THE U.S.-MEXICAN border environment:

Trade, Energy, and the Environment: Challenges and Opportunities for the Border Region, Now and in 2020

Edited by
David A. Rohy

SCERP Monograph Series, no. 7
Southwest Center for Environmental Research and Policy

THE U.S.-MEXICAN border environment
Trade, Energy, and Environment: Challenges and Opportunities

SCERP Mission

The Southwest Center for Environmental Research and Policy (SCERP) was established by the U.S. Congress in October 1990 to "initiate a comprehensive analysis of possible solutions to the acute air, water quality, and hazardous waste problems that plague the United States-Mexico border region." SCERP is a consortium of five U.S. universities (Arizona State University, New Mexico State University, San Diego State University, University of Texas at El Paso, and University of Utah) and five Mexican universities (El Colegio de la Frontera Norte, Instituto Tecnológico de Ciudad Juárez, Instituto Tecnológico y de Estudios Superiores de Monterrey, Universidad Autónoma de Baja California, and Universidad Autónoma de Ciudad Juárez). SCERP carries out its mission through a cooperative agreement with the U.S. Environmental Protection Agency. A permanent administrative office is maintained by the consortium in San Diego.

Environmental Problems of the U.S.–Mexican Border Region

The border region lies 100 kilometers (60 miles) on each side of the U.S.–Mexican border and encompasses parts of four states in the United States (Texas, New Mexico, Arizona, and California) and six Mexican states, including Baja California, Sonora, Chihuahua, Coahuila, Nuevo León, and Tamaulipas. Approximately 13 million people live in the U.S. counties and Mexican municipalities on the border. The high density of people and increased industrialization since the passage of NAFTA have placed an even greater burden on the inadequate infrastructure and environmental resources of the region. Exacerbating the problem is the fact that many U.S. counties along the border are categorized as "economically distressed," and few communities possess the resources needed to address environmental concerns. Just some of the critical border environmental issues include:

- Rapid urbanization and lack of adequate infrastructure
- Air pollution from open burning, vehicle emissions, and industrial operations
- Contamination of surface and groundwater from open sewers and industrial waste
- Overuse of aquifers and surface steams
- Transportation and illegal dumping of hazardous wastes
- Destruction of natural resources

The SCERP Solution

SCERP uses a broad, integrated, multidisciplinary approach to address the issues of the border. SCERP's researchers collaborate with the U.S. Environmental Protection Agency (EPA) and Mexico's Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT), as well as local and state governments, business and industry, nongovernmental organizations, and communities of the border region. SCERP organizes research, outreach, and training programs devoted to improving environmental conditions and to building capacity in the border region for resolving critical environmental problems. SCERP is pioneering a model of binational cooperation that brings U.S. and Mexican researchers together and introduces new skills and perspectives in binational environmental problem solving.

CENTRO DE INVESTIGACION Y POLITICA AMBIENTAL DEL SUROESTE

SOUTHWEST CENTER FOR ENVIRONMENTAL RESEARCH & POLICY

THE U.S.–MEXICAN border environment:

for the Border Region, Now and in 2020

SCERP 7

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A series edited by Paul Ganster

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The Southwest Center for Environmental Research and Policy (SCERP) is a consortium of U.S. and Mexican universities dedicated to addressing environmental issues of the U.S.-Mexican border region through applied research, outreach, and regional capacity building.

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San Diego State University Press

Published by
San Diego State University Press
5500 Campanile Drive
San Diego, CA 92182-4403
http://www-rohan.sdsu.edu/dept/press

Cover photos
U.S. Army Corps of Engineers

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Printed in the United States of America

ISBN 092561339-8

Previously published volumes in the SCERP Monograph Series,
The U.S.-Mexican Border Environment

No. 1 A road map to a sustainable 2020
No. 2 Water issues along the U.S.-Mexican border
No. 3 Economy and environment for a sustainable border region
No. 4 U.S.-Mexican border communities in the NAFTA era
No. 5 Overcoming vulnerability: The Southwest Center for Environmental Research and Policy's research program (1990-2002) and future agenda
No. 6 Air quality issues along the U.S.-Mexican border

About this volume:
All times are local
All monetary figures are US$ unless otherwise specified

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Glossary

af	acre-feet
AF/MW/yr	acre-feet per megawatt per year
BAQA	Border Air Quality Alliance
bbl/d	billion barrels per day
BECC	Border Environment Cooperation Commission
Btu	British thermal unit
CFE	Comisión Federal de Electricidad
CONAE	Comisión Nacional para el Ahorro de Energía
CRE	Comisión Reguladora de Energía
DOE	Department of Energy
EIA	Energy Information Agency
EPA	Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
GDP	Gross Domestic Product
GW	gigawatt
GWh	gigawatt-hours
IBWC	International Boundary and Water Commission
INEGI	Instituto Nacional de Estadística, Geografía e Informática
IPP	independent power producer
ITESM	Instituto Tecnológico y de Estudios Superiores de Monterrey
kV	kilovolt
kW	kilowatt
kWh	kilowatt-hour
LNG	liquid natural gas
LPG	liquid petroleum gas
MW	megawatt
NACM	North American Common Market
NADBank	North American Development Bank
NAFTA	North American Free Trade Agreement
NGO	non-governmental organization
Pemex	Petróleos Mexicanos, Mexico's state-run oil and gas monopoly
SANDAG	San Diego Association of Governments
SE	Secretaría de Energía
SEMARNAT	Secretaría de Medio Ambiente y Recursos Naturales
USMBR	U.S.-Mexican border region
UV	ultra-violet

Foreword

The Southwest Center for Environmental Research and Policy (SCERP) began studying the relationship between energy and the environment during the early 1990s. With the increased trade, border population, and industrialization since the passage of the North American Free Trade Agreement (NAFTA) in 1994, energy has become an even more critical and complex issue in the U.S.-Mexican border region as more stakeholders compete for access to affordable energy resources. Yet, energy continues to be an issue that is dealt with indirectly and is on the periphery of cross-border cooperation through programs such as Border XXI or Border 2012.

In 1994, SCERP supported a comprehensive study of energy and the environment in the California-Baja California region, in which researchers examined the political, economic, and ecological factors affected by energy production, distribution, and consumption for the region. Published in 1995 as Alan Sweedler, Paul Ganster, and Patricia Bennett, eds., Energy and the Environment in the California-Baja California Border Region (San Diego: Institute for Regional Studies of the Californias), this study, along with dozens of others on air quality and energy issues, helped stimulate discussions of the role of energy for the region and the transboundary nature of the environmental impacts related to energy. By bringing together specialists from the private sector, government agencies, and academia for a one-day workshop, SCERP set the stage for dealing with energy issues in a multi-stakeholder context. Since the mid 1990s there has been deregulation and an energy crisis in the Californias, along with increased private sector investment in power plants and natural gas pipelines throughout the border region. Thus, in 2001 SCERP decided to revisit, update, and expand its analysis of the issue of energy and the environment in the U.S.-Mexican border region by adopting these themes as the core discussion at its third Border Institute. This volume contains the papers and findings of Border Institute III.

The Border Institute series is an annual think tank event that allows top-level border stakeholders and decision-makers to analyze policy issues and options for important environmental challenges in the U.S.-Mexican border region. The first Border Institute addressed demographics, economics, and the environment. The second addressed infrastructure and the environment. Energy was a logical subject to follow in Border Institute III because of its strong interrelationship with these subjects and the topics of the subsequent Border Institutes—water and environmental health. Energy also complements the topics of air and water quality from past monograph volumes.

The editor of this volume on energy, David Rohy, is a SCERP energy researcher, current co-chair of the San Diego Regional Energy Office, and former commissioner of the California Energy Commission.

The volume and series editor would like to acknowledge the expertise of the authors exploring these complex issues and the expertise and efforts of the Border Institute participants. The editors also recognize the efforts of Louise Rohy, copy editor, Guillermo Torres at Universidad Autónoma de Baja California, who assistanced in translating sections into Spanish, Amy Conner, who coordinated the production of this volume, and graphic artists Jenny Carlsson and Mayra Navarro for their work on the figures contained herein.

Paul Ganster, San Diego State University
SCERP Monograph Series General Editor

Executive Summary

Conclusions and Recommendations of Border Institute III

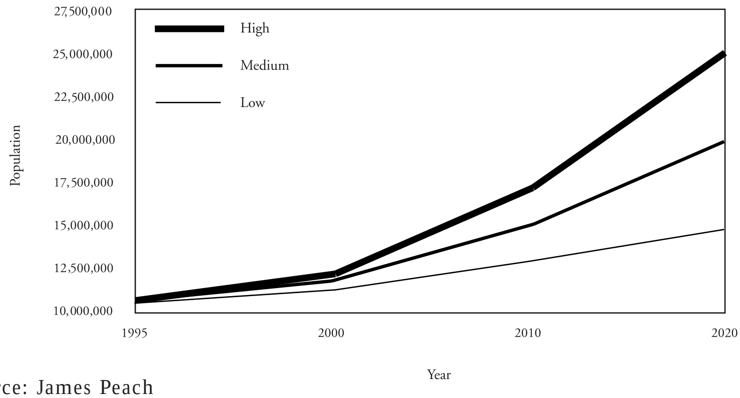
Border Institute III convened in Rio Rico, Arizona, April 30 to May 2, 2001, to address issues related to energy and the environment in the U.S.-Mexican border region. The purpose of the meeting was to assemble stakeholders from both sides of the border to consider a set of critical issues, as well as the long-term implications of those issues. Border Institute conveners—the Southwest Center for Environmental Research and Policy (SCERP), the U.S. Environmental Protection Agency (EPA), the Border Trade Alliance (BTA), and the U.S.-Mexico Chamber of Commerce—firmly believe that border communities must be part of solutions and that local, regional, tribal, and federal decision-makers need to understand the long-term implications of contemporary problems in order to improve the quality of life and support the sustainability of the border region.

The vision for the border, derived from Border Institute I, held in 1998, is: “A sustainable and responsible border economy, involved binational community, healthy natural environment, and proper resource management that provides all its residents a satisfactory and secure quality of life through enhanced employment, education, and business opportunities.”

The Context

The counties and municipalities of the border region currently have a population of more than 12 million, a figure that will nearly double to 24 million by the year 2020 (Figure 1). The region is among the fastest growing of North America, as has been the case for the past half-century. The growth is largely concentrated in U.S. and Mexican urban areas located across the international boundary from each other in sister city pairs. The border region is arid, with fragile ecosystems and limited natural resources, and is not capable of sustaining the current high rates of population growth and urbanization.

