CHAPTER ONE

Introduction

Vicente Fox, leader of the National Action Party (PAN), was elected president of Mexico in 2000, largely because he was seen as a "president of change." Before his election, the country had been ruled for seventy consecutive years by the Institutional Revolutionary Party (PRI). President Fox presented visionary proposals for sustainable development, organized into four major goals:

1. The first is long-run growth in living standards spread across all segments of the population. This goal would alleviate poverty by creating new jobs, investing in human capital chiefly through improved public education, and facilitating financing for housing and small- and medium-sized firms.
2. The second objective is social and infrastructure development to provide electricity to more people, especially in rural areas. Since most new electricity will be generated by natural gas, this goal will require massive expansion in natural-gas pipelines.
3. The third goal, which is fundamental to the first two, is to increase the production and consumption of commercial energy. Growth in energy consumption goes hand in hand with economic growth, especially in developing countries.[1] Much more natural gas will be required for the ambitious programs to increase electric power. Some of the additional gas can be imported, but most of it must be produced domestically.
4. The fourth objective is to improve the environment, both locally and globally. Mexico City is the world's most populous city and suffers the world's worst air pollution.[2] This pollution is a result of its location in a huge valley that traps and holds oxides of nitrogen, sulfur, and carbon. An estimated 70 percent of Mexico City's air pollution is attributed to transportation emissions.

Even before Fox took office, the government had enacted several measures that proved to be effective in improving air quality in Mexico City. For all areas of high urbanization, industrialization, and air pollution, President Fox proposed even more stringent air-quality goals, which are stated clearly in ecological norms 085 and 086.[3]

The Fox administration is also committed to fighting global warming. The most effective way to do so is to reduce global emissions of nitrogen oxides and carbon dioxide. Produced by burning fossil fuels, nitrogen dioxide (NO_2) is a short-lived greenhouse gas that plays a major role in the formation of smog.

Nitrous oxide (N_2O) and carbon dioxide (CO_2) are long-lived greenhouse gases. The human activity responsible for almost all of the emissions of these two gases and sulfur dioxide (SO_2) is the burning of fossil fuels.[4]

A fundamental dilemma is this: Mexico relies almost completely on fossil fuels for commercial energy. How can it increase the fossil-fuel consumption required for economic growth and at the same time reduce carbon dioxide emissions? One possibility is to substitute natural gas for oil and coal because the combustion of natural gas emits about half as much carbon dioxide per million BTUs (British thermal units) of energy as coal and about two-thirds as much as oil. Another possibility is to substitute nuclear and renewable energy for the electricity produced by fossil fuels. We stress that neither of these alternatives is feasible for at least another quarter century because Mexico will have neither the gas pipeline infrastructure nor adequate nuclear or renewable energies required to implement such large-scale substitutions.

Sustainable growth in Mexico encompasses four major goals: long-run, widespread gains in standards of living; social and infrastructure development; growth in the production and consumption of commercial energy; and environmental improvement. These objectives are linked in fundamental ways. Some can be achieved harmoniously, but others pose basic conflicts.

REAL LIVING STANDARDS

Mexico is one of the largest of the world's developing countries. Its population, estimated to be 99.4 million in 2001, is growing by 1.9 percent annually.[5] If this growth rate persists for thirty-nine years, the population will double to 200 million by 2040. Simply to maintain a constant average standard of living would then require that real gross domestic product (GDP) grow at the same rate.

Despite a rapidly increasing population, Mexico enjoyed impressive growth in real living standards from 1965 to 1979: Real gross domestic product per capita (real GDP/capita) increased by 3.7 percent annually. This brisk development was driven by high rates of capital formation, equally high growth in commercial energy consumption, and technological progress embodied in new capital stocks. If real GDP/capita grew indefinitely by an annual rate of 3.7 percent, real living standards would double every twenty years. This would have been a stunning economic achievement, but it did not occur.

Instead, the period of remarkable progress, 1965–1979, was followed by twenty years of continuous stagnation. From 1980 to 2000, real GDP/capita remained practically constant.

Why were 15 years of impressive growth followed by 20 years of stagnation? That is the subject of chapter 2, where we show that the period from 1980 to 2000 was marked by a series of sharp peso devaluations. These reductions caused rapid increases in the cost of imports, notably machinery and equipment, imported chiefly from the United States. As a consequence, Mexico's rate of real-capital formation decreased sharply. Commercial energy per worker also stagnated for 20 years.

