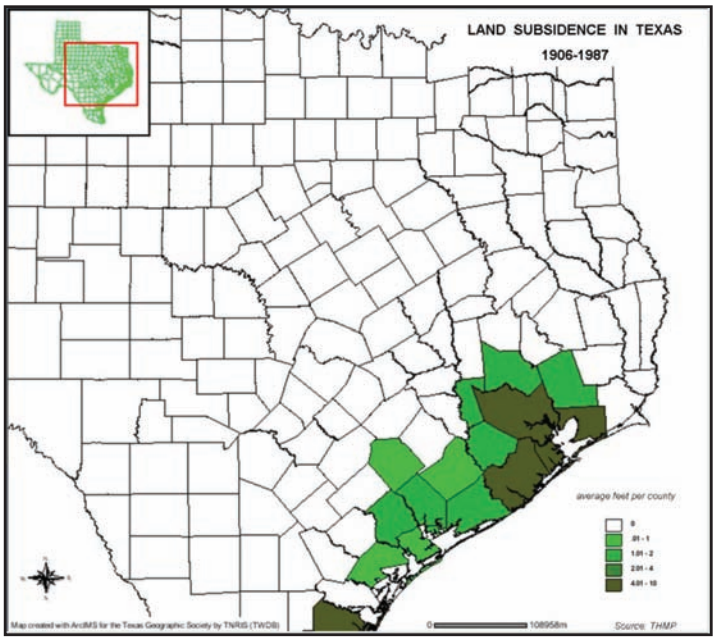

Figure 7. Land Subsidence, 1906-1987.
Source: THMP.

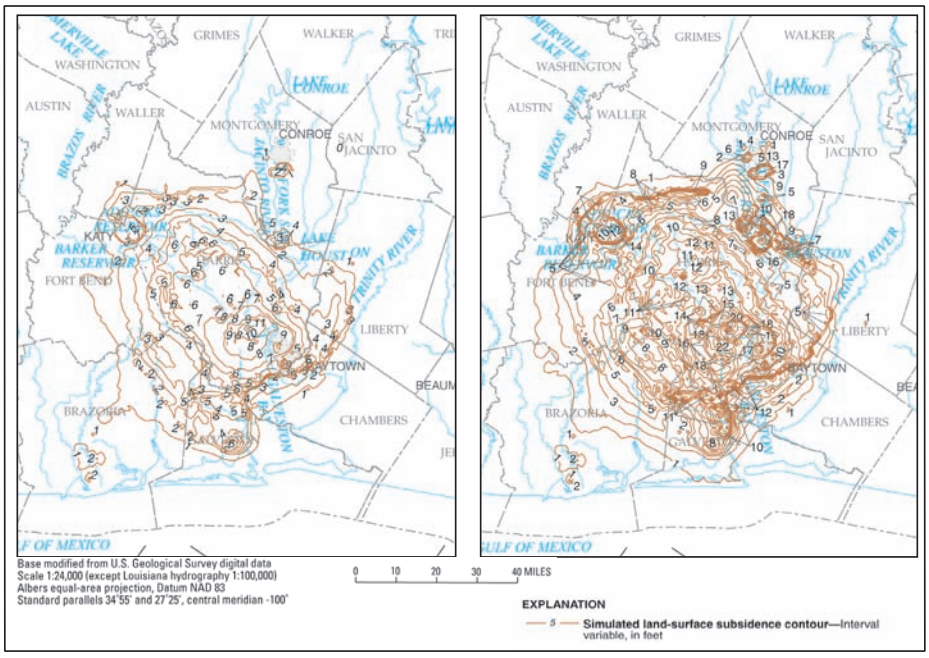

Figure 8. Simulated 1995 and 2030 land-surface subsidence in the NGC GAM model.
Resulting from HGCSD withdrawal scenario in the Houston-Galveston area.

POPULATION

This concentration of people and activities in a small area is a recent trend, posterior to World War II. Since then, the state as a whole, and the Texas Urban Triangle in particular, benefited from a set of strategic investments from the federal government, especially in high-technology sectors linked to the military (Meinig 1969). Industrialization and the availability of air-conditioned indoor environments attracted new activities and residents to the state.

Texas has been outpacing the nation's population growth rates due to higher birth rates, and a strong and continuous in-flow of migrants. According to the state's Comptroller office, net migration since 1950 has accounted for more than one third of the net population growth, and Hispanic net migration amounted to more than one half of legal migrants (Sharp 1993). In the national context, Texas has a relatively young population, with the second lowest resident median age in the nation at 33.1 years per the 2006 US Census Estimates, well below the national average. Only Utah was lower (USBC 2006.)

Despite the consistently high population growth in Texas over the last one and a half centuries, there have been major regional differences across the state. In 1850, Texas was very sparsely populated, the largest settlement being the coastal town of Galveston, with just over four thousand inhabitants. Austin, the state capital, just surpassed 600 (McGregor 1936).