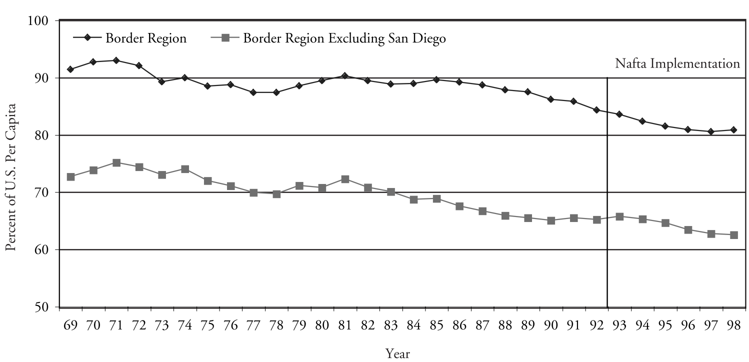
Figure 1. Population Projections for Border Counties and *Municipios*



Source: James Peach

The U.S. southwestern border region is the poorest region of the United States, even when including relatively well-off San Diego County, and continues to fall further behind the national average in per capita income (Figure 2). The Mexican border region is prosperous by Mexican national indicators, but the asymmetries with the adjacent areas in the United States are remarkable.

Figure 2. Border Region Per Capita Income as Percent of U.S. Per Capita Income



Source: James Peach and James Williams

Both regions have lacked local financial resources and federal support to provide the infrastructure and public services required by the growing population. The huge increase in bilateral trade stimulated by the North American Free Trade Agreement (NAFTA) brought greater economic expansion to the border region, but not prosperity and development. The border region has absorbed a disproportionate share of negative impacts of the trade that has benefited both nations as a whole. The border region has been marginalized by both nations from comprehensive planning, funding, and improvements.

Natural resource constraints, poverty, and rapid growth have combined to produce a range of environmental problems in border communities. A notable lack of infrastructure has produced deterioration of surface and underground water quality due to untreated waste water or renegade sewage flows. Every border community faces an impending crisis in providing water for urban, industrial, and agricultural purposes. Natural resources, endangered species, and important ecosystems are threatened by rapid urbanization and industrialization. Many border communities cannot meet U.S. or Mexican air quality standards, and corresponding human health impacts are on the rise.

Energy Issues

The most recent infrastructure and environmental crisis to impact the border region relates to energy. The crisis is the result of poor long-term planning by fuel producers and importers and electricity generators and transmitters, flawed public policy decisions like energy deregulation in California, and lack of long-term planning mechanisms in the binational border region. While it is clear that the days of cheap energy are over, extreme price volatility and doubtful future sources threaten the security of all sectors of the economy and the quality of life of most residents.

Mexican electricity demand is increasing nationally at 6.6% annually for a population that grew at an annual rate of 1.58% from 1995 to 2000. Much faster population growth in the border region (about 5.1% annually), coupled with an expanding middle class and a strong dependence in the region on the energy-intensive assembly, or maquiladora, industry translates into an even faster growth rate of electricity demand in the border region, probably closer to 15% per year. The capital requirements to meet Mexico's medium and long-term electricity needs are enormous (currently estimated at about $49 billion) and cannot be met solely with domestic sources of financing.

The cost just to meet Mexico's internal demand for natural gas by developing untapped natural gas reserves and building pipelines is estimated at between $30 billion and $50 billion over the next 10 years. The cost to develop the infrastructure to export gas is estimated at $50 billion to $60 billion. These are enormous sums, given that Mexico's annual federal budget is about $150 billion. This translates into the need for major private sector investment. However, the current legal and regulatory framework in Mexico, the historic importance of energy as a domestic political issue, and the exemption of energy under the NAFTA process are all bottlenecks to the flow of private investment toward the Mexican energy sector. Improving the private sector investment environment in energy is a significant challenge for the Mexican administration and congress.

The response to the energy crisis is a rush to the border region to provide new capacity to supply regional or statewide needs. The Mexican border zone is considered desirable for siting new energy plants due to adjacent markets in the United States, an easier permitting process, and lower environmental standards on the Mexican side of the binational air basins (Figure 1). The Mexican Energy Secretary, Ernesto Martens, speaking at the 10th Annual Conference on Energy in Latin America at the Institute of the Americas, indicated in May 2001 that Mexico would approve any number of Baja California plants to serve consumers in the United States, the *San Diego Union-Tribune* reported. Due to the energy crisis in California, the permitting process for new plants has been streamlined, allowing for the building of so-called "peaker plants" with a capacity of under 50 megawatts (MW). They do not have to meet the same requirements for emissions control and impact mitigation as larger plants. These peaker plants are ostensibly designed to supply power during daily peak demand periods, but technically are capable of operating up to 8,000 hours per year. Due to the lower emission controls, dirtier fuels, and a lowered level of anticipated maintenance, these peakers emit significantly more air pollutants

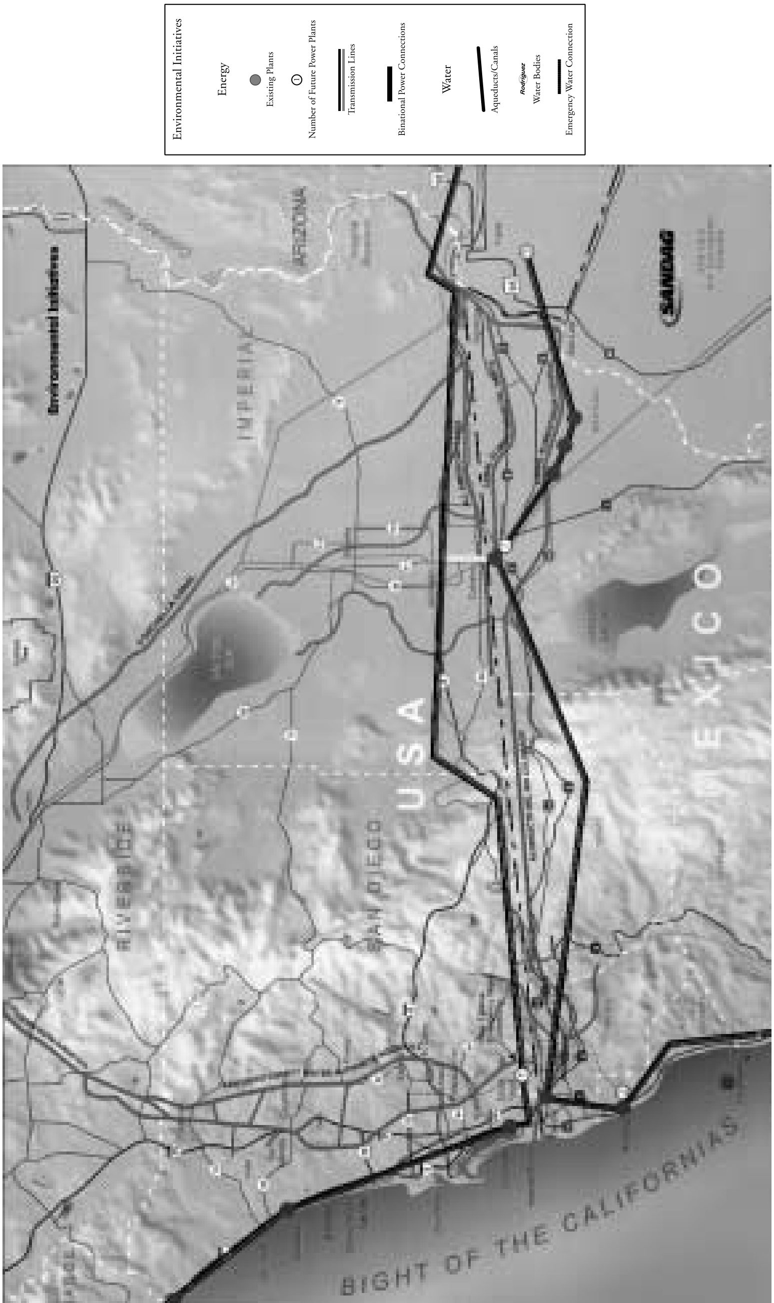


Figure 1. San Diego-Tijuana Energy Infrastructure

than the fully regulated base load plants. The plant permitting and locating process does not include regional or binational planning and coordination. California and Baja California are examples of this inadequate coordination, but other U.S. and Mexican border states are apparently beginning to experience similar problems, if not worse. In Arizona, where the permitting process is easier and less complicated than in California, a significant number of new generating facilities are in the works, most destined to export power to California.

The current situation in the California-Baja California binational region with respect to electricity generating facilities serves as an example of the issues appearing everywhere along the U.S.-Mexican border. Almost half of the border population lives in the California-Baja California border region, so regional power generating concerns here are relevant to the entire border region.

The southern part of San Diego County is the location for a flurry of energy-related projects and plans:

- The South Bay Power Plant (706MW) is an older, dual-fuel facility that had been operating at full capacity through most of the 1990s. Local authorities planned to demolish this facility since it is sited in a sensitive wetlands area. There is now interest in repowering and upgrading the facility to 1,000MW.
- The just-approved Otay Mesa Power Plant is to be located in Otay Mesa near the international border. A base load plant of 510MW, it has an application pending to increase capacity to 1,000MW. The plant will use gas turbine, combined-cycle technology and will be air cooled, even though a plentiful source of reclaimed water will soon be available from the South Bay Water Reclamation Plant. This means that the plant will not use the most efficient—and least polluting—technology available. Although meeting California air standards, this plant will have negative impacts on the air quality in Tijuana, its closest neighbor.
- Ramco has a new peaker power plant in Chula Vista with a capacity of 44MW. An application is pending to add an additional 57.6MW under the emergency permitting process.
- Wildflower Energy's Larkspur Facility in Otay Mesa has been permitted under the California Energy Commission's emer-

gency process. This will be a 90MW peaker plant.

- CalPeak Power's Lonestar No. 4 Power Plant is a 49.3MW peaker plant to be located one mile from the Larkspur facility. It has received preliminary approval by the Air Pollution Control District.