In 2001, Mexico's real GDP/capita, measured in international dollars adjusted for purchasing power parity (PPP), stood at $8,770, about one-fourth of the $34,870 in the United States.[6] Real GDP/capita, adjusted for PPP, is probably the best single index for comparing international differences in real *average* living standards. However, it is a purely monetary measure of average living standards and is therefore incomplete. It fails to account for international differences in poverty, ignores environmental concerns, and overlooks a host of demographic variables such as life expectancy, infant mortality, illiteracy, access to public health and electricity, and unemployment.

SOCIODEMOGRAPHIC CONCERNS

Demographic disparities are genuinely important in comparing real living standards. In 1997, for example, male life expectancy at birth was 69 years in Mexico but 74 in the United States; female life expectancy at birth was 75 in Mexico, compared to 79 in the United States.[7] Mortality rates for children under the age of 5 were much higher in Mexico, which experienced 35 deaths per 1,000 children in 1998, compared to only 9 deaths per 1,000 children in the United States. These disparities can be narrowed by improving the overall standards of public health and extending their reach to lower-income families.

Poverty and income inequality remain major problems in Mexico. According to a survey conducted in 1998, 10.1 percent of Mexico's population lives below the national poverty line and receives only 1.3 percent of the nation's income. By contrast, families in the top 10 percent of the income distribution receive 41.7 percent of the nation's income.[8] Household income in the United States, although highly unequal, is distributed somewhat more equally than in Mexico: In 1997, families in the top 10 percent of the distribution received 30.5 percent of income, while those in the lowest 10 percent received 1.8 percent.

In 1996, per-capita consumption of electricity in Mexico was 1,381 kilowatt hours (kWh), compared to 11,796 kilowatt hours in the United States.[9] An ample and widespread supply of electricity is essential for broadly based improvement in living standards.

Unemployment is a serious problem in Mexico, particularly among younger people, the fastest-growing segment of the population. The Instituto Nacional de Estadística Geografía e Informática México examined employment statistics covering forty-eight urban areas in 2002. Unemployment rates averaged 6.6 percent for potential workers aged 12–19 years; 5.3 percent for those from 20 to 24 years of age; and 1.3 percent for those 45 and older. Although unemployment rates in Mexico are measured differently than in the United States, it is clear that joblessness in Mexico is much higher among younger workers.

PRODUCTION, CONSUMPTION, AND EXPORTS OF ENERGY

Mexico is rife with paradox. It is richly endowed with natural resources, particularly oil and natural gas. In 2002, its oil reserves were estimated at 25.4 billion barrels, exceeding estimated U.S. reserves of 22 billion.[10] Yet Mex-

ico produces only 3.8 million barrels a day, less than half the U.S. production of 7.87 million.[11] Why is there so little production with such huge reserves in Mexico and so much more production from smaller reserves in the United States? The main reason is that oil in the United States is produced by thousands of unregulated producers intent on maximizing profits, so they produce reserves at a fast rate to obtain cash flow. In Mexico, however, oil is produced by PEMEX, a state-owned monopoly that is tightly controlled by the federal government. Chapter 3 spells out the symbiotic relation between PEMEX and the government.

Mexico produces more energy—particularly oil—than it consumes. It also produces slightly less coal than it consumes. Furthermore, since 1990, Mexico has been a net importer of natural gas. The paradox is that Mexico has enormous untapped gas reserves. Oil has always been of the highest priority both because its reserves are quite large and because oil exports are a principal source of foreign exchange.

In order for us to compare energy from different sources, it is essential to express all types of energy in a common unit. To enable such comparisons, the U.S. Energy Information Administration converts all types of energy in the United States, Mexico, and other countries into one unit of measure: quadrillion BTUs.[12] This conversion to a common unit permits easy comparisons of production, consumption, and exports.

Production

As table 1.1 shows, crude oil (including lease condensates) is the dominant fossil fuel. The 4.26 quadrillion BTUs of oil produced in 1980 accounted for 77 percent of Mexico's total fossil fuels. Similarly, the 6.93 quadrillion BTUs of oil produced in 2001 amounted to 76 percent of total fossil fuels. This percentage is nearly constant from 1980 to 2001. Approximately three-quarters of Mexico's oil production comes from the Bay of Campeche, located in the Mexican Gulf along the Yucatán Peninsula. The most productive field in the Bay of Campeche is Cantarell, which is located about sixty miles offshore. Cantarell produces about 1.9 million barrels of oil per day, half of the country's total production.