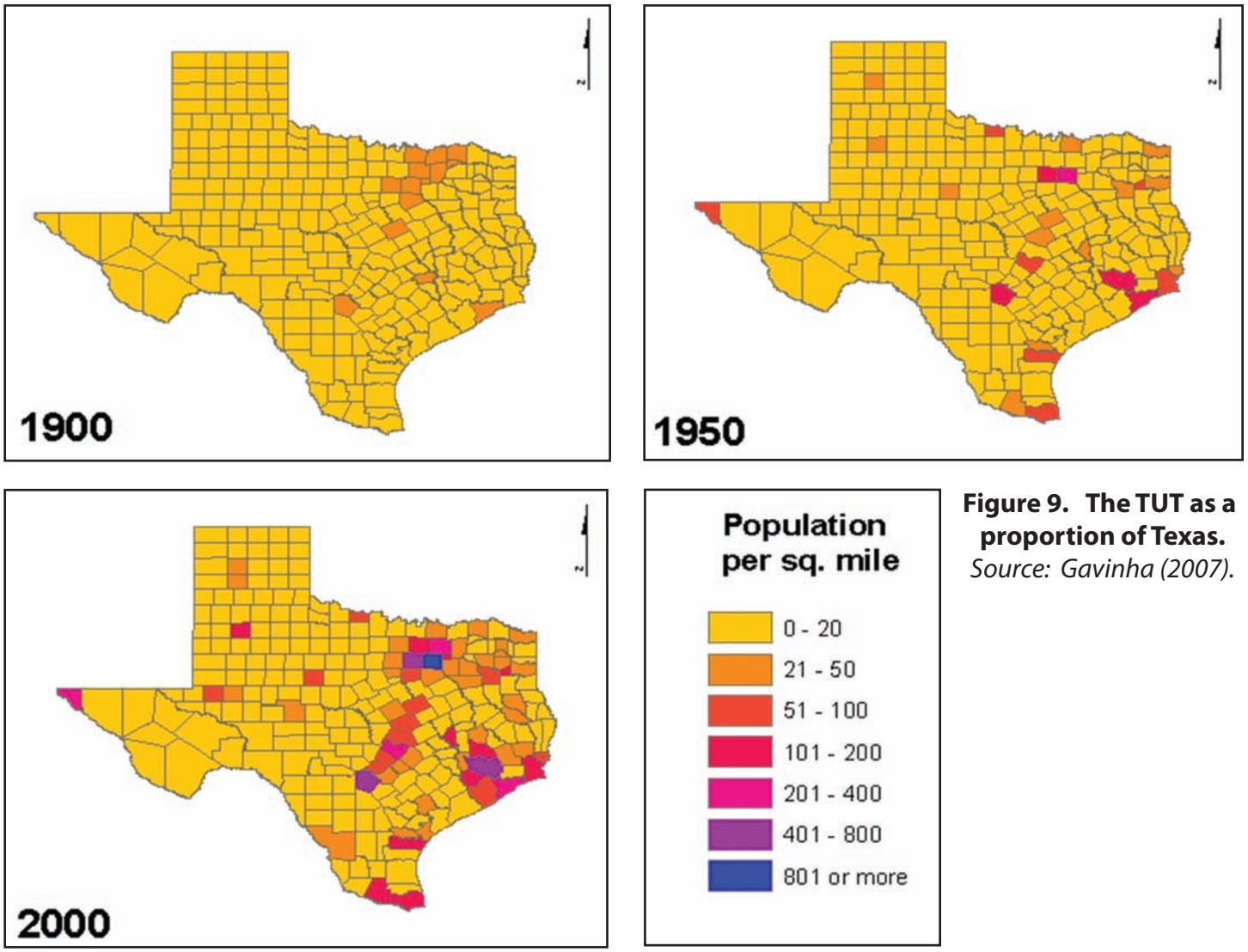

Figure 9. The TUT as a proportion of Texas. *Source: Gavinha (2007).*

Since then the state population increased almost 100 times over a period of 150 years, but this growth has been very unevenly distributed across the state geographically.

From the examination of Figure 9, it is apparent that density did not increase significantly in the majority of counties of Texas. By 1900 all county densities were below 50 persons per square mile, and in only 14 counties the density was greater than 20 per square mile. By 1950 counties containing larger towns had shown substantial density increases, and five counties, those containing the urban settlements of Fort Worth, Dallas, San Antonio, Houston and Galveston, had surpassed the density of 100 persons per square mile; but the large majority of counties remained with densities below 20 persons per square mile. By year 2000, the trend for concentrated population growth had been reinforced, with core urban counties having densities over 400 persons per square mile, and suburban counties around Dallas, Houston, Austin and San Antonio also showing significant density gains. Densities in the counties of rural Texas remained low.

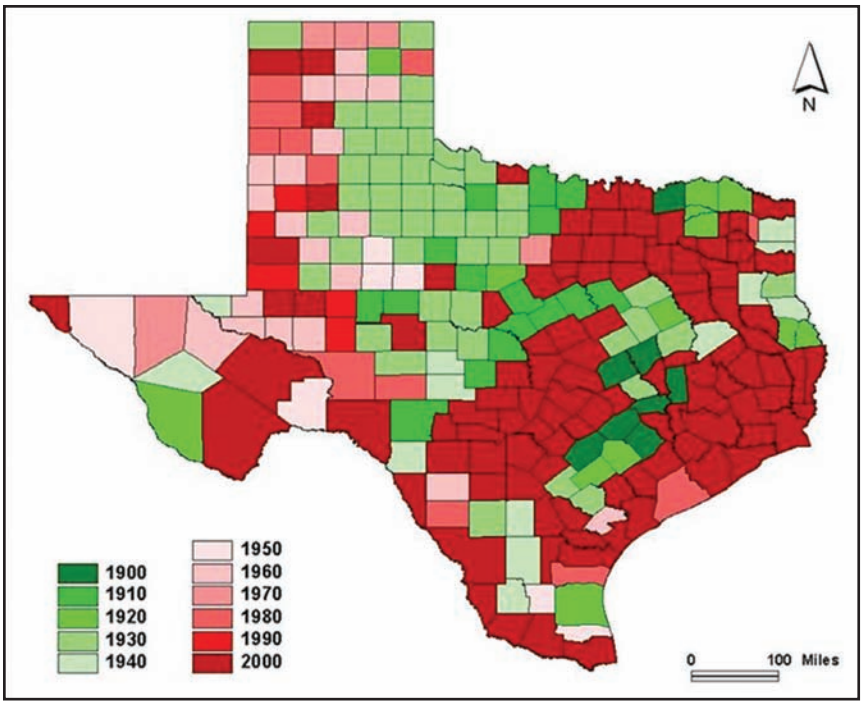

Figure 10. Census peak populations in Texas counties, 1900-2000.
Source: Gavinha (2007).

Another surprising but important fact is that many counties in Texas have been losing population, and some of them over relatively long periods. Figure 10 shows in which census county populations peaked over the 20th century. By analyzing this data, it is possible to divide the state in two halves, northwest and southeast. In the southeastern half, counties in and close to the large cities of the Texas Urban Triangle (as well as around Corpus Christi and in the lower portion of the Rio Grande valley) reached their peak population in the most recent census. In the northwest half of the state, most of the rural counties had their peak several decades ago, and some at the turn of the *last* century, in 1900. We can observe how the southeastern half of the state containing the Texas Urban Triangle is the robust half with growing population and employment.

The demographic trends of the Texas Urban Triangle's metro areas – on a rapid growth curve – have diverged from most of its rural areas, which have been declining. Thus, being within the emerging triangular megalopolis has not been an advantage.

POPULATION

The five largest cities in the Texas Urban Triangle have been posting significant net population gains over the last decades. See Figure 11. From 1950 to 2000, the population of Austin increased by 359%, Houston by 209%, San Antonio by 175%, Dallas by 150%, and in Fort Worth by 76%. But these impressive figures are somewhat incomparable amongst themselves, because they do not indicate important gains in their geographic size due to annexation. This is a factor of major relevance, since Texas cities have been incorporating new land at rates significantly higher than their population growth. Over the same five decades Austin's area increased by 705%, San Antonio's by 493%, Houston's by 276%, Dallas' by 244%, Fort Worth's by 219%.

Cities	1950	1960	1970	1980	1990	2000
Austin	132.5	186.5	251.8	345.5	465.6	608.1
Dallas	434.4	679.7	844.4	904.1	1.006.9	1,085.6
Fort Worth	278.8	356.3	393.5	385.2	447.6	489.3
Houston	596.2	938.2	1,232.8	1,594.1	1,630.6	1,841.1
San Antonio	408.4	587.7	654.2	785.4	935.9	1,123.6

Note: population shown in thousands.
Sources: United States Bureau of Census and Gavinha (2007).

Figure 11. Population of Selected Cities in Texas, 1950-2000.
Source: Gavinha (2007).

In Texas, home rule cities can annex adjacent territory within their extraterritorial jurisdiction (land 5 miles beyond the boundary for a large city) with relative ease, a direct consequence of a state constitutional amendment approved in 1912. The annexation process was further regulated by the Municipal Annexation Act, passed by the Texas Legislature in 1963, which restricted annexations to up to 10% of the existing city area per year, in order to prevent or minimize big seizures of non-urbanized areas, as had happened in the 1950s. Those annexations in that earlier period led to massive land speculation in the urban fringe, with the attendant suburban sprawl.