Thus, within a short time, the southern part of San Diego County could be the location of 1,400MW of existing and new power production, with the possibility of increasing to 2,241MW within a few years. There are a number of concerns with this situation:

- The synergies of locating so many plants in the same region apparently have not been adequately considered
- The peaker plants avoid the stringent emissions and mitigation requirements that base load plants have to meet, and in some cases are able to burn much dirtier fuels including diesel, a source of carcinogenic fine particulate matter
- The population in the areas surrounding these facilities is heavily Hispanic and has some of the lowest incomes of San Diego County, raising serious concerns about environmental justice
- Although there is transport of air pollution in both directions across the international border, the predominant direction of the air flow in most seasons is north to south; thus, these plants will have significant impacts on Tijuana's airshed, yet there was inadequate discussion and consultation with agencies and the citizens of Tijuana

In the Imperial Valley-Mexicali region of the Baja California-California border region, there are also serious concerns about poorly coordinated increases in electrical generating capacity in the area. Imperial Valley, with hydropower, natural gas, and geothermal facilities, is well-supplied with electrical power for regional use. Mexicali, with significant increases in population and industry for the past decade, is facing potential electric power shortages, both locally and for the Baja California electric grid. Currently, a number of generating projects are planned for Mexicali:

- InterGen is constructing a combined-cycle, gas-fired plant that will provide 750MW when completed in 2003—250MW of this output is slated for export to Southern California—howev-

er, it is designed to use less than state-of-the-art pollution control technology
- Sempra Energy is moving forward with a 500MW gas-burning, combined-cycle plant that is scheduled to begin operations in 2005, and sell all production to the United States
- American Electric Power has discussed a 269MW plant to be online by 2005

If all these plants were put in operation, they would add significant amounts of pollutants to the Imperial Valley-Mexicali airshed. Imperial Valley currently is not in compliance with U.S. federal standards for particulates (PM_{10}) and ozone.

While these new projects will help meet the energy demands in the border and elsewhere, they also pose the risk that the border region will suffer a disproportionate share of environmental impacts due to the location of a large number of new facilities in the region without proper evaluation of regional and transborder air quality impacts. The border faces the threat of becoming a pollution haven for energy production, absorbing significant environmental costs for other regions.

These plants will also place a severe strain on natural gas supplies, none of which are indigenous. Since most of the plants are dual-fuel, if natural gas supplies are restricted, there will be a natural tendency, especially by Mexico's state-run oil and gas monopoly Petróleos Mexicanos (Pemex), to use fuel oil that contains sulfur, exacerbating already-polluted air basins. While the specific cases discussed here are for the California-Baja California border region, similar issues and concerns are present and emerging elsewhere along the U.S.-Mexican border.

Conclusions and Recommendations

The discussions at Border Institute III produced a number of specific and general recommendations. These were developed in the discussions in topical panels throughout the meeting and also at breakout roundtables designed to summarize and focus the content of the meeting. The recommendations dealt with three main themes for the U.S.-Mexican border region: increasing cooperation and participation, changing environmental policy, and building a sustainable economy.

Increasing Cooperation and Participation at a Binational, Regional Level

- The United States should create a cabinet-level position called "border coordinator" to facilitate the involvement of all federal agencies in addressing border energy and other issues. This position would be the counterpart to the position recently established by Mexican President Vicente Fox.
- Policymakers and other stakeholders should build on existing institutions and arrangements rather than create new administrative mechanisms when developing solutions to coordinate energy and environment in the transborder region. Public participation, involvement of all sectors, and transparency should be central to all such efforts.
- The Border XXI process must be reinvigorated, with increased local and state participation. Under previous presidential administrations, the United States and Mexico made considerable progress in addressing border environmental problems through Border XXI, but the proposed Border 2012 Program under Mexican President Fox and U.S. President George W. Bush has yet to gain the momentum of its predecessor.
- A transborder environmental impact assessment process needs to be established to protect border communities from potentially harmful transborder environmental impacts. Local and state participation is key in this process. Under previous presidential administrations, some progress has been made on the establishment of a transboundary environmental impact process. This process needs to be accelerated to protect border communities from transborder environmental impacts.
- Binational pilot programs should be initiated to address energy and environmental issues in the border region. These programs should include extensive participation from stakeholders in many sectors, including private industry, non-governmental organizations (NGOs), government agencies, and communities.

Changing Environmental Policy

- An energy working group should be added to the Border XXI working groups. Border environmental work groups should also be added to Pemex, Federal Energy Regulatory Commission (FERC), Comisión Federal de Electricidad (CFE), the U.S. Department of Energy (DOE), and the Secretaría de Energía (SE).
- When coordinating and planning for future energy facilities, the resulting future energy needs for water should be taken into account. This water-energy connection is increasingly important in the arid border region. A holistic approach will result in more efficient use of water, energy, and other utilities.
- Regulations for power plants should be harmonized for the border region to decrease air quality impacts and transboundary effects. If regulations are harmonized for the border region, there is a smaller likelihood that companies will locate there to escape stricter regulations elsewhere.
- A binational energy database should be developed for adequate planning and coordination purposes in the region and for both nations. This database will require the availability of harmonized and easily accessible data for the border zone. Currently, no energy balances (identification and quantification of energy sources and uses) are available for Mexican states.
- A process should be established to require that the most advanced and cleanest technology be used for plants located in the binational border region. Mexico should designate the border region a “critical zone” as it has for Mexico City. Accordingly, it should direct Pemex to reformulate fuels for use in the border region.

Building a Sustainable Economy

- More demand-side management and energy efficiency measures should be used in the border region. A regional, binational approach needs to be developed to prohibit the export of used energy-wasting appliances, such as refrigerators and air conditioners. Additionally, a regional, binational program for retiring and scrapping old electrical appliances is needed. Electricity bills should include tiered rates and electricity meters should show rates by time of use so that consumers understand the true costs of their electricity usage patterns.

- Stakeholders in the border region should capitalize on the renewable energy sources available to meet part of the demand for energy. For example, large new housing developments in U.S. and Mexican border communities could easily employ inexpensive and proven technologies for solar water heating.
- The private sector must be included as a major part of the solution to the border energy and air pollution problems. Clear and consistent regulations, emissions trading programs, binationally harmonized incentive programs, and market based approaches will facilitate private sector action.

The current energy crisis in the border region should be taken as a signal of the dangers of thinking only with a short-term view and resolving immediate problems at the expense of the health and well-being of border communities. Stakeholders in both countries need to accept the challenge of putting content and meaning into the word "sustainable." The futures of the two nations are laced together through multiple ties. Energy is a key challenge to create a realistic and equitable framework in which the well-being of those living on the border is central. Resolving the energy crisis provides an opportunity for stakeholders to engage in long-term binational coordination and planning to create innovative solutions. It is up to all stakeholders to develop appropriate environmental policies and build a sustainable economy to promote future well being.

Resumen Ejecutivo

Conclusiones y Recomendaciones del III Instituto Fronterizo

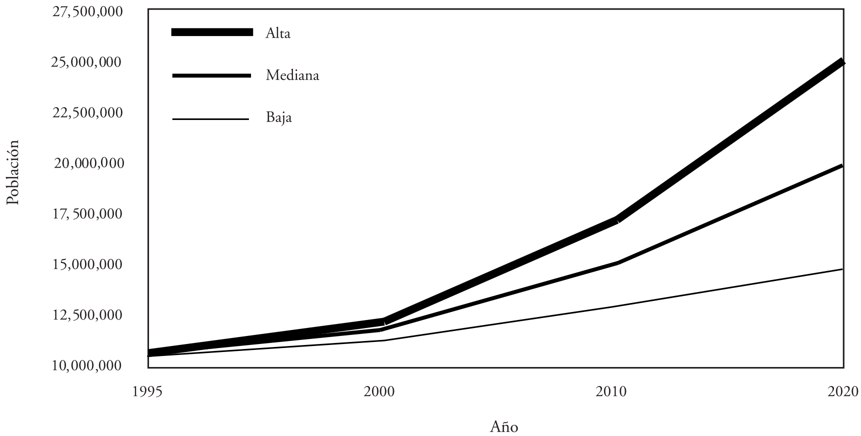
El III Instituto Fronterizo se reunió en Rio Rico, Arizona, del 30 de abril al 2 de mayo del 2001 para atender asuntos relacionados con la energía y el medio ambiente en la región fronteriza México-E.U. El propósito de la reunión fue el reunir a los actores clave de ambos lados de la frontera para considerar una serie de asuntos críticos, así como sus implicaciones al largo plazo. Los integrantes del Instituto Fronterizo—el Centro de Investigación y Política Ambiental del Suroeste (CIPAS), la Agencia de Protección Ambiental de los Estados Unidos (U.S. EPA, por sus siglas en inglés), la Alianza de Comercio Fronterizo (BTA, por sus siglas en inglés), y la Cámara de Comercio México-E.U.—creen firmemente que las comunidades fronterizas deben ser parte de las soluciones y que los tomadores de decisiones a nivel local, regional, tribal y federal deben comprender las implicaciones a largo plazo de los problemas contemporáneos para poder mejorar la calidad de vida y apoyar la sustentabilidad de la región fronteriza.

La visión para la frontera, derivada de la primera reunión del Instituto Fronterizo celebrada en 1998, es: "Una economía fronteriza sustentable y responsable, una comunidad binacional participativa, un ambiente natural saludable, y una administración apropiada de recursos que provee a todos sus residentes una calidad de vida satisfactoria y segura a través de mejores empleos, educación y oportunidades de negocio."

El Contexto

Los condados y municipios de la región fronteriza actualmente tienen una población de más de 12 millones, cifra que casi se duplicará a 24 millones en el año 2020 (Figura 1). La región está entre las de más rápido crecimiento en América del Norte, como ha ocurrido durante el medio-siglo pasado. El crecimiento está concentrado en su mayor parte en las áreas urbanas de E.U. y México localizadas en ambos lados de la frontera internacional en pares de ciudades gemelas. La región fronteriza es árida, con ecosistemas frágiles y recursos naturales limitados y no es capaz de sostener las altas tasas de crecimiento poblacional y de urbanización actuales.