The Cantarell complex consists of four major subfields: Akal, Nohoch, Chac, and Kutz. Cantarell is one of the largest oil-bearing complexes ever discovered, with an estimated 35 billion barrels of oil originally in place.[13] Production began in 1979. At the outset, production per well averaged a phenomenal thirty-five thousand barrels per day.

As production continued and reservoir pressure dropped throughout the years, production fell continuously. In 1997, to increase reservoir pressure and production, PEMEX awarded a large contract to an international consortium of private firms to inject 1.2 billion cubic feet (BCF) of nitrogen per day. The contract paid off. By 2002, Cantarell's production increased to 1.9 million barrels daily, double the rate in 1995.

PEMEX continues to develop Cantarell. It now plans to drill fifty-three new wells and to build two new wellhead platforms. Despite these new investments,

Table 1.1. **Fossil Fuel Production in Mexico, 1980–2001 (Quadrillion BTUs)**

Year	Crude oil production including lease condensate	Natural gas plant liquids	Dry natural gas	Coal	Total
1980	4.26	0.26	0.95	0.08	5.54
1981	5.07	0.32	1.02	0.08	6.49
1982	6.03	0.34	1.10	0.09	7.56
1983	5.90	0.35	1.08	0.12	7.45
1984	6.12	0.34	1.06	0.13	7.65
1985	6.02	0.36	1.05	0.13	7.56
1986	5.34	0.47	0.93	0.14	6.88
1987	5.59	0.45	0.94	0.17	7.15
1988	5.53	0.49	0.95	0.15	7.12
1989	5.53	0.51	0.91	0.16	7.11
1990	5.60	0.57	1.00	0.17	7.34
1991	5.88	0.60	1.00	0.15	7.64
1992	5.87	0.60	0.98	0.14	7.59
1993	5.86	0.61	1.05	0.15	7.68
1994	5.89	0.61	1.08	0.16	7.74
1995	5.74	0.59	1.06	0.16	7.56
1996	6.28	0.56	1.21	0.18	8.23
1997	6.63	0.51	1.25	0.20	8.59
1998	6.74	0.56	1.34	0.21	8.85
1999	6.37	0.58	1.36	0.19	8.51
2000	6.63	0.58	1.39	0.21	8.81
2001	6.93	0.57	1.38	0.22	9.09

Source: Energy Information Administration, www.eia.doe.gov.

PEMEX estimates that Cantarell's production will decline to 1.5 million daily barrels by 2006 and perhaps 1.2 million per day by 2008.

Dry natural gas and natural-gas plant liquids account for a much smaller share of production than oil. For example, in 1980, dry natural gas plus plant liquids accounted for 1.21 quadrillion BTUs—22 percent of the overall fossil-fuel production. Their combined production in 2001 was 1.95 quadrillion BTUs, or 21 percent of all fossil fuels.

Current natural-gas reserves are located primarily in the southwestern states of Tabasco and Chiapas, where large reserves were discovered in 1978. In March, 2002, PEMEX announced the discovery of three new gas fields in the state of Veracruz. PEMEX estimates that, when these fields are developed, they could account for one-quarter of Mexico's total gas reserves. Production from these and other gas fields enabled nonassociated gas production to increase by approximately 22 percent from 2001 to 2004. Other major gas basins are located in the northern region: the Sabinas-Tamaulipas platform with 85 exploratory opportunities, the Burgos platform with 500, the Lamprea platform with 108, and the Lankahuasa platform with 72.[14]

Coal production is insignificant: It accounted for about 1.4 percent of total fossil fuels in 1980 and about 2.4 percent in 2001. Coal reserves, estimated to be approximately 1.3 billion tons, are located chiefly in the northeastern state of Coahuila. Almost all of Mexico's coal is used to produce electricity.