Texas cities have been taking full advantage of these provisions, but most recently there is a noticeable slowing of annexation rates. One of the major reasons for this slowing has been the incorporation of suburbs as independent cities. These newly incorporated cities thus become physical barriers to expansion of the central city. This process is especially noticeable around Dallas, and to a lesser extent, southeast of Houston.

Cities	1950	1960	1970	1980	1990	2000
Austin	32.1	49.4	72.1	116.0	217.8	258.4
Dallas	112.0	279.9	265.6	333.0	342.4	385.0
Fort Worth	93.7	140.5	205.0	240.2	281.1	298.9
Houston	160.0	328.1	433.9	556.4	578.5	601.7
San Antonio	69.5	160.5	184.0	262.7	333.0	412.1

Note: area shown in square miles; both land and water portions included.
Sources: United States Bureau of Census, Sharp (1993) and Gibson (1998).

Figure 12. Area of Selected Cities in Texas, 1950-2000.
Source: Gavinha (2007).

POPULATION IN THE FUTURE

Projections based on from the Office of the State Demographer (OSD) point to the continuation of this strong population growth in the Texas Urban Triangle. Projections are based on cohort-component projections, and reflect historical trends for each cohort (people of the same gender and race, by 5-year age intervals). The method calculates annual variations in the population based on the natural growth (births versus deaths) and net migration (in- versus out-migration) trends.

The OSD proposed alternative scenarios, primarily based in changing migration trends. For this Texas Urban Triangle regional analysis, scenario 0.5 was considered as most suitable, by offering a reliable and middle-of-the-ground projection. From 1990 to 2000, Texas experienced a period of strong demographic expansion, which caused a surge in immigration. However, the state economy has slowed down, which is expected to slow migration rates. The 0.5 scenario works with a growth rates about 1.5 % lower than the high rates found in 1990-2000. OSD figures were readjusted taking in consideration more recent projections on the growth of housing (before the housing slowdown of 2007).

Projections for 2030 show that Harris will have the largest county population with close to 5.2 million residents, followed by the counties of Dallas (3.4 million), Tarrant (2.1 million), Bexar (1.8 million), and Travis (1.2 million). In aggregate, these five counties are expected to increase their population by nearly 50 percent over the next 25 years. The highest projected densities will be in Dallas (3,738 persons/sq. mile), Harris (2,903), and Tarrant (2,399) counties.

The two maps in Figure 13 show the actual and projected population density per county in 2000 and 2030, respectively. The most relevant element is the increase in density in the counties situated at the edge of the largest metropolitan areas, most noticeably in the Austin area.

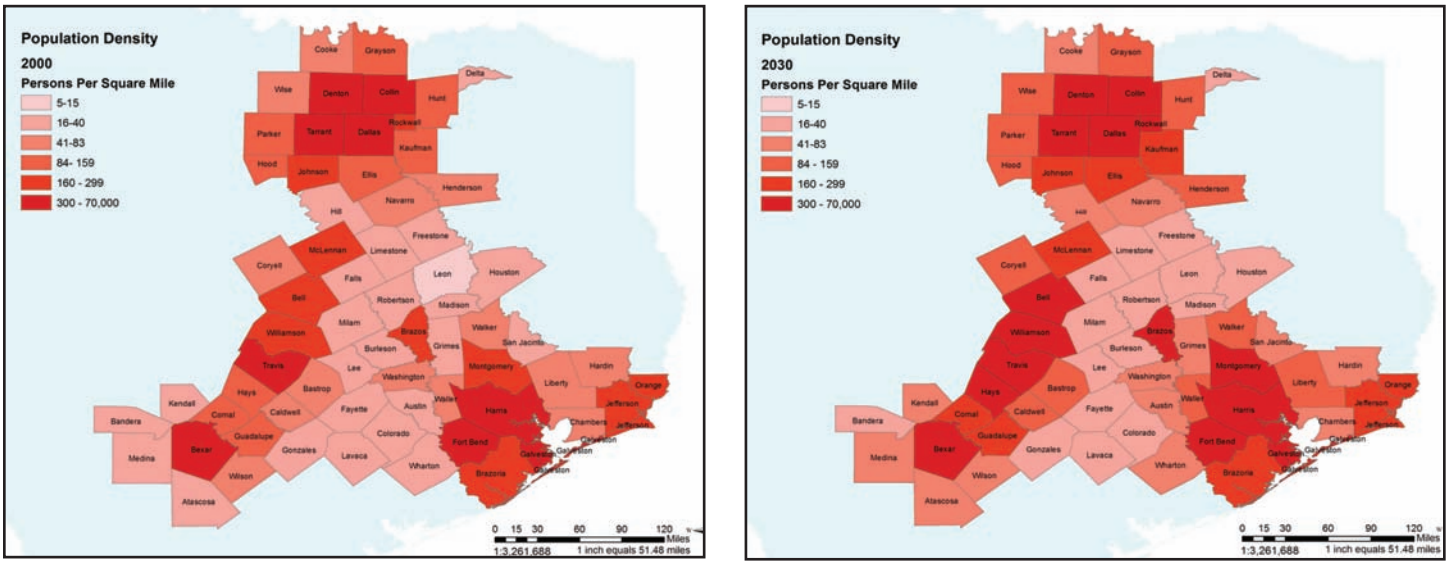

Figure 13. Density per county, 2000 and 2030.
Source: Hilgemeier (2007).

HOUSING SUPPLY TRENDS

The type of new units built in Texas are increasingly single-family units (see Figure 14). Permits for buildings accommodating more than five units were very significant until the late 1980s, but since then the overwhelming majority of permits was for single units. After the last recession, single units have been commanding the growth of the sector, surging from 38 thousand in 1990 to 165 thousand in 2005. Over the same period, permits for buildings with more than five units went from 7,000 in 1990 to nearly 50,000 in 2006.