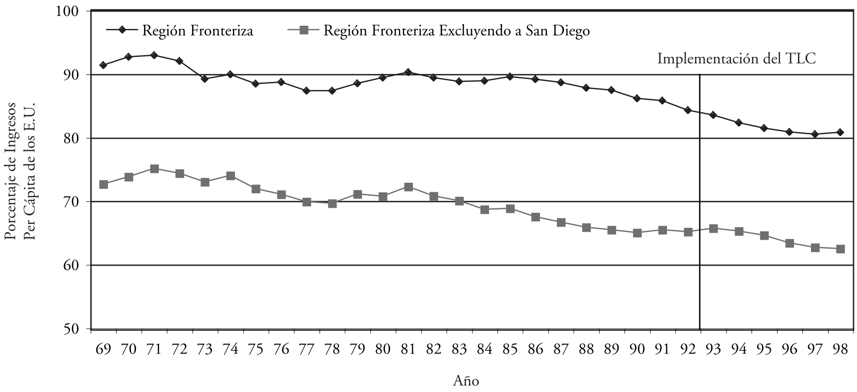
Figura 1. Proyecciones Poblacionales para Condados y Municipios Fronterizos



Fuente: James Peach

La región fronteriza Suroeste de los E.U. es la región más pobre de los Estados Unidos, aún incluyendo al próspero condado de San Diego, y continúa decayendo cada vez más por debajo del promedio nacional de ingresos per cápita (Figura 2). La región fronteriza de México es próspera bajo indicadores nacionales mexicanos, pero las asimetrías con las áreas adyacentes en los Estados Unidos son notables.

Figura 2. Ingresos Per Cápita en la Región Fronteriza como Porcentaje de Ingresos Per Cápita de los E.U.



Fuente: James Peach y James Williams

Ambas regiones han carecido de recursos financieros locales y apoyo federal para proporcionar la infraestructura y servicios públicos requeridos por la población creciente. El enorme incremento en el comercio bilateral estimulado por el Tratado de Libre Comercio (TLC) trajo una mayor expansión económica a la región fronteriza, pero no prosperidad y desarrollo. La región fronteriza ha absorbido una cantidad desproporcionada de impactos negativos del tratado que ha beneficiado a ambas naciones como un todo. La región fronteriza ha sido marginada por ambas naciones en planeación comprensiva, fondos y mejoras.

Restricciones de recursos naturales, pobreza y rápido crecimiento se han combinado para producir una serie de problemas ambientales en comunidades fronterizas. Una notable carencia de infraestructura ha producido deterioro en la calidad del agua superficial y subterránea causada por aguas residuales no tratadas o fugas de aguas negras. Cada comunidad fronteriza enfrenta una crisis cercana en el abastecimiento de agua para fines urbanos, industriales y agrícolas. Recursos naturales, especies en extinción y ecosistemas importantes son amenazados por la rápida urbanización e industrialización. Muchas comunidades fronterizas no pueden cumplir estándares de calidad del aire mexicanos o de los E.U. y los correspondientes impactos en la salud humana van en aumento.

Asuntos de la Energía

La más reciente crisis ambiental y de infraestructura que impactará la región fronteriza tiene relación con la energía. Esta crisis es el resultado de una pobre planeación a largo plazo por parte de empresas generadoras y productoras de energía, decisiones erróneas de políticas públicas como la desregulación de energía en California, y la carencia de mecanismos de planeación a largo plazo en la región fronteriza binacional. Mientras está claro que los días de energía barata han terminado, una extremada volatilidad en precios y dudosas fuentes futuras amenazan la seguridad de todos los sectores de la economía y la calidad de vida de la mayoría de residentes.

La demanda mexicana de electricidad a nivel nacional está aumentando 6.6% anualmente para una población que creció a una tasa anual de 1.58% de 1995 al 2000. Un mayor crecimiento de población en la región fronteriza (aproximadamente 5.1% anualmente), unido a una clase media en expansión y una fuerte dependencia en la región de industria de ensamble con uso intensivo de energía, o industria maquiladora, se traduce en un aún mayor crecimiento en la demanda de energía para la región fronteriza, probablemente cercana al 15% anual. Los requerimientos de capital para satisfacer las necesidades de electricidad a mediano y largo plazo de México son enormes (actualmente estimados en $49 billones) y no pueden ser satisfechos con fuentes internas de financiamiento.

El costo sólo para satisfacer la demanda interna de gas natural de México desarrollando reservas de gas natural y construyendo gasoductos se estima entre $30 y $50 billones durante los siguientes 10 años. El costo para desarrollar la infraestructura para exportar gas se estima de $50 a $60 billones. Estas son sumas enormes, siendo que el presupuesto federal anual de México es aproximadamente de $150 billones. Esto se traduce en la necesidad de mayor inversión del sector privado. Sin embargo, el marco legal y normativo en México, la importancia histórica de la energía como un asunto de política interna y la no consideración de la energía bajo el proceso del TLC, son cuellos de botella para el flujo de inversiones privadas hacia el sector energético mexicano. El mejorar el ambiente de inversión para el sector privado en energía es un reto significativo para el gobierno y el congreso de México.

La respuesta a la crisis energética es una carrera de la región fronteriza para proveer nuevas capacidades para abastecer necesidades regionales o estatales. La zona fronteriza mexicana es considerada deseable para ubicar nuevas plantas de energía debido a mercados adyacentes en los Estados Unidos, un proceso de permisos más sencillo y estándares ambientales más bajos en el lado mexicano de las cuencas atmosféricas binacionales. El Secretario de Energía de México, Ernesto Martens, en su discurso de la 10ma Conferencia Anual sobre Energía en América Latina en el Instituto de las Américas, indicó en Mayo del 2001 que México aprobaría cualquier número de plantas en Baja California para abastecer a consumidores en los Estados Unidos, según reportó el *San Diego Union-Tribune*. Debido a la crisis energética en California, el proceso de permisos para las nuevas plantas ha sido ajustado, permitiendo la construcción de las llamadas “plantas pico” con una capacidad por debajo de los 50 megawatts (MW), las cuales no tienen que cumplir con los mismos requerimientos para el control de las emisiones y la mitigación de impactos como las plantas más grandes. Estas plantas pico ostentan estar diseñadas para abastecer energía durante periodos pico diarios de demanda, pero técnicamente son capaces de operar hasta 8,000 horas por año. Debido a controles menores de emisiones, combustibles más sucios, y un nivel más bajo de mantenimiento preventivo, estas plantas emiten significativamente más contaminantes de aire que las plantas base completamente reguladas. El proceso de localización y autorización no incluye planeación y coordinación regional o binacional. California y Baja California son ejemplos de esta coordinación inadecuada, pero otros estados mexicanos y estadounidenses están comenzando aparentemente a experimentar problemas similares, si no es que peores. En Arizona, donde el proceso de permisos es más fácil y menos complicado que en California, un número significativo de plantas generadoras están en proceso, la mayoría destinadas a exportar energía a California.

La situación actual en la región binacional California-Baja California referida a la infraestructura generadora de electricidad, sirve como ejemplo de los asuntos que aparecen por todas partes a lo largo de la frontera México-E.U. Casi la mitad de la población fronteriza vive en la región California-Baja California, por lo cual la preocupación relacionada con la generación de energía en esta región es importante para toda la región fronteriza.

La parte sur del condado de San Diego es el sitio de confluencia para una ráfaga de proyectos y planes relacionados con la energía:

- La Planta de Energía de South Bay (706MW) es una planta de ciclo combinado más antigua que había estado operando a toda su capacidad durante la mayoría de los años 1990. Autoridades locales planeaban demoler la planta debido a que siendo que está situada en una área sensible de humedales. Existe ahora interés en reactivar y actualizar la planta a 1,000MW.
- La recientemente aprobada Planta de Energía Otay Mesa se localizará en la Mesa de Otay de E.U., cerca de la frontera internacional. Una planta base de 510MW, tiene una solicitud pendiente para incrementar su capacidad a 1,000MW. La planta utilizará gas turbina, tecnología de ciclo-combinado y será enfriada por aire, aunque pronto una gran cantidad de agua estará disponible proveniente de la Planta de Recaudación de Agua South Bay. Esto significa que la planta no utilizará la tecnología más eficiente—y menos contaminante—disponible. Aunque cumple con los estándares de aire para California, esta planta tendrá impactos negativos en la calidad del aire en Tijuana, su vecino más cercano.
- Ramco tiene una nueva planta pico en Chula Vista con una capacidad de 44MW. Una solicitud para agregar 57.6MW adicionales está pendiente bajo el proceso de per-misos de emergencia.
- La planta de energía Larkspur de Wildflower en Mesa de Otay ha sido aprobada bajo el proceso de emergencia de la Comisión de Energía de California. Esta será una planta pico de 90MW.
- La Planta Lonestar No. 4 de Calpeak Power es una planta pico de 49.3MW a ser situada a una milla de la Planta Larkspur. Ha recibido aprobación preliminar del Distrito de Control de la Contaminación del Aire.

Por lo tanto, dentro de poco tiempo, la parte sur del Condado de San Diego podría ser sede de 1,400MW a partir de la nueva y la ya existente producción de energía, con la posibili dad de incrementarse a 2,241MW en el lapso de pocos años. Existen una serie de asuntos preocupantes con esta situación:

- Las sinergias al situar tantas plantas en la misma región aparentemente no han sido adecuadamente consideradas
- Las plantas pico evitan las emisiones severas y requerimientos de mitigación que deben cumplir las plantas mayores, y en algunos casos son capaces de quemar combustibles más sucios, incluyendo diesel, una fuente de materia particulada fina car cinogénica
- La población en áreas rodeando estas plantas es predominante mente hispánica y tiene algunos de los índices más bajos de ingresos del Condado de San Diego, lo que provoca preocupa ciones serias sobre la justicia ambiental
- Aunque existe un transporte de contaminantes atmosféricos en ambas direcciones de la Frontera Internacional, la dirección pre dominante de flujo de aire en la mayoría de estaciones del año es de Norte a Sur; por lo cual estas plantas tendrán un impacto significativo en la cuenca de Tijuana, aún cuando ha habido una inadecuada consulta y discusión con agencias y ciudadanos de Tijuana

En la región Valle Imperial-Mexicali de la zona fronteriza California-Baja California, también hay serias preocupaciones respecto a los incrementos en la capacidad de producción eléctrica pobremente coordinados en esta área. El Valle Imperial con su potencial hidroeléctrico, gas natural, y plantas geotérmicas está bien abastecido de energía eléctrica para uso regional. Mexicali con un aumento significativo de población e industria en las décadas pasadas, enfrenta una escasez potencial de energía para la red eléctrica de Baja California y el abasto local. En la actualidad una serie de proyectos generadores están planeados para Mexicali:

- InterGen construye una planta de combustión de gas y ciclo-combinado que proveerá 750MW al completarse en el 2003—250 MW de esta producción está reservada para exportación al Sur de California—aunque se encuentra diseña da para usar menos que la tecnología de punta para el control de la contaminación
- Sempra Energy se mueve adelante con una planta de ciclocombinado con combustión de gas de 500MW la cual está progra

mada para comenzar operaciones en el 2005, vendiendo toda la producción a Estados Unidos
- American Electric Power ha planteado tener una planta de 269MW operando para el año 2005

Si todas estas plantas fueran puestas en operación, agregarían cantidades significativas de contaminantes a la cuenca del Valle Imperial-Mexicali.