Table 1.2. **Fossil Fuel and Total Primary Energy Consumption in Mexico, 1980–2001 (Quadrillion BTUs)**

Year	(1) Petroleum and petroleum products	(2) Dry natural gas	(3) Coal	(1) + (2) + (3) Total fossil fuels	Total primary energy consumption
1980	2.59	0.84	0.11	3.54	3.74
1981	2.83	0.91	0.10	3.84	4.11
1982	2.96	0.99	0.12	4.07	4.33
1983	2.70	0.99	0.13	3.82	4.06
1984	3.07	1.00	0.13	4.20	4.47
1985	2.98	1.04	0.16	4.17	4.48
1986	3.12	0.92	0.15	4.19	4.46
1987	3.20	0.94	0.17	4.30	4.57
1988	3.27	0.95	0.16	4.39	4.68
1989	3.36	0.92	0.17	4.46	4.80
1990	3.44	1.02	0.17	4.62	4.98
1991	3.45	1.06	0.16	4.66	5.02
1992	3.47	1.06	0.18	4.71	5.12
1993	3.44	1.08	0.18	4.71	5.13
1994	3.62	1.14	0.19	4.95	5.30
1995	3.47	1.16	0.21	4.84	5.31
1996	3.56	1.23	0.24	5.03	5.55
1997	3.63	1.26	0.26	5.15	5.65
1998	3.83	1.36	0.27	5.46	5.93
1999	3.91	1.34	0.25	5.50	6.06
2000	3.90	1.46	0.27	5.63	6.19
2001	3.77	1.45	0.27	5.49	6.00

Source: Energy Information Administration, www.eia.doe.gov.

Consumption

Fossil fuels account for almost all of Mexico's energy consumption. Table 1.2 shows the consumption of petroleum and petroleum products, dry natural gas, coal, and their sum (total fossil fuels). The last column lists total primary energy consumption, which is all of the energy consumed by end users, excluding electricity but including the energy consumed at electric utilities to generate electricity.

Fossil fuels clearly dominate energy consumption. They account for 95 percent of the total energy consumed in 1980 and about 92 percent in 2001. Among the individual fossil fuels, petroleum and petroleum products represent 69 percent of the total primary energy in 1980 and 63 percent in 2001. Dry natural gas accounts for 22 percent of the total primary energy in 1980 and 24 percent in 2001; coal accounts for a meager 3 percent in 1980 and 4.5 percent in 2001.

Exports

The difference between fossil fuels produced (table 1.1) and consumed (table 1.2) is exports. For example, in 1980, Mexico produced 4.26 quadrillion BTUs of crude oil and lease condensate, consumed 2.59 quadrillion BTUs of petroleum and petroleum products, and exported 1.67 quadrillion BTUs of crude oil. Put differently, the country exported 39 percent of the oil it produced. In 2001, the country produced 6.93 quadrillion BTUs of oil, consumed 3.77 quadrillion

BTUs, and exported 3.16 quadrillion BTUs, or 46 percent, of its oil.[15] Oil exports are the single most important source of Mexico's foreign exchange.

By comparing tables 1.1 and 1.2, one confirms that oil has been exported every year since 1980 and natural gas imported each year since 1990. The government has given oil priority over gas for at least three reasons: (1) Oil is easily exported on tankers; (2) oil exports are the country's principal source of foreign exchange; and (3) natural gas cannot yet be widely consumed because the country lacks the pipeline infrastructure for transmission. Mexico's entire natural-gas pipeline network extends only about six thousand miles, so gas consumption is severely constrained.

Electricity

Mexico has installed an electric-power-generating capacity of 42.3 million kilowatts (or 42,300 megawatts). Electricity production more than tripled, from 63.6 billion kWh in 1980 to 198.6 billion kWh in 2001. We are chiefly interested in two important questions: How is electricity produced, and how important are fossil fuels in its production?

Table 1.3 shows that Mexico had no nuclear power until 1990. Even by 2001, the country had only two nuclear plants producing 8.3 billion kWh, or about 4 percent of its electricity.[16] There are no nuclear plants under construction or being planned at present, so nuclear capacity cannot be expanded for at least ten years. These facts concerning present and near-term nuclear energy underscore the importance of fossil fuels in the foreseeable future of electricity. The rapid expansion of nuclear energy is a near-term impossibility. The burden of growth in electricity must necessarily be borne by fossil fuels, chiefly natural gas.