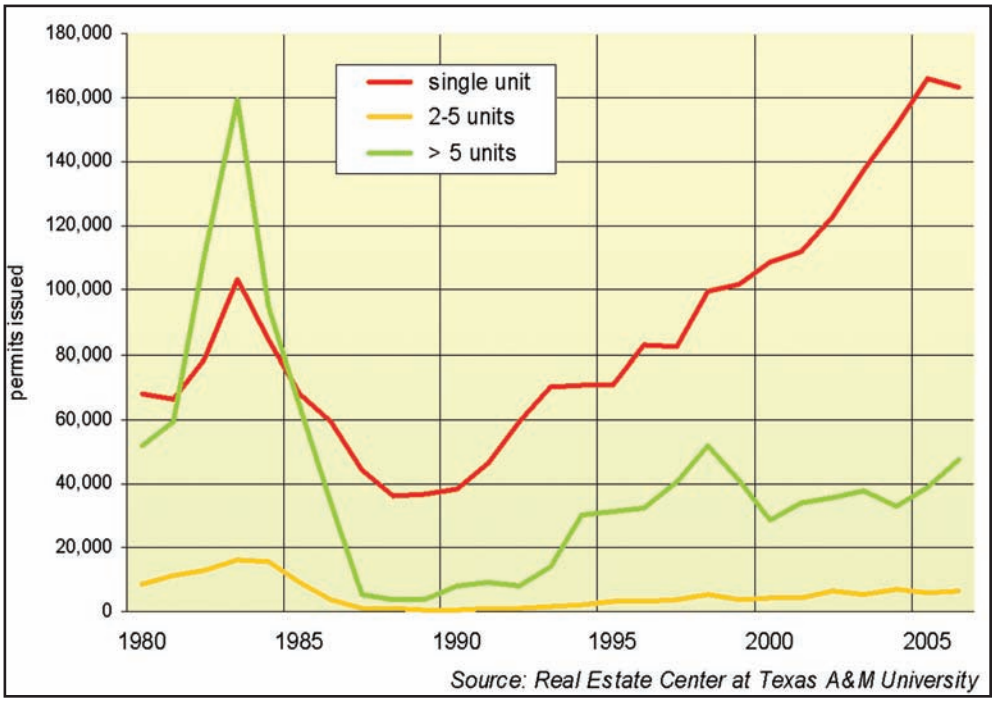

Figure 14. Building permits issued in Texas, 1980-2006.
Source: Real Estate Center at Texas A&M University.

AFFORDABLE HOUSING

The Department of Housing and Urban Development (HUD) defines affordable housing as housing that costs no more than 30 percent of the residents' gross income (Afflerbach 2007). According to the Texas Low Income Housing Information Service, the number of families facing a housing cost burden is growing three times faster than the supply of affordable housing. The problem is growing beyond lower-income groups, also affecting middle-income individuals and families.

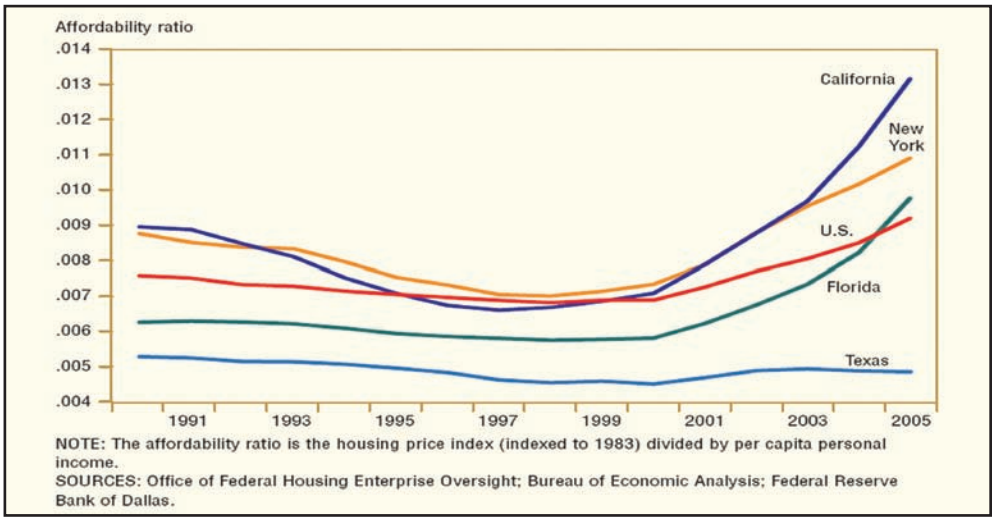

Figure 15. Housing affordability in Texas and selected states, 1990-2006.
Source: Petersen (2006).

Despite the decrease in affordable housing supply, the situation in Texas is still less stressful than in other parts of the nation. The price-to-income ratio has remained relatively flat in the state, suggesting housing is relatively more affordable than in other states (See Figure 15).

FUTURE HOUSING PROJECTIONS

The number of housing units needed in the Texas Urban Triangle was projected using the housing unit method (Smith and Lewis 1980). The projections used recent building permits data obtained from the Texas Real Estate Center. The number of households, trends in the average household size, occupancy rates, building permits, and demolitions at the county level were the primary data.

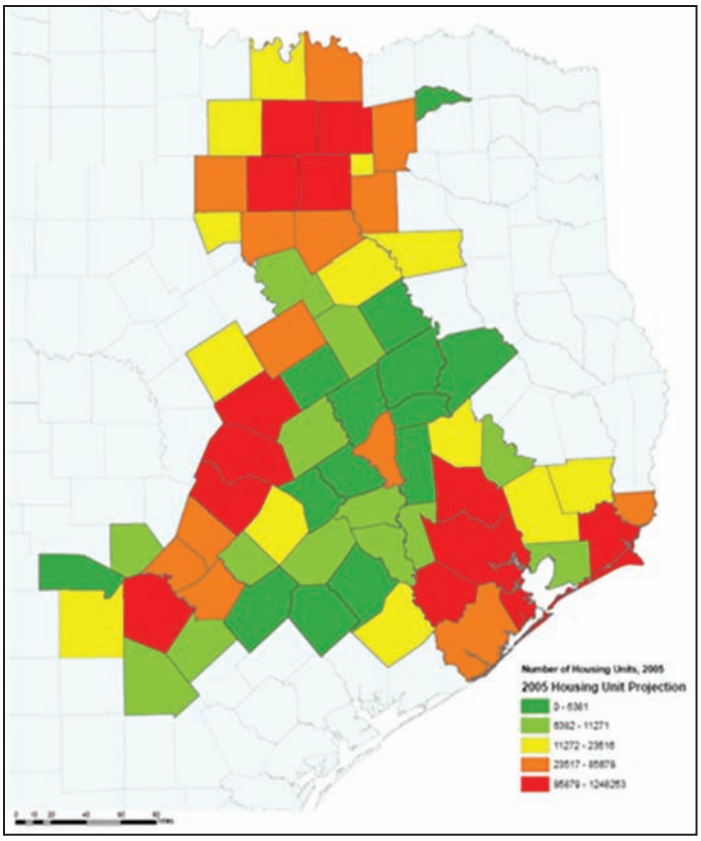

Figure 16. Housing units in Texas Urban Triangle counties, 2005.
Source: Browning (2007).