El Valle Imperial actualmente se encuentra en incumplimiento de los estándares de E.U. para partículas (PM_{10}) y ozono. Mientras que estos nuevos proyectos ayudarán a satisfacer las demandas de energía en la frontera y otros lados, también presentan el riesgo de que la región fronteriza sufra una cantidad desproporcionada de impactos ambientales debido al establecimiento de un gran número de plantas en la región sin evaluación apropiada del impacto regional y transfronterizo en la calidad del aire. La frontera enfrenta la amenaza de convertirse en un paraíso de contaminación para la producción de energía, absorbiendo costos ambientales significativos por otras regiones.

Estas plantas también provocarán una presión severa sobre las fuentes de abastecimiento de gas natural, de las cuales ninguna es local. Debido a que la mayoría de las plantas emplean dos tipos de combustible, si el abastecimiento de gas natural es restringido, existirá una tendencia natural, en especial por el monopolio estatal de gas y petróleo de México, Petróleos Mexicanos (Pemex), de usar combustible que contiene azufre, incrementando las ya contaminadas cuencas atmosféricas. Aunque los casos específicos aquí discutidos son para la región fronteriza California-Baja California, asuntos y preocupaciones similares están presentes y emergiendo en otros lados a lo largo de la frontera México-E.U.

Conclusiones y Recomendaciones

Las discusiones del III Instituto Fronterizo produjeron un número de recomendaciones generales y específicas. Estas fueron desarrolladas en las discusiones de los paneles temáticos durante el transcurso de las reuniones así como en mesas redondas diseñadas para resumir y enfocar el contenido de las reuniones. Las recomendaciones consideraban tres temas principales para la región fronteriza México-E.U.: incremento en la cooperación y participación, cambio en la política ambiental y la construcción de una economía sustentable.

Incremento en la Participación y Cooperación a Nivel Binacional, Regional

- Estados Unidos debe crear una posición a nivel gabinete llamada “coordinación fronteriza” para facilitar el envolvimiento de todas las agencias federales a la atención de problemas de energía en la frontera así como otros. Esta posición sería la contraparte de la recién establecida posición del Presidente de México Vicente Fox.
- Creadores de políticas y otros interesados deben modificar los acuerdos e instituciones establecidas en vez de crear nuevos mecanismos administrativos al desarrollar soluciones para coordinar energía y ambiente en la región transfronteriza. Participación pública, involucrar a todos los sectores, y transparencia deben ser características centrales en todos los esfuerzos.
- El proceso Frontera XXI debe ser revigorizado, con incrementada participación local y estatal. Bajo pasadas administraciones presidenciales, los Estados Unidos y México hicieron progresos considerables en atender problemas ambientales fronterizos a través del Programa Frontera XXI, pero el Programa 2012 propuesto bajo la presidencia del Presidente Vicente Fox y el presidente de los Estados Unidos George W. Bush todavía no lleva el impulso del programa anterior.
- Un proceso de evaluación de impacto ambiental transfronterizo necesita ser establecido para proteger a comunidades fronterizas de potenciales impactos ambientales transfronterizos perjudiciales. Participación local y estatal son claves en este proceso. Bajo pasadas administraciones presidenciales, se ha logrado algún progreso en establecer un proceso de evaluación de impacto ambiental transfronterizo. Este proceso necesita ser acelerado para proteger comunidades fronterizas de impactos ambientales transfronterizos.

- Programas piloto binacionales deben ser iniciados para atender problemas ambientales en la región fronteriza. Estos programas deben incluir participación extensiva por parte de interesados de varios sectores, incluyendo la industria privada, ONGs, agencias de gobierno y comunidades.

Cambiando la Política Ambiental

- Un equipo de trabajo en energía deberá ser incluido en los grupos de trabajo de los Programas Frontera XXI y 2012. Grupos de trabajo para el medio ambiente fronterizo también deberán ser agregados a Pemex, la Comisión Federal Reguladora de Energía (FERC, por sus siglas en inglés), Comisión Federal de Electricidad (CFE), el Departamento de Energía de los Estados Unidos (DOE, por sus siglas en inglés) y la Secretaría de Energía de México (SE).
- Al planear y coordinar para futuras plantas, deberán tomarse en cuenta las necesidades futuras resultantes de energía para agua. Esta conexión energía-agua es cada vez más importante en la región árida de la frontera. Un enfoque holista resultará en el uso más eficiente de agua, energía y otros recursos.
- La regulación de plantas deberá ser armonizada en la región fronteriza para mermar impactos al aire y efectos transfronterizos. Si la regulación para la región fronteriza es armonizada existe una menor probabilidad de que compañías se instalen ahí para escapar regulaciones estrictas en otros lados.
- Una base de datos binacional de energía deberá ser desarrollada con fines de planeación y coordinación adecuada en la región y para ambas naciones. Esta base de datos requerirá disponibilidad de datos armónicos y fácilmente accesibles para la zona fronteriza. Actualmente, ningún balance de energía (identificación y cuantificación de fuentes de energía y uso) se encuentra disponible en México.
- Un proceso deberá establecerse para requerir el uso de la más avanzada y salubre tecnología para plantas localizadas en la región binacional fronteriza. México debería designar la región fronteriza como “zona crítica” como lo ha hecho con la Ciudad de México. Asimismo, deberá instruir a Pemex la reformulación

de combustibles para uso en la región fronteriza.

Construyendo una Economía Sustentable

- Más políticas que tratan la demanda de recursos energéticos y medidas de eficiencia de energía deberán ser utilizadas para regiones fronterizas. Un enfoque regional binacional necesita ser desarrollado para prohibir la exportación de electrodomésticos usados de desperdiciadores de energía, tales como refrigeradores y aires acondicionados. Adicionalmente, un programa regional, binacional para retirar y desechar electrodomésticos viejos es necesario. Los cobros de electricidad deberán incluir tarifas con varios niveles y los medidores de electricidad deberán mostrar las tarifas por tiempo de uso para que los consumidores entiendan el costo real de sus patrónes de uso.
- Interesados de la región fronteriza deberán capitalizarse en las fuentes renovables de energía disponibles para satisfacer parte de la demanda de energía. Por ejemplo, nuevos desarrollos grandes de hogares en las comunidades de la frontera de E.U. y México pueden emplear fácilmente tecnologías baratas y probadas para el calentamiento de agua.
- El sector privado debe incluirse como gran parte de la solución a los problemas energético y ambiental de la frontera. Regulaciones claras y consistentes, programas de intercambio de emisiones, programas incentivos armonizados binacionalmente, y enfoques basados en el mercado facilitarán acciones del sector privado.

La actual crisis energética en la región fronteriza debe tomarse como señal de los peligros de pensar con un punto de vista a corto plazo y de resolver problemas inmediatos a expensas de la salud y bienestar de comunidades fronterizas. Interesados de ambos países necesitan aceptar el reto de poner significado y contenido a la palabra “sustentable”. El futuro de ambas naciones se encuentra atado por varios lazos. La energía es un reto clave para la creación de un marco de trabajo razonable y equitativo en el cual el bien estar de aquellos viviendo en la frontera es central. Resolver la crisis energética brinda la oportunidad a inversionistas para involucrarse en una coordinación y plantación binacional a largo plazo para crear soluciones innovadoras. Está en manos de todos los interesados el desarrollar políticas ambientales apropiadas y construir una economía sustentable para promover el bienestar futuro.

I

The Long Run and the Energy Sector in the Border Region

James Peach

Abstract

The environmental and energy future of the U.S.-Mexican border region will be determined largely by long-run national trends in population growth and per capita income. Per capita electricity consumption in the United States is roughly five times as high as the corresponding figure in Mexico and these national figures are reflected in border region electricity and non-electric energy consumption patterns. Per capita energy consumption in Mexico, including the border region, is lower than in the United States because per capita income in Mexico is lower than in the United States.

All projections of border region energy demand, cited in the following chapters, depend critically on projected population size and per capita income. Border region population growth and per capita income, in turn, depend mainly on the corresponding national trends of these two variables. The main focus of this chapter is these long-run trends and how they might be influenced by national policies, but two short digressions are necessary.

First, the three main ways in which national economies affect regional economies such as the border region are discussed. Interregional trade flows are important because the smaller the

region, the less likely it is to produce all of the goods and services its population consumes. The region must import these goods and services from elsewhere and the region must export something to pay for the imports. The maquiladora industry is a good example of the importance of interregional trade. Capital and labor mobility are also important determinants of regional economic conditions. Workers will often migrate based on regional economic conditions and capital may be attracted to capital-short regions. Finally, there are regional differences in the impact of national policies. For example, trade policy and immigration policy affect some regions more than others.

The second digression is a brief tour of short-run macroeconomic conditions in Mexico and the United States. Short-run economic conditions can have lasting effects, both nationally and in the border region. A classic example is the creation of the Bracero Program in 1942 in response to labor shortages in the United States. But there is another reason for examining the short run. All too often, we have a tendency to think that current economic conditions will continue indefinitely. Many observers felt that the U.S. economic expansion of the late 1990s was so strong that the United States had entered a fundamentally new economic era. Mexico's economic expansion of the late 1990s has been remarkable as well. But it is possible that both expansions are coming to an end. Because Mexico's expansion is so closely tied to U.S. economic conditions, it is important not to consider current economic conditions as a lasting feature shaping the regional economies.

A major task of this chapter is to examine long-run national trends in population and suggest what these trends might mean for the border region. The population history of the United States and Mexico is a study in contrasts and variability. During the 19th century, the U.S. population increased much more rapidly than Mexico's. By 1900, the U.S. population of 75 million people was more than five times as large as Mexico's population of 13.6 million. Since about 1930, however, Mexico's population has been growing at a much higher rate than the U.S. population. Since the mid-1970s, Mexico's population growth rate has fallen dramatically in response to deliberate policy actions. In short, even a quick examination of population trends in the two nations leads to the conclusions that population growth rates vary considerably from decade to decade, national policies (e.g., immigration) matter, and future population growth in the two nations are not independent.