Hydroelectricity accounts for 28.2 billion kWh, or about 14 percent of all electricity produced. There are plans to construct El Cajón, a 750-megawatt hydroelectric project on the west coast. Its estimated cost is $650 million, the largest publicly funded infrastructure to be financed by the Fox administration. Completion is slated for the end of August, 2007. When finished, this project will augment Mexico's total installed electric-generating capacity by about 1.8 percent. No other hydroelectric projects are now being planned, so hydroelectricity offers limited opportunity for growth.[17]

All other renewable resources (geothermal, solar, wind, wood, and waste) account for 5.8 billion kWh, or about 3 percent of the total electricity production. Apart from hydropower, geothermal appears to be the most promising source of renewable energy. In 2002, Mexico reported 855 megawatts of installed geothermal capacity. Two new geothermal plants are under construction: the 100-megawatt Los Azufres facility in Michocán and the 10-megawatt Las Tres Vigenes plant in Baja California. Currently only two wind-power projects are in operation. Together they account for 2.1 megawatts of installed capacity. Although the government has announced goals to increase the wind-generated capacity by 2006, it is clear that nonhydroelectric renewables will continue to account for a small percentage of electricity production.

Table 1.3. **Sources of Electricity Production in Mexico, 1980–2001 (Billion kWh)**

Year	Nuclear	Hydroelectric	Geothermal, solar, wind, wood, and waste	Fossil fuels	Total
1980	0.0	16.7	0.9	46.0	63.6
1981	0.0	24.4	0.9	48.0	73.3
1982	0.0	22.7	1.3	56.4	80.4
1983	0.0	20.5	1.4	60.2	82.0
1984	0.0	23.4	1.4	61.9	86.7
1985	0.0	26.0	1.6	65.5	93.1
1986	0.0	19.8	3.4	73.7	96.9
1987	0.0	18.2	4.3	82.0	104.6
1988	0.0	21.0	4.7	84.2	109.9
1989	0.0	24.4	4.7	88.7	117.7
1990	2.8	23.2	4.9	85.7	116.6
1991	4.0	21.6	5.2	89.7	120.5
1992	3.7	25.9	5.5	88.7	123.8
1993	4.7	26.0	5.6	93.1	129.4
1994	4.0	19.8	5.3	110.5	139.7
1995	8.0	27.3	5.4	104.2	144.9
1996	7.5	31.1	5.4	110.4	154.5
1997	9.9	26.2	5.2	124.8	166.2
1998	8.8	24.4	5.7	133.4	172.3
1999	9.5	32.5	5.9	134.7	182.5
2000	7.8	32.8	6.1	147.2	193.9
2001	8.3	28.2	5.8	156.3	198.6

Source: Energy Information Administration, www.eia.doe.gov.

Fossil fuels have always been the primary source of electricity, and their importance is growing. They accounted for 46 billion of the 63.6 billion kWh of electricity produced in 1980. By 2001, however, they were responsible for 156.3 billion of the 198.6 billion kWh produced—nearly 80 percent of the total.

Coal-fired plants now account for 10 percent of electricity.[18] Country-wide coal consumption amounted to 15 million tons in 2001, of which 10 million were used in Rio Escondido and Carbon II, two generating plants operated by the state-owned Comisión Federál de Electricidad. Kimberly Clark, a U.S. manufacturing firm, and steelmakers Ispat and Altos Hornos de México plan to construct coal-fired generating plants near their production facilities. Nevertheless, these plants will add little to the total generating capacity.[19]

Oil-fired and gas-fired plants are now responsible for producing about 70 percent of electricity. The task of increasing the production of electricity will fall on these two fuels, especially natural gas. The burden will be eased somewhat by recent reforms that have reduced state control over electricity production. In 1992, Mexico adopted the Public Electricity Service Act, which allowed private companies to generate limited amounts of electricity. However, they are required to sell all of their power to the government-owned Comisión Federál de Electricidad, which resells it to consumers. The act, however, enabled the development of a very small, independent electricity-producing sector, which has attracted some foreign investment.

In November, 2002, the Fox administration introduced a bill to the Senate that would modify the Mexican constitution by creating separate generation, transmission, and distribution companies and allow greater participation by private firms.[20] By attracting private investment, the Fox administration hopes that Mexico will be able to add 30,000 megawatts of capacity during the next ten years. If this target is achieved, then the country's total generating capacity would nearly double from the current 42,300 megawatts. The lion's share of this ambitious goal would be fueled by natural gas.

ENVIRONMENTAL CONCERNS

Another goal in President Fox's vision of sustainable development is the protection of the global environment. He has pledged to reduce future emissions of carbon dioxide by switching fuel consumption from oil to natural gas. Crude oil now accounts for about 63 percent of primary energy consumption, while natural gas accounts for about 24 percent. Accomplishing such a large-scale switch in fuels will require enormous growth in both the production and the distribution of natural gas. Although vast gas resources are yet to be developed, converting latent resources into producible gas will require an ambitious, long-term drilling program. The government will simultaneously have to vastly expand the nation's gas-pipeline system. Gas without pipelines is useless.