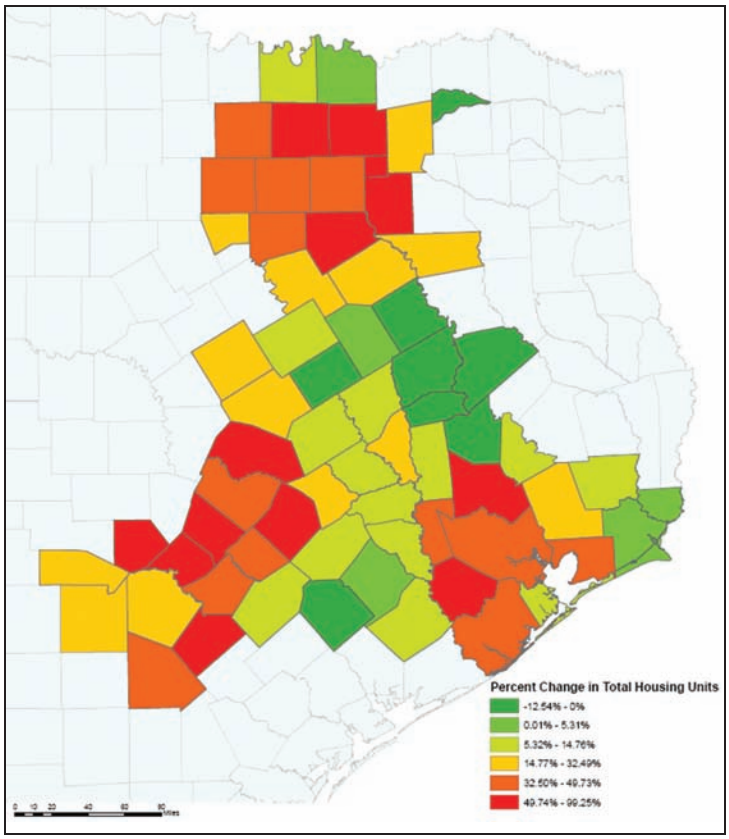

Figure 17. Housing growth rates in Texas Urban Triangle counties, 2005-2030.
Source: Browning (2007).

The provision of housing units within the TUT is expected to increase faster between 2010 and 2020, when it is projected to experience a growth rate close to 14% (from 5.7 million units in 2010 to 6.6 million in 2020), primarily concentrated in metropolitan counties. The growth rate will remain high in the following decade, 2020 to 2030, with close to an additional million units entering the market. By year 2030 the most significant increases in housing units, consistently with current trends and population projections, are projected to be in the largest metropolitan areas, and especially in their inner ring of suburban counties (see Figure 17).

ECONOMY AND JOBS

For most of its history, the economy of Texas has been rooted in the land. Subsistence agriculture was supplemented by the production of cotton, primarily for export, by the 1860s (Fehrenbach 1983). After the Civil War a second wave of economic growth was driven by the cattle industry, which took advantage of new technologies such as barbed wire and railroads, to satisfy the needs of northern markets (Yemma 1987). Cotton and cattle, and to a lesser extent lumber, all primarily oriented to industrialized northeastern states, remained the pillars of the Texas economy until the discovery of oil. After the Spindletop oil strike in 1901, the structure of state economy and its role within the nation changed significantly (Wright 1990; Sharp 1993).

year	*GSP (2005 $)*	*growth rate*
1980	228.58	-
1985	347.96	52.2 %
1990	485.99	39.7 %
1995	502.08	3.3 %
2000	759.08	51.2 %
2005	886.15	16.7 %

Notes: GSP in billion of real $ of 2005; 2005 figures are estimates.
Sources: Texas Comptroller of Public Accounts, U.S. Bureau of Economic Analysis and U.S. Bureau of Energy.

Figure 18. The Texas gross product, 1980-2005.

The drivers of the Texas economy changed from prime materials to industry during World War II, with the creation of aircraft plants close to Dallas and petrochemical industries on the Gulf Coast. Both were linked to military needs and benefited from federal and private spending. After the war, the popularity of cars and new uses for plastics and synthetic rubber boosted petroleum-linked industries (Pratt 1980). War efforts also supported the development of specialized metal and construction industries (Williamson *et al.* 1963).

Sector	*1980*	*1985*	*1990*	*1995*	*2000*	*2003*
Agriculture	2.0	1.9	2.0	1.4	1.3	1.4
Mining	15.2	12.4	7.0	6.8	6.2	6.5
Construction	6.3	5.4	4.2	4.3	4.9	5.1
Manufacturing	19.3	15.6	16.6	16.4	13.0	11.4
Transportation & Utilities	9.8	10.3	11.2	10.8	11.2	11.1
W. & Retail Trade	15.1	16.0	15.3	16.1	17.4	17.2
F., I. & R.E.	11.9	14.8	14.7	14.4	15.1	15.4
Services	11.2	13.6	17.7	17.8	19.8	20.5
Government	9.2	10.1	11.3	12.0	11.1	11.5

Notes: 2003 figures are estimates; 'W. & Retail Trade' for 'Wholesale and Retail Trade,' 'F., I. and R.E.' for 'Finance, Insurance and Real Estate'; figures for 'Government' include local, state and federal administration.
Sources: Texas Comptroller of Public Accounts and U.S. Bureau of Economic Analysis.

Figure 19. Share of Texas gross state product by sector, 1980-2003.

2030 JOB PROJECTIONS

Total employment in the Texas Urban Triangle by year 2030 is estimated to surpass 14 million, assuming a total average annual growth rate of 1.4%. Estimations by sector are shown in Figure 20.

"Education, Training and Personal Development" is expected to become the largest single sector of employment, followed by "Business and Financial Services". Each of the top six sectors is expect to grow above the region's average, and by 2030 employ over a million persons. In aggregate, their share of the regional employment will rise from 56% in 2003 to 66% in 2030.

TWC data sets were used to project future employment in the Texas Urban Triangle. The methodology used linear regression to calculate medium-term (1990-2003) and short-term (1999-2003) trends in employment by sector, and then both figures were averaged to establish a composite annual growth rate. These rates were used to estimate future employment by sector.

TWC sector	employment by sector		growth rate	
	2003	2030	2003-2030	annual
Biotechnology, Life Sciences and Medical	648,424	1,260,869	94%	2.9%
Electronics and Applied Computer Equipment	274,835	219,013	-20%	-1.0%
Telecommunications and Information Services	355,587	511,527	44%	1.6%
Legal, Protective and Human Support Services	313,773	517,685	65%	2.2%
Corporate HQ, Administrative and Government	631,013	1,027,922	63%	2.1%
Business and Financial Services	1,278,405	2,190,535	71%	2.4%
General Line Store Retailers	767,415	951,940	24%	0.9%
Tourism, Hospitality and Leisure	880,303	1,597,567	81%	2.6%
Distribution, Transportation and Logistics	389,936	576,210	48%	1.7%
Heavy and Special Trade Construction	579,214	1,040,402	80%	2.6%
Energy, Mining and Related Support Services	171,612	159,413	-7%	-0.3%
Petroleum Refining and Chemicals	229,278	173,196	-24%	-1.2%
Transportation Equipment	325,174	387,784	19%	0.8%
Production Support and Industrial Machinery	309,149	284,702	-8%	-0.4%
Agriculture, Forestry and Food	217,934	150,864	-31%	-1.6%
Education, Training and Personal Development	1,088,081	2,225,812	105%	3.2%
Apparel, Leather, Wood and Related Non-durables	144,364	76,428	-47%	-2.7%
Personal and Residential Services	463,890	793,187	71%	2.4%
Total (all sectors)	**9,068,387**	**14,145,056**	**56%**	**2.0%**

Note: calculations based on historic trends published by the Texas Workforce Commission.

Figure 20. Employment in the Texas Urban Triangle, 2003-2030.
Source: Texas Workforce Commission and author's calculations.