Major urban areas along both sides of the border have been growing rapidly for decades, but there is no reason to adopt a Malthusian gloom-and-doom scenario for the border region. The Malthusian assumption of (constant) exponential population growth rates is not warranted by the population histories of either Mexico or the United States. Malthusianism is simply not meaningful in the regional context. Rather, what should be planned for in the border region is a great deal of variation in population growth rates.

A second critical variable in the context of the border region energy sector is per capita income. Per capita income on the U.S. side of the border (in 25 border counties) is low relative to the U.S. average and has been falling relative to the national figure in recent years. On the Mexican side of the border, per capita income (as measured by Gross State Product per person) is considerably higher than the Mexican national average. Still, differences in income on the two sides of the border are substantial and largely reflect national averages.

U.S. Gross Domestic Product (GDP) per person in 2000 was $36,000 while in Mexico it was $4,500. There is no realistic possibility of income convergence between the two nations in the next few decades. Mexico’s real (inflation adjusted) GDP per capita in 2000 barely exceeded its previous peak, which was recorded in 1981. The simple arithmetic of compound annual growth rates effectively prohibits income convergence anytime soon. If Mexico’s real GDP per capita could increase by 2% per year, it would take 108 years for Mexico’s real GDP per person to reach the current level of U.S. GDP per person. Indeed, at a 2% per year growth rate it would take 36 years for Mexico’s real GDP per person to reach $9,000. A 2% per year increase in real GDP per person reflects the U.S. growth rate over the past century. No one would question Mexico’s economic success if it were able to accomplish such a feat.

Income convergence between the United States and Mexico is not an impossibility, but current national policies in the two nations will not produce that result. The North American Free Trade Agreement (NAFTA) and Mexico’s adoption of an export-led growth model will not produce income convergence. U.S.-Mexican trade has increased dramatically since NAFTA was adopted, but that trade was already increasing in the five years before NAFTA was implemented. In any case, it is clear that exports must grow continuously at very high rates in order for export-led growth to substantially narrow the U.S.-Mexican income gap. The maquiladora industry, often described as Mexico's most dynamic economic sector, is far too small and pays wages that are generally far too low to close the income gap. Greater reliance on the private sector in Mexico and the United States may indeed produce gains in efficiency in some sectors in both nations, but will not result in U.S.-Mexican income convergence. Greater sophistication among central bankers and the possibility of monetary policy stability in the two nations also will not result in income convergence.

A number of policies could be effective in narrowing the U.S.-Mexican income gap. The United States, Mexico, and Canada could agree to complete labor mobility among the three nations as an extension of NAFTA. Such a labor mobility pact would go a long way toward eliminating wage and income differences among the three nations. Another possibility would be for the three nations to agree on a common North American minimum wage, set at the currently highest minimum wage, that of the United States. A North American minimum wage would not affect many workers in either the United States or Canada, but would boost the incomes of a large portion of Mexico's labor force. It would also increase (domestic) aggregate demand in Mexico considerably, offering expanded markets and many new business possibilities. Labor mobility and a common minimum wage could also be implemented gradually and together.

Another interesting policy possibility is the North American Common Market (NACM) proposed by Mexico's President Vicente Fox. A Free Trade Agreement (FTA) such as NAFTA is a weak form of economic integration, requiring only the elimination of trade barriers among participating nations. A common market, such as the proposed NACM or the European Union, is a much stronger form of economic integration. A common market requires the elimination of trade barriers, a common trade (tariff) policy toward non-members, and the removal of barriers to the cross-border movement of capital and labor among member nations. The proposed NACM could result in more rapid income convergence.

There are several reasons why the proposed NACM may be given serious consideration:

- Major political figures and parties in the United States and Mexico are openly receptive to the idea that markets promote economic efficiency.
- There is historical precedent. The United States may be viewed as a giant common market. The European Union provides another reasonably successful example.
- A common market consisting of the three NAFTA nations, by eliminating the remaining trade barriers, offers a much larger market size.
- NACM offers at least a partial solution to the immigration problem.
- Long-run demographic and economic trends imply the need for greater economic integration. For example, the United States faces a potential labor shortage in the coming decades due to the aging of the population, while job creation for a growing labor force is a major problem in Mexico.

NACM and other policy options offering the potential to reduce the U.S.-Mexican income gap may appear to be politically impossible, however, keep in mind that a decade ago NAFTA was not even being discussed. Perhaps NACM will never exist. The basic point is that without a major policy shift, large differences in per capita income will persist at the national level and in the U.S.-Mexican borderlands.

Without major policy changes, the most probable description of the border region in the year 2020 is a region in which per capita incomes on both sides of the border have grown substantially in real terms; per capita incomes on the Mexican side of the border will remain higher than in other parts of Mexico; per capita incomes on the U.S. side of the border will remain substantially lower than for the United States as a whole; and there will be no significant binational income convergence. As a result, border energy issues in 2020 will be confronted in an economic context that is not significantly different from what is seen today in the border region.

El Largo Plazo y el Sector Energético en la Región Fronteriza

James Peach

Resumen

El futuro de la energía y del medio ambiente de la región fronteriza entre México y los Estados Unidos será determinado en gran medida por las tendencias nacionales a largo plazo del crecimiento poblacional y el ingreso per cápita. El consumo per cápita de electricidad en los Estados Unidos es cerca de cinco veces más que el consumo estimado en México y estas cifras se distinguen claramente en los patrones de consumo de energía eléctrica y no eléctrica en la región fronteriza. El consumo per cápita de energía en México, incluyendo la región fronteriza, es menor a la de Estados Unidos simplemente porque el ingreso en México es menor al de Estados Unidos.

Todas las proyecciones de demanda de energía en la región fronteriza, citadas en investigaciones del Instituto Fronterizo, dependen en gran medida del tamaño de la población e ingreso per cápita. El crecimiento en la región fronteriza y el ingreso per cápita, dependen principalmente de las tendencias nacionales correspondientes a estas dos variables. El enfoque principal de este trabajo está en estas tendencias a largo plazo y como estas tendencias pueden ser influenciadas por las políticas nacionales, pero dos pequeñas disgresiones son necesarias.

Primero se debe de discutir los conceptos de las tres principales vías en que las economías nacionales afectan las economías regionales, como la región fronteriza. El flujo de *comercio interregional* es importante debido a que entre más pequeña sea la región, hay menos posibilidades de que pueda producir todos los bienes y servicios que su población consume. Dicha región debe importar estos bienes y servicios de otra parte además de exportar sus productos para poder pagar lo que se importó. La industria maquiladora es un buen ejemplo del significado del comercio interregional. *Movilidad de capital y mano de obra* son también factores determi-

nantes del bienestar económico de una región. Los trabajadores por lo general emigran de acuerdo con las condiciones económicas y el capital puede ser concentrado en regiones de poco capital. Para terminar, se muestra también diferencias regionales en el impacto de las *políticas nacionales*. Por ejemplo, la política de comercio y la política de inmigración se acentúan más en unas regiones que en otras.

La segunda disgresión es un breve recorrido por las condiciones macroeconómicas de México y Estados Unidos. Las condiciones económicas a corto plazo pueden tener efectos duraderos, en el ámbito nacional y en la región fronteriza. Un ejemplo clásico fue la creación del programa Bracero en 1942 en respuesta a la escasez de mano de obra en Estados Unidos. Pero además hay otra razón para examinar el corto plazo. Frecuentemente, tenemos una tendencia a pensar que las condiciones económicas actuales continuarán indefinidamente. Muchos observadores sienten que la expansión económica de los Estados Unidos, a finales de los años noventas era tan fuerte que se había entrado en una nueva era. También la expansión económica de México fue remarcable. Es muy posible que estas expansiones económicas ya hayan terminado. Debido a que las expansiones de México están altamente relacionadas con aquellas de los Estados Unidos, es importante que no se consideren las condiciones económicas actuales como una última posición de agudeza para la economía regional.

Una de las tareas principales de este trabajo es examinar las tendencias nacionales de largo plazo en cuanto a población se refiere y lo que estas tendencias puedan significar para la región fronteriza. La historia de la población de los Estados Unidos y México es un estudio de contraste y versatilidad. Durante el siglo 19, la población de Estados Unidos incrementó a un nivel más acelerado que el de México. Para 1900, la población en los Estados Unidos era de 75 millones de personas; esto significaba cinco veces la población de México, el cual era de 13.6 millones de gentes. Sin embargo, para 1930, la población de México había crecido a una tasa más grande que la de Estados Unidos. Desde la mitad de la década de los setentas, la población mexicana había caído a niveles dramáticos debido a acciones de políticas deliberadas. Una evaluación de las tendencias poblacionales en las dos naciones da como conclusión que: El crecimiento poblacional varia de década en década, las políticas nacionales sí cuentan, y el crecimiento poblacional de las dos naciones no son independientes.

Las principales áreas urbanas en las dos fronteras han crecido en una forma acelerada por muchas décadas, pero no hay necesidad de montar un escenario Malthusiano para la región fronteriza. El razonamiento Malthusiano de tasa de crecimiento exponencial (constante) no es garantizado por la historia poblacional ni de México ni de Estados Unidos, el Malthusianismo simplemente no tiene ningún sentido en el contexto regional. En vez, lo que debemos de esperar en la región fronteriza es una gran variación en las tasas de crecimiento poblacional.

La segunda variable crítica en el contexto del sector energético en la región fronteriza es el ingreso per cápita. El ingreso per cápita en la región fronteriza de Estados Unidos es bajo comparado al promedio de Estados Unidos y ha caído en los últimos años de acuerdo con las más recientes estadísticas nacionales. Por parte de la región fronteriza mexicana, el ingreso per cápita (medido como Producto Interno Bruto Estatal por persona) es considerablemente alto comparado con el promedio del ingreso en el país. Pero aún hay diferencias en el ingreso en los dos lados de la frontera que son sustanciales y se reflejan en gran medida en las estadísticas nacionales.

El producto interno bruto estadounidense por persona en el año 2000 fue de $36,000 mientras que en México fue de $4,500, por lo que no hay una real convergencia en el ingreso entre las dos naciones en las próximas décadas. El PIB real per cápita (ajustado a la inflación) en el 2000 excedió su máxima cantidad registrada en 1981. La simple aritmética de tasa de crecimiento anual compuesta, efectivamente prohibe la convergencia del ingreso en un tiempo muy corto. Si el PIB per cápita en México pudiera incrementarse a 2% por año, se tomaría 108 años para igualar el PIB real por persona de Estados Unidos del 2000. De hecho tomaría 36 años para alcanzar los $9,000 tomando en cuenta un crecimiento de 2% en el PIB real per cápita en México. Un incremento del dos por ciento por año en el PIB real por persona, refleja el crecimiento de Estados Unidos en el siglo pasado. Nadie podría cuestionar el éxito económico de México si se llegara a estas cifras.