Environmental Paradoxes

Carbon dioxide is widely viewed as the major cause of global warming in the past 140 years. Atmospheric scientists now firmly believe that global increases in human carbon dioxide emissions are responsible for 60 – 80 percent of observed global warming.[21] Combustion of fossil fuels accounts for about 85 percent of the world's synthetic carbon dioxide emissions.

In 2000, world emissions of carbon dioxide were estimated at 6,417 million metric tons. Emissions originating in Mexico were 99 million metric tons, or only 1.5 percent of the total. In that same year, U.S. emissions were estimated at 1,578 million metric tons, or about 25 percent of the total.[22] Yet Mexico's Congress has ratified the Kyoto Treaty, which is designed to reduce the world's carbon dioxide emissions. The treaty has never been considered by the U.S. Congress.[23]

The first paradox is clear: Acting alone, Mexico can do nothing to reduce global carbon dioxide emissions because it accounts for only 1.5 percent of the total. If, hypothetically, Mexico cut its emissions to zero, its unilateral action would have no substance. Yet the Fox administration and the Mexican Congress have pledged to reduce their nation's meager portion. Even if they do, it will make no difference whatsoever from a global standpoint. The pledge is politically expedient but globally inconsequential.

A second paradox is less transparent but equally compelling: Energy per worker must increase as a cornerstone of productivity growth. With roughly constant labor-force participation, rising energy per worker implies rising

energy per capita. And rising energy per capita implies larger emissions per capita. It will be next to impossible for Mexico to achieve rising standards of living without increasing per-capita carbon dioxide emissions. Increasing per-capita emissions would, of course, be compounded by population growth, currently at 1.9 percent annually.

The Fox administration intends to reduce carbon emissions by switching fuel consumption from coal and oil to cleaner-burning natural gas. Combustion of coal emits about 217 pounds of CO_2 per million BTUs of energy; oil emits about 173 pounds of CO_2 per million BTUs; and natural gas releases approximately 117 pounds of CO_2 per million BTUs.[24] Thus the substitution of natural gas for oil—and especially for coal—could mitigate the growth in CO_2 emissions. According to the Secretaría de Energía, "The engine of growth in natural gas demand will come from the increase in electricity generation in combined cycle plants. These plants present a *new growth path in favor of natural gas* because of its thermal efficiency and the reduced atmospheric contamination compared with other fossil fuels as coal and 'combustoleo.' We calculate that the use of natural gas in electricity generation will go from 23.3% in 2000 to 61.1% in 2010. Thus, the availability of natural gas in Mexico is a fundamental factor for the *regional sustainable growth* which will increase the competitiveness of the productive capacity, will be able *to generate more employment* in the economy, and will increase, in general, the population welfare" [italics in the original].[25]

It is the height of irony that Mexico has largely neglected its domestic-gas resources for so long. Indeed, the country now imports gas from the United States and is building liquefied natural gas (LNG) terminals, enabling it to import even more from other countries. Imports now account for about 10 percent of Mexico's gas consumption. The government has outlined ambitious plans to increase consumption by approximately 8 percent annually through 2010.

A second irony is this: *Mexico consumes so little coal (about fifteen million tons annually, mostly to generate electricity) that, even if coal consumption were to cease, the planned growth in natural-gas usage would lead to more CO_2 emissions in 2010 than in 2001.* So, even if natural gas were to entirely replace coal in generating electricity (and such complete substitution is impossible), this hypothetical substitution would undoubtedly increase CO_2 emissions because of greater planned electricity production.

SUMMARY AND PREVIEW OF REMAINING CHAPTERS

The goals of sustainable development are clear, but they will be difficult to achieve. In the following chapters we present a realistic analysis of the objectives and major policy changes that will be required for achieving them. Long-term increases in living standards require corresponding gains in labor productivity. Productivity has stagnated for more than twenty years, and unemployment among younger members of the labor force is high.

Several important changes must occur to ensure productivity growth: lower unemployment, improved infrastructure for the transmission of electricity and natural gas, sustained growth in utilized capital and energy per worker, and improvements in technology. These are the topics of chapter 2, where we show that, from 1965 through 1979, productivity increased rapidly because of concomitant growth in utilized capital and energy per worker and improvements in technology. After 1979, productivity growth came to a standstill because of a slowdown in investment and stagnation in utilized capital and energy per worker.