Texas is the second largest state in the U.S. in both area and population. Consequently, it has an extensive transportation network. Texas has the largest road and rail networks in the country, and is among the top three states in seaports and airports (DMN 2006). Given the large population and economy concentrated in the Texas Urban Triangle, and its strategic position in three major corridors – NAFTA north-south and Interstates 10 and 20 east-west – along with its commanding airport and seaport hubs. The Texas Urban Triangle maintains a commanding and strategic position in North America. The central urban region of Texas is poised for continued growth, and infrastructure plays a major role in that growth.

Strategic location, demographic and economic concentrations, and infrastructure all generate large flows of traffic in and through the Texas Urban Triangle. This section covers passenger and freight transportation in Texas and the Texas Urban Triangle, and highlights major trends and the most relevant proposals to improve the infrastructure stock and correct current shortcomings.

ROADS AND HIGHWAYS

The Texas highway system has been expanding continuously since the opening of the Gulf Freeway in Houston in 1948. According to the Texas Department of Transportation (TxDOT) as of 2004, there were close to 190,000 miles of public highway lanes in Texas (up from about 142,000 in 1984). Over one third of these miles are in the Texas Urban Triangle. The highway system in Texas includes 79,535 miles of roadway classified as state, interstate, farm to market, and freeways (Texas Highwayman 2006). Road traffic amounted to close 450 million

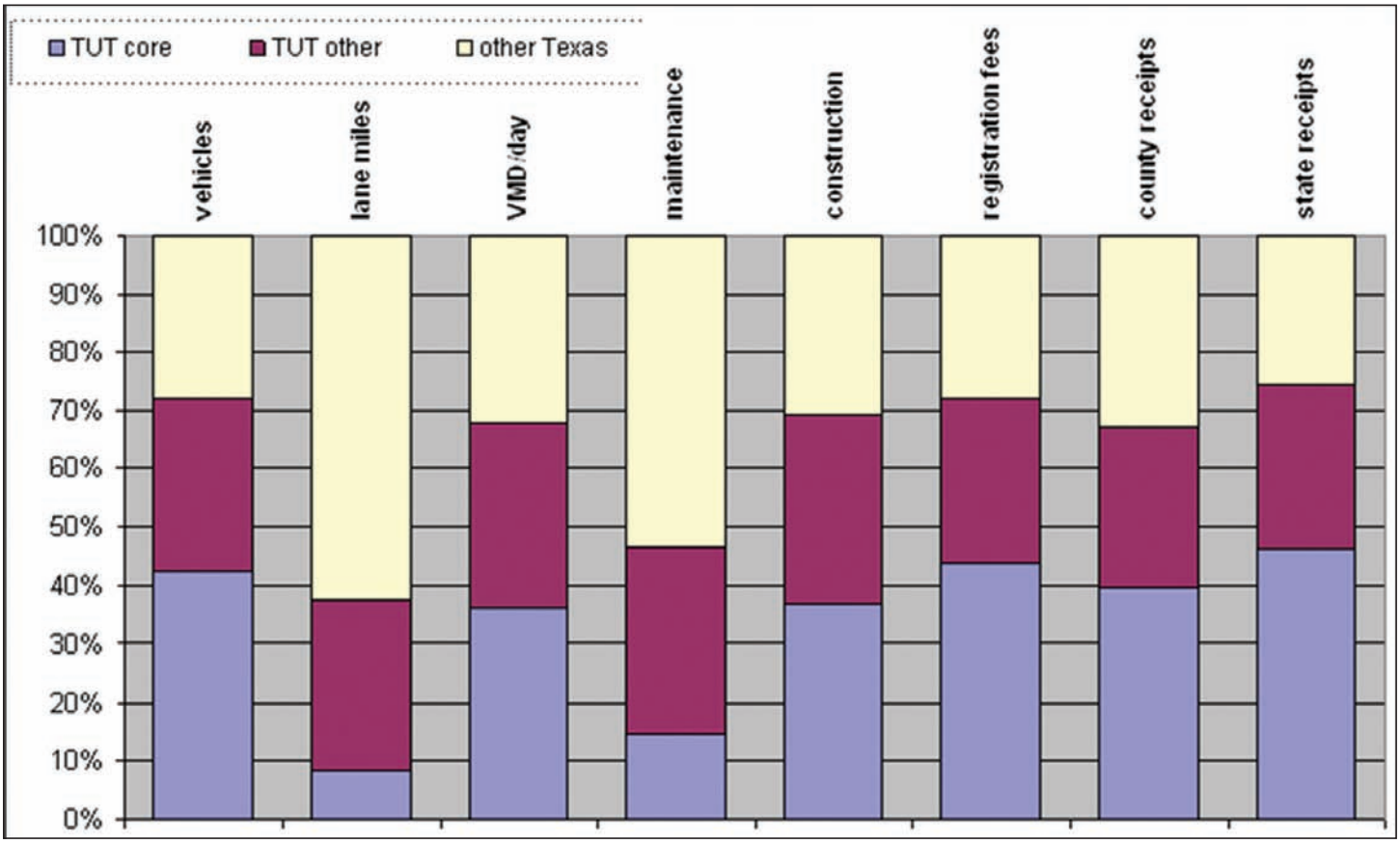

Figure 21. Automobiles in the Texas Urban Triangle, 2004.
Source: Texas Department of Transportation and DMN (2007).

vehicle miles driven per day in 2004 (DMN 2007). Maintaining and expending the Texas road and street network required expenditures of $2.4 billion from the federal government, $3.4 billion from the state, $0.9 billion from counties, and $1.2 from cities in year 2005 – a total of nearly eight billion dollars.

The Texas Urban Triangle is a major contributor to the size of the car fleet and vehicle traffic in the state (see Figure 21).

Despite accounting for about 38% of the total lane miles, the Triangle's share of the number of vehicles, road construction, and state receipts (through registration fees) was close to 70% in 2004. Five core counties - Bexar, Dallas, Harris, Tarrant and Travis - accounted for more than 40% of the state totals. While the most road mileage (and expenditures in road maintenance) is outside the Triangle, it is inside the functional core of Texas where most traffic is generated.