La convergencia del ingreso entre los Estados Unidos y México no es un imposible, pero debido a las políticas nacionales actuales en las dos naciones, no se permitirá realizar tal resultado. El Tratado de Libre Comercio (TLC) y la adopción de un modelo de crecimiento guiado a la exportación, no producirá la convergencia del que el TLC se implementara. En todo caso, es claro que las exportaciones deben de crecer para cerrar el vacío del ingreso entre las dos naciones. La industria maquiladora, por lo general descrita como el sector económico más dinámico, es demasiada pequeña y paga salarios demasiado bajos para que se pueda cerrar el vacío del ingreso entre las dos naciones. Una mayor confianza en el sector privado en México y Estados Unidos podría tener una mayor eficiencia en algunos sectores en ambas naciones, pero no resultaría en la convergencia del ingreso de México-Estados Unidos. Una mayor sofisticación de los bancos centrales y la estabilización de la política monetaria tampoco resultaría en la ya mencionada convergencia del ingreso.

Hay un gran número de políticas que podrían cerrar el espacio del ingreso, con gran efectividad, entre México y Estados Unidos. Los Estados Unidos, Canadá y México podrían acordar una “movilidad de la mano de obra” entre los tres países como una extensión del Tratado de Libre Comercio. Tal pacto de movilidad en la mano de obra, llevaría a la eliminación de las diferencias en cuanto a ingresos y salarios entre las tres naciones. Otra posibilidad sería el acuerdo de un salario mínimo estándar para las tres naciones—puesto al máximo salario mínimo entre las tres naciones. Un salario mínimo estándar entre las tres naciones no afectaría a la mayoría de los trabajadores en los Estados Unidos o Canadá, pero sí se incrementarían los ingresos de la mayor parte de la fuerza laboral mexicana. Esto también incrementaría la demanda agregada (doméstica) en México considerablemente, ofreciendo mercados en expansión y la posibilidad de nuevas fuentes de negocios. La movilidad de mano de obra y el acuerdo del salario mínimo se podrían implementar juntas y gradualmente también.

Otra de las posibles políticas interesantes es la del Mercado Común de Norteamérica (NACM, por sus siglas en inglés) propuesta por el presidente de México Vicente Fox. Un acuerdo comercial, como el TLC, es una forma débil de integración económica, que requiere de la eliminación de barreras comerciales entre las naciones participantes. Un mercado común como el ya propuesto NACM o como el de la Unión Europea sería una integración económica mucho más fuerte. Un mercado común requiere de la eliminación de barreras comerciales, una política de mercado común (a través de tarifas) hacia las naciones que no sean miembros del mercado común y la remoción de barreras que pudieran limitar la movilidad del capital y mano de obra entre las naciones participantes (en este caso México, Estados Unidos y Canadá). El ya mencionado NACM pudiera resultar en una vía más rápida de convergencia del ingreso.

Hay una serie de razones por las cuales el NACM podría ser tomado en cuenta seriamente.

- Los personajes y partidos políticos en los Estados Unidos y México están convencidos abiertamente de la idea de que los mercados promueven una mejor eficiencia económica.
- Hay un precedente histórico. Los Estados Unidos puede ser visto como un mercado común y el Mercado Común Europeo es un ejemplo de lo que aquí se dice.
- Un mercado común consistente en los participantes del TLC, pero con la eliminación de las barreras comerciales existentes, ofrece un mercado más grande y efectivo.
- El NACM ofrece una solución viable, pero parcial al problema de la inmigración.
- Las tendencias demográficas y económicas a largo plazo demuestran que debe haber una integración económica más fuerte. Por ejemplo, los Estados Unidos enfrentará una escasez de mano de obra en las próximas décadas debido al desaceleración en el crecimiento de la población mientras que la creación de empleos para una gran fuerza laboral es un problema importante en México.

NACM y otras políticas que ofrecen reducir el espacio de ingreso entre México y Estados Unidos pueden parecer potencialmente imposibles, pero recordemos que en la pasada década el TLC ni se discutía. Posiblemente el NACM nunca exista. El punto básico es que sin un cambio significativo en las políticas, la diferencia del ingreso per cápita persistirá en el ámbito nacional y entre los dos países.

Sin un cambio mayor en las políticas, la descripción más obvia en la región fronteriza en el año 2020 es una región en que: (a) El ingreso per cápita en ambos lados de la frontera crecerá en términos reales, (b) El ingreso per cápita en la región fronteriza por parte de México será mayor a la del interior del país, (c) El ingreso per cápita en la región fronteriza de Estados Unidos se mantendrá por abajo del promedio del resto del país, (d) No habrá una convergencia significativa binacional. Como resultado, los temas de la energía en la región fronteriza en el 2020 serán confrontados en el contexto económico de una región fronteriza que no es significativamente diferente a la actual.

Introduction

The participants at Border Institute I produced a "shared vision for the border environment in the year 2020" (Ganster 1999). This vision called for "a healthy sustainable natural environment ... as a basis for a secure and adequate quality of life for all border inhabitants." Whether or not such a vision can or will be achieved requires us to look far beyond the narrow geographic confines of the border region. The environmental future of the U.S.-Mexican border region, including the energy issues that were the focus of Border Institute III, will be determined mainly by long-term economic and demographic trends in Mexico and the United States. These binational trends are not independent of each other. Economic and demographic conditions in one nation directly affect conditions in the other nation.

California's recent electricity crisis is a stark reminder that energy issues can be region-specific. But regional energy issues occur within a national and international context. There is, for example, no meaningful sense in which border region energy supply and demand determine national or international prices for oil, natural gas, or other energy sources. Indeed, regional energy prices and supplies depend mainly upon national and international trends and events. Long-term planning for the energy needs of the border region is important, but successful regional planning must take into account a larger national and binational context.

Per capita consumption of electricity in the United States (11,763 kilowatt-hours [kWh] per capita in 1999) is five times as high as the corresponding figure in Mexico (1,757kWh per capita) and these national figures are reflected in border region electricity and non-electric energy consumption patterns (U.S. Department of Energy [DOE] Energy Information Agency [EIA] 2001). Elegant models are not needed to explain the binational differences in energy consumption. Energy consumption per capita in Mexico, including the border region, is lower than in the United States because per capita income in Mexico is lower than in the United States. All projections of border region energy demand, cited in the following chapters, depend critically on population size and economic conditions such as per capita income and industry mix. The possibility of U.S.-Mexican income convergence and the growth of total population are the critical border region energy issues. Both population growth and income trends are powerfully influenced by national policies that are often only remotely related to the energy sector.

This chapter examines long-run economic and demographic trends and their potential effects on future energy conditions in the U.S.-Mexican border region.

National and Regional Interaction

Within a single nation-state, economists recognize three main ways in which regional economies are affected by the national economy and other regions:

- Interregional trade flows
- Labor and capital mobility
- The differential regional impacts of national policies

In a binational border region, these patterns of national-regional interaction become more complex. In large regions, the possibility of regional-to-national influences should also be considered.

Interregional trade flows are particularly important determinants of regional economic conditions. The smaller the region, the less likely it is to produce all the goods and services its population consumes. Thus, smaller regions are said to have a higher propensity to import than larger regions. In turn, it is often argued that regional exports to the rest of the nation or to international markets are essential to pay for imports and provide regional employment and income. The national and international demand for regionally produced goods and services is thus critical to regional economic well-being. Consider, for example, the maquiladora industry that now employs more than 1 million people in 3,500 plants located mainly along the Mexican side of the border. This industry depends almost entirely on national market conditions in the United States and would probably not exist except for the U.S. market. In addition, the border region serves as a transportation conduit through which much of the international trade between the United States and Mexico flows.

Capital and labor mobility within a nation-state suggest a different set of national-regional links. In highly simplified form, economic theory suggests that workers will migrate from areas of high unemployment and low income to areas of low unemployment and high income. Out-migrants decrease the supply of labor in high unemployment regions and increase the supply of labor in the low-unemployment destination region. Theoretically, such migration will continue until regional differences in unemployment and real income are eliminated.

In a similar fashion, investors seeking the highest possible rate of return would be expected to invest in low-wage regions in which the marginal return to capital is presumably higher. In short, standard theory implies that the mobility of capital and labor will tend to result in a regional-national equilibrium in which regional differentials disappear. Again, the border region appears more complex. Many counties on the U.S. side of the border have experienced high rates of in-migration simultaneously with high unemployment rates and low per capita incomes for decades. On the Mexican side of the border, high rates of in-migration have been associated with relatively low unemployment rates and higher incomes as is suggested by standard regional theory.

Regional variations in the impact of national economic policies constitute the third major form of national-regional interaction. Some national policies that have particular significance in the borderlands are rather obvious. Trade policies established nationally, binationally, or multi-laterally (NAFTA, for example), exchange rate regimes, and immigration law are felt keenly in the borderlands. The geographic distribution of federal expenditures is far from uniform in either Mexico or the United States.

Other national policies that have regional impacts are less obvious. A change in monetary policy that increases interest rates may increase regional income inequality because those receiving substantial interest income are unlikely to be concentrated in low-income regions like the borderlands. In contrast, an increase in the legally mandated minimum wage may affect a greater portion of employees in a low-income region than in high-income regions. A reduction in federal expenditures on public welfare will likewise have differing regional effects. Similarly, increases or decreases in Social Security retirement benefits may have disproportionate regional impacts depending on region-specific age and sex distributions, labor force participation rates, and industry mix.

While it is difficult to imagine a regionally neutral national policy action in either Mexico or the United States, the important thing is to try to identify national policy trends that will have a particularly strong impact in the border region. Two other features of the national policy context should be mentioned. First, the United States has very little that can be properly called regional policy, and Mexico's regional policies, while more explicit than those of the United States, can hardly be deemed a success story. Second, as borderlanders in both nations have known for decades, the national policies that set the context for border region growth are not determined in the borderlands.