Broadly based gains in living standards will require effective employment of young, low-income workers. Greater investment in public education, including vocational training, will enable younger workers to acquire the skills necessary for effective job performance. It is essential to reduce joblessness among younger workers. Although educational investments that improve marketable skills are beyond the scope of this book, they constitute an issue of first-order importance for the country.

More than half of Mexico's new machinery and equipment is imported, mostly from the United States. Imports require foreign currency that can be earned only by exports. Since oil exports are now the single most important source of foreign currency, larger imports of machinery and equipment will require still greater exports of oil. However, to increase the volumes of oil necessary for larger exports and domestic consumption, oil production must increase substantially beyond the present 3.8 million barrels per day.

Oil production and reserves are two of the major topics of chapters 6 and 7. Reserves are the essential basis of production. A long-term problem that cries out for a solution is that oil reserves decreased steadily from 1985 to 2000: Estimated reserves in 2000 were only 70 percent as high as those in 1985. Since oil is the most important export and also the most important source of domestic energy, the decline in oil reserves must be reversed. Sustainable development requires it.

Natural-gas production and reserves are two of the other major topics of chapters 6 and 7. Until now, gas has been secondary to oil. As table 1.1 shows, dry gas plus gas plant liquids account for only 21 percent of fossil-fuel production. They will play a much larger role in the future, however. The first reason is quite specific: The planned expansion in electricity will be generated almost entirely by gas-fired plants. A broader reason is the Fox administration's environmental commitment to substitute gas for oil and coal when substitution is economically feasible. The Secretaría de Energía (SENER) states that gas consumption will increase not only in the production of electricity but also in the steel, chemical, glass, and paper-products industries "in search of clean combustion."[26] Substitution of gas for fuel oils ("combustoleo") is now targeted in areas of high urbanization, industrialization, and air contamination.[27]

Nevertheless, gas reserves are also in long-term decline. Apart from a short-term aberration in 1986 and 1987, gas reserves reached a peak in 1983 and have

declined continuously since then. Gas reserves in 2000 were only 69 percent as high as in 1983. Since gas consumption is projected to increase by about 8 percent annually until 2010, domestic reserves and production must increase as well. Sustainable development requires it.

Oil and gas reserves are in long-term decline because of a twenty-year depression in drilling for new reserves. In 1980, for example, PEMEX drilled 432 wells. Then drilling went into a tailspin, reaching an all-time low of 63 wells in 1994. Drilling began a weak recovery, leading to an annual average of 184 wells from 1996 to 2000, then increased to 446 wells in 2001. Only a long-term recovery in successful drilling to the annual rates of 1980 or 2001 can reverse the serious decline in oil and gas reserves.

Drilling is expensive, especially offshore, where most of the exploration and development has occurred since 1985. The drilling depression was caused by a financial squeeze that lasted for two decades. PEMEX's drilling investments must be approved each year by Congress. The direct reason for the severe decline in drilling was the ever-tightening investment budgets that Congress granted to PEMEX. A broader reason, however, is that PEMEX is a creature of the government with little political control over its revenues. These revenues have been taxed at progressively higher rates, exceeding 60 percent in recent years. In chapter 3 we describe the political framework for PEMEX budget negotiations and the reasons for the collapse in drilling investment.

Chapter 4 econometrically analyzes the drilling for oil and gas. Here we link the number of wells PEMEX drills each year to a cash-flow constraint: the net (after-tax) Mexican oil price. We also incorporate the short-term boost in drilling that occurred after 1998, when PEMEX was granted the right to negotiate private loans. Its inability to repay the principal and interest on these loans proved to be financially disastrous.

Drilling is risky. And new reserves can be developed *only by successful drilling*. Exploration wells drilled in new areas are riskier than development wells drilled after exploration has succeeded. The fraction of exploration wells leading to the discovery of producible hydrocarbons is the *exploration success ratio*. Similarly, the *development success ratio* is the fraction of development wells proving to be commercially successful. Exploration and development success ratios exhibited impressive increases in Mexico from 1975 to 2000. In chapter 5 we analyze some of the reasons for their growth. Because successful drilling is the only way to increase producible reserves, sustainable development requires it.