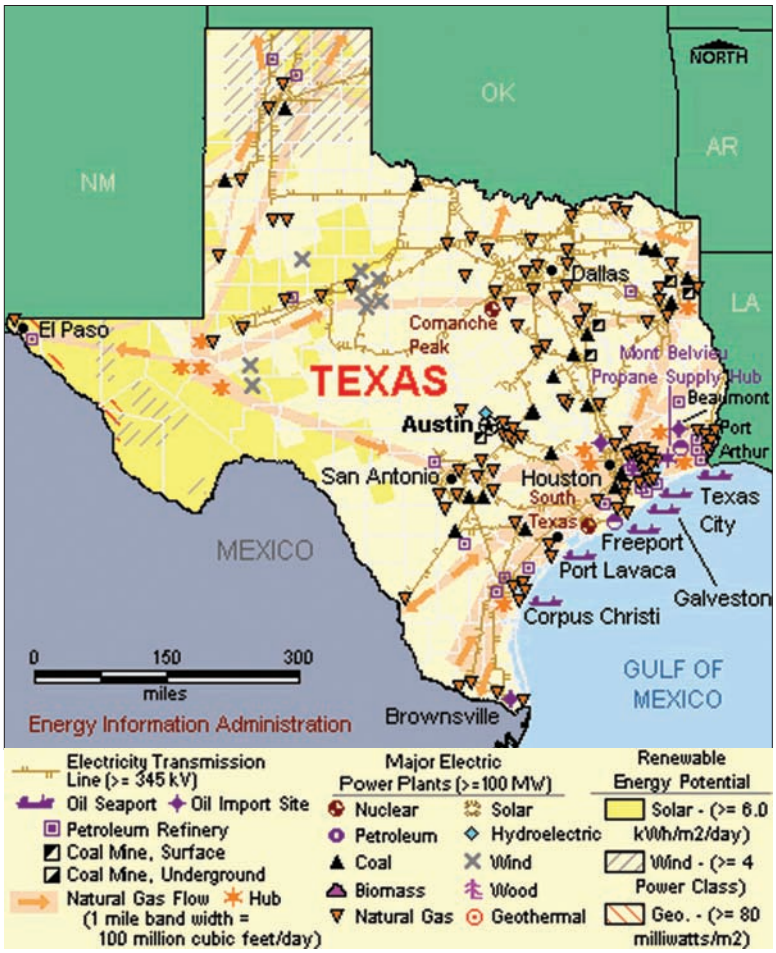

Figure 22. Major energy-related infrastructure.
Source: (from http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=TX).

ENERGY

Texas leads the United States in many facets of energy. Consider the following data:

- Texas is the leading crude oil-producing state in the country.
- West Texas Intermediate (WTI) – is the primary benchmark for crude oil.
- 25 refineries account for more than one-fourth of total U.S. refining capacity.
- Texas is the leading natural gas-producing state in the country, contributing more than one-fourth of total national output.
- Texas also leads in wind-powered generation capacity, with over 6 million megawatts in 2006 (EIA 2007c).

Overall, Texas generates and consumes more electricity than any other state, and its per capita residential and industrial use are significantly above the national average (*idem*).

The large majority of energy-related infrastructure in the state is concentrated in the four metropolitan areas of the Texas Urban Triangle (Figure 22). Most energy consumption also occurs in these metro areas, due to their large share of state's population and economic activities.

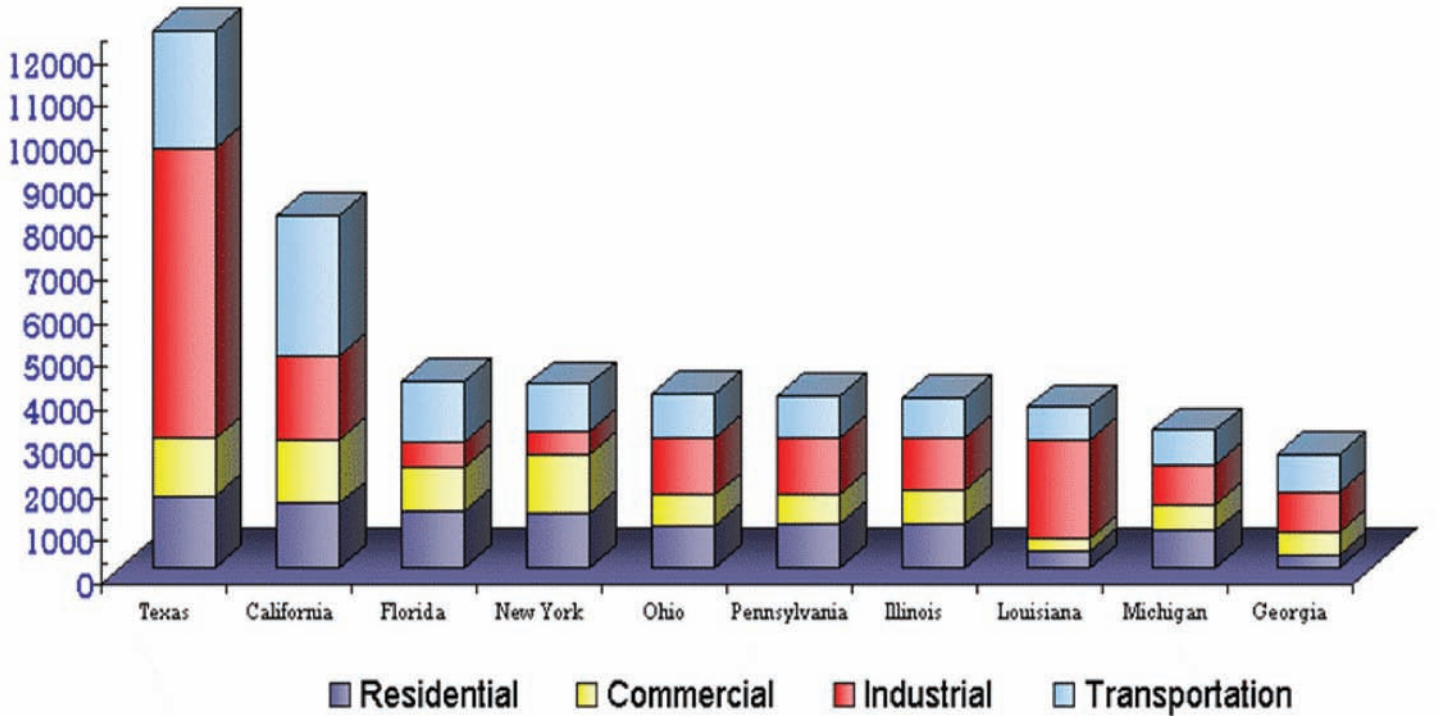

Figure 23. Total energy consumption by state, 2004.

ENERGY DEMAND

Texas is not only the largest producer in the country, but also the largest consumer (EIA 2007a). Historically the state has been self-sufficient, but in recent years energy production has been lagging behind demand, requiring imports. During the period 1960-2000, while population posted an average annual growth rate of +1.96%, energy consumption grew at +2.54% (TSCD 2006 and EIA 2007a). As population doubled, energy consumption nearly tripled.

In 2004, with a population less than 8%, the Lone Star state consumed 12 trillion BTUs (Figure 23), or 12% of all energy consumed in the United States (EIA 2007a). Texas was the largest consumer of energy for industrial uses, and the second (after California) for residential, commercial and transportation uses. Over one-half (53%) of the state's energy consumption was related to the industrial sector, a figure well above the national average of 33%; these figures include associated losses. In the same year, the energy consumption per capita in the state was above national average for industrial (243%) and transportation (123%) uses, and slightly below for commercial (94%) and residential (93%) uses.

Overall, the 2004 energy consumption per capita in Texas (over 0.5 billion BTUs/person per year) more than doubled the equivalent figures for states like California, New York, Florida and Arizona, all of them with values between 0.20 and 0.25 billion BTUs/person per year (EIA 2007a and USCB 2007).

The share of energy consumption for industrial uses has been decreasing, falling from 67% in 1960 to 47% in 2004. During the same period, there was an increase in the share of transportation (18% to 23%), while the shares of residential and commercial usage declined slightly (EIA 2007a).

ENERGY LOSSES

The most important change during the period 1960-2004, perhaps even more relevant than the decrease in the share of industrial net consumption, was the increase in other uses (from 7% to 20%), which the EIA defines as electrical system energy losses (EIA 2007a). They include energy used in the generation, transmission, and distribution of electricity, plus plant use and other unaccounted losses; in other words, system inefficiencies, which do not include losses related with end-user less efficient technologies. Comparing 1960 and 2004 figures, Texas losses rose from 302 to 2,435 trillion BTUs, a staggering eight-fold increase over 44 years; during the same period the national increase was close to 364%. Unquestionably system losses and their quick growth are becoming crucial issues for policy making, but still insufficiently researched and understood. Transmission over long distances is likely the reason, suggesting local consumption of local production. The most remarkable finding is their rapid growth, in all sectors except transportation (Figure24).

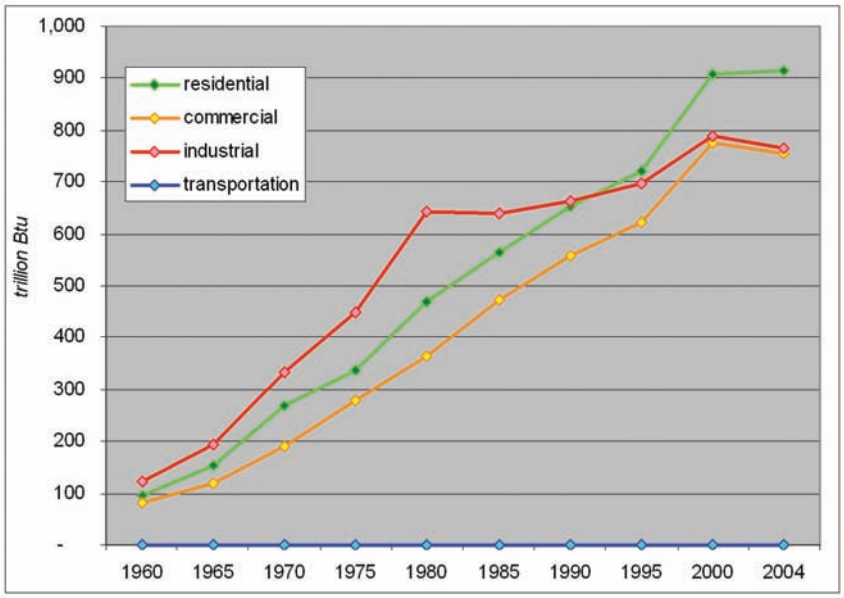

Figure 24. Electric system energy losses in Texas by type of use, 1960-2004.
Source: Energy Information Administration.

During the period 1960-2004, residential-related system losses have grown faster than other types of uses, passing from 32% to 38% of all losses, slightly above the corresponding national averages of 29% and 37% (EIA 2007a).

The production of energy in Texas has primarily relied in local resources, but there have been important shifts throughout the last decades. In 1960 practically all energy was produced from natural gas and petroleum, which accounted for 98% of all energy consumption. By 2004 their combined share had fallen to 80%, and petroleum had become the most important source. During that period, coal and to a lesser extent nuclear became increasingly important, and by 2004 they combined to account for 18% of total consumption. Nevertheless, greenhouse gas producing fossil fuels still account for the vast majority of energy production in Texas in 2004, 94%!

TEXAS ENERGY DEMAND PROJECTIONS

If current growth rates remain unaltered, the consumption of energy in Texas may reach 23,000 trillion BTUs by 2025 (Figure 25). This total cannot be satisfied by exploiting existing natural reserves and using current technologies. State agencies and forums like the Texas Energy Council have been addressing the issue and advancing policy proposals (TPEC 2005). Major challenges remain, especially considering that most proposals target only electric power, either by aiming reducing consumption or developing renewable sources, but rarely addressing major issues such as energy losses, system inefficiency, technology innovation, and non-electric power energy uses; most of which occur in the Texas Urban Triangle and are correlated to land use location and distribution.

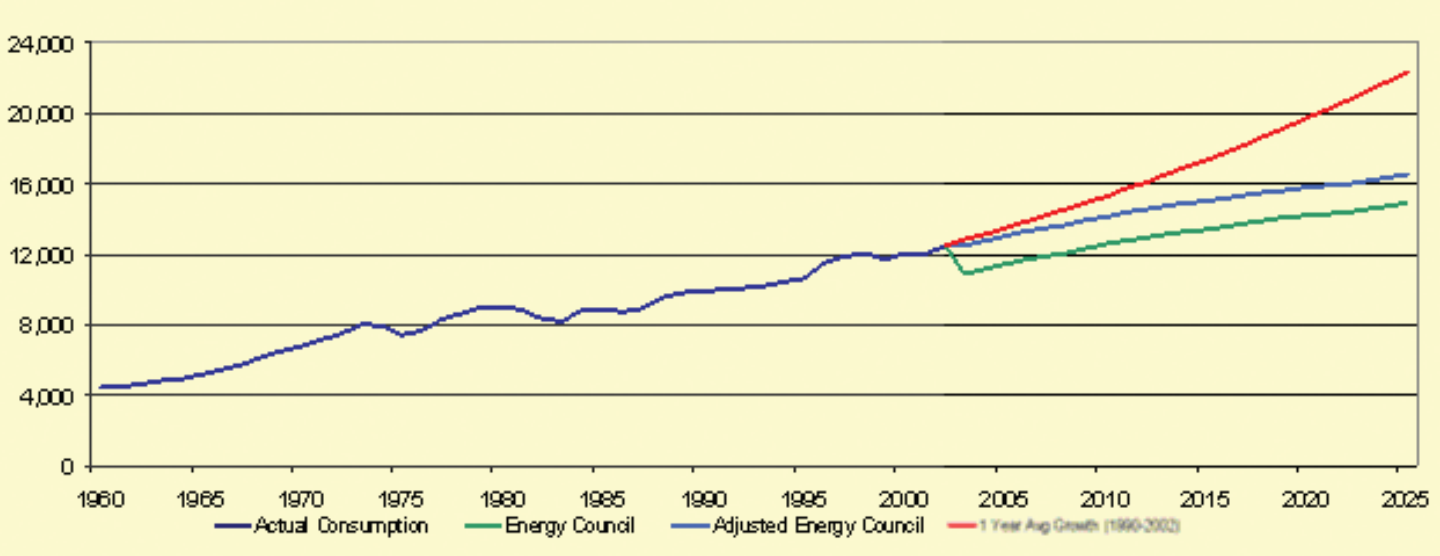

Figure 25. Total energy demand in Texas, 1960-2025.
Source: Energy Information Administration.

INFRASTRUCTURE INVESTMENTS FOR A DIVERSIFIED PORTFOLIO

Infrastructure, especially transportation and energy, give a tremendous opportunity for Texas to lead the nation. A large and diversified economic and infrastructure capital investment portfolio will provide options to reduce reliance on a single mode of passenger (automobile) and freight (truck) transport on roads and highways, and over-reliance on fossil fuels as the preferred energy sources. These investments can bring Texas into the forefront with advanced technologies such as wind; solar; new generation nuclear; as well as high speed rail and urban mass transit.