A Digression on the Short Run

The short run is also important. Keynes (1971) reminded us: "In the long run, we are all dead." Sometimes, short-run economic conditions can have lasting effects. A classic example with direct relevance to the border region was the tight labor market in the United States in 1942 that led to the creation of the Bracero Program, which allowed Mexican laborers to enter the United States to work in agricultural fields and lasted for more than two decades. It is not an exaggeration to suggest that the abolishment of the Bracero Program in 1964 by then U.S. President Lyndon Johnson, in combination with seldom used provisions of the U.S. tariff laws, led directly to the creation of the maquiladora industry. A more recent example of the long-term consequences of short-term economic conditions was the passage of the hotly debated NAFTA in 1993. NAFTA was passed the U.S. House of Representatives by a very narrow vote. If the U.S. economy had been in a serious downturn in 1993, it is not likely NAFTA would have been approved.

There is a tendency to think current economic conditions will continue indefinitely. However, economic conditions do change. During the 1970s and 1980s in the United States, there was a common presumption that the U.S. economy had somehow fallen behind other nations and the country could no longer be "competitive" in international markets. Japan was the example of an economic success story. Japan's economy during the 1970s and 1980s was often described as invincible because that nation had found the keys to successful economic management and was also rapidly becoming one of the world's most technologically advanced nations. By 1990 the Japanese bubble had burst and for the remainder of that decade it was the U.S. economy that was the envy of the world. While examining the borderlands, it should not be assumed U.S. economic dominance and invincibility will continue forever.

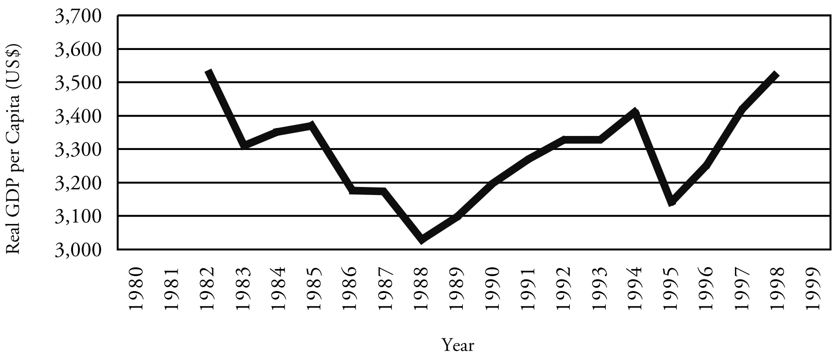
The remarkable U.S. economic expansion during the 1990s, particularly 1995 to 2000, needs little comment. Never before in U.S. history has there been such a long expansion. The U.S. unemployment rate fell to 3.9% in August 2000 from 7.8% at the beginning of the expansion in June 1991. U.S. Gross Domestic Product (GDP) grew at very high rates and by 2000, it had reached $10 trillion. The expansion was also associated with such high rates of growth of investment in new technology and productivity per worker that many otherwise-sane and seemingly rational people began to speak of something called "the new economy." In the new economy, the business cycle had been conquered and with careful economic management (monetary policy) rapid economic growth could presumably go on indefinitely (McTeer 2000).

What a difference a few months can make. According to the National Bureau of Economic Research, the private nonprofit agency charged with establishing business cycle reference dates, there were 20 complete business cycles during the 20th century in the United States. In Mexico, there is no agency charged with the task of establishing dates for business cycles, but GDP data for

Mexico suggests a comparable number of cycles there. There is no reason to expect that the business cycle has been eliminated as a permanent feature of the U.S. or Mexican economic landscape.

The last few years have been remarkable economic years in Mexico as well. By 2000 Mexico was in the sixth year of an economic expansion that began during the summer or fall of 1995. Until the current expansion, Mexico had not seen six consecutive years of economic growth since the energy-led boom from 1976 to 1981. Depending on how it is calculated, in late 1999 or early 2000 Mexico's real GDP per capita exceeded the previous peak that occurred in 1981 (Figure 1). This achievement may signal the end of two decades of economic instability and stagnation in real income per person. The current expansion in Mexico is remarkable, too, because inflation as measured by the consumer price index (CPI) has decreased each year since 1995. Six years of GDP growth without rapid increases in the CPI has not occurred in Mexico since the 1960s. Finally, the current expansion in Mexico is remarkable because the cycle of presidential election year economic crises has apparently been broken for the first time in 25 years. Mexico experienced economic crises in 1976, 1982, 1988, and 1994-95. Each of these was a presidential election year.

Figure 1. Mexico's Real GDP Per Capita (1990, in US$)



Source: Interamerican Development Bank

Mexico's current expansion is, however, closely tied to U.S. expansion. When U.S. expansion ends, so too will Mexico's. Mexico now exports approximately one-third of its GDP and more than 85% of its exports go to the United States. Traditionally, U.S. imports increase during expansions and decrease during contractions. There is no way of avoiding economic difficulties in Mexico if U.S. demand for Mexican goods and services declines.

Whatever the short-term economic future, the environmental issues of the U.S.-Mexican border region will not receive high priority without prosperous national economies. The policy decisions made under what may be adverse economic conditions may have a considerable impact on the possibility of achieving the vision of Border Institute I.

Long-Term Demographic Trends in Mexico and the United States

The population of the United States is currently more than two-and-a-half times larger than the population of Mexico and the demographic characteristics of the two nations are very different. But that has not always been the case. In 1790, just after U.S. independence from Britain but a generation before Mexico's independence from Spain, population censuses were conducted in both nations. Despite the possibility of large errors in both censuses, some broad comparisons are worthwhile. The 1790 population of Mexico (then New Spain) of 4.68 million people (Instituto Nacional de Estadística, Geografía e Informática [INEGI] 1990) was about 20% larger than the census-reported figure of 3.92 million people for the United States (U.S. Bureau of the Census 1998).

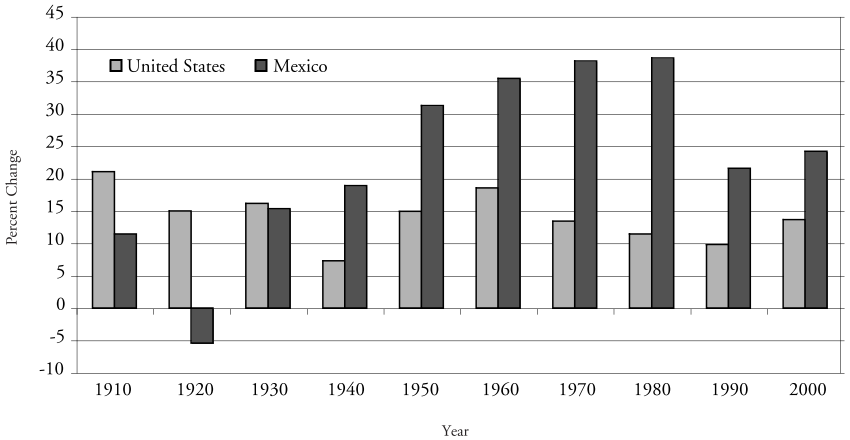
During the 19th century, Mexico's population increased three-fold to roughly 14 million in 1900. Meanwhile the U.S. population increased by 15 times to about 75 million in 1900. Some perspective on these numbers is needed. Mexico's 19th century population growth occurred at approximately the same rate as U.S. population growth during the 20th century. In sharp contrast, if the U.S. population had grown at the same rate in the 20th century as it did in the 19th, the United States would now have a population of 1.07 billion, greater than India's 1.01 billion and slightly smaller than China's

1.26 billion populations.

Although the data are sketchy, 19th century birth and death rates in Mexico and the United States were about the same. In both nations, family size was large by modern standards and death rates were high. Life expectancy at birth in 1800 did not exceed 30 years in either nation. What happened? The major difference in population trends in the two nations during the 19th century was that the United States experienced a great deal of immigration, mainly but not exclusively, from Europe. It is true that Mexico lost a good deal of its territory to the United States during the 19th century, but this was not the main cause of the vastly different population growth rates. The territory lost to the United States after Texas independence and the Mexican-American War was not densely populated even by the standards of the time.

In 1900, the U.S. population of 75 million was nearly six times as large as Mexico's 13.6 million. As shown in Figure 2, 20th century population growth rates by decade varied considerably in the United States and Mexico. In Mexico, the 1921 census recorded 825,000 fewer people than the 1910 census. This decrease of 5.4% of Mexico's total population in a single decade was not entirely the result of battle-related deaths during the Mexican revolution (1911-1920). The migration of Mexicans to the United States during the revolution was certainly a large number. There were also fewer births during the revolution than in the previous decade and large numbers of deaths can be attributed to a severe influenza epidemic in 1918 and 1919. The usual estimates of about 2 million deaths during the revolution far understate the deaths from natural causes that could be expected from a population with a life expectancy of only 30 years.

Figure 2. Decade-to-Decade Percent Change in Population in the United States and Mexico



Arguably the most important demographic impact of the Mexican revolution was the official endorsement and adoption of a pro-natalist population policy, not increased mortality (Loyo 1931 and 1935, Cardoso 1978, Alba 1986, González Navarro 1974). There were two goals of the new policy: first, to increase Mexico's total population, and second, to increase the population of Mexico's northern border states. The logic underlying the program was simple (Alba 1986). An under-populated Mexico presented an attractive target for the aggressive tendencies of the United States; conversely, a more densely populated Mexico with a larger GDP would be a less-attractive target. A secondary consideration was that rapid population growth might produce higher rates of economic growth. Further, higher rates of population growth might induce greater government concern with providing adequate social services and infrastructure.

Mexico's post-revolutionary population policy was a far greater success than could have been anticipated. As shown in Figure 2, population growth rates were higher in Mexico than in the United States from the 1930s to the 1990s. In the early 1970s Mexico reversed its population policy and introduced a serious family planning effort to reduce population growth rates. Again, this policy (along with increasing income and declining infant mortality) was effective, and Mexican population growth rates declined to about

2.1% in the 1990s from more than 3% per year in the 1960s. The decline in Mexico's population growth rates was in sharp contrast to most contemporary (1970s and 1980s) projections (Looney 1978, United Nations 1954) that implied Mexico's population would reach 135 million people by the year 2000. Mexico conducted a mid-decade census in 1995 and recorded a population of 92 million, a figure well below projected trends for the year 2000. Preliminary results from Mexico's 2000 census indicate a total population of 97.2 million, a figure likely to be adjusted upward by 2% or 3% when final figures are available. Remarkably, the 100 million figure for the year 2000 is exactly the planning target Consejo Nacional de Población (CONAPO) and other government agencies established years ago.

The massive wave of European migration to the United States peaked during the 1920s, but by 1930 the U.S. population of 123 million was nearly eight times Mexico's population of 16 million. During the 1930s, the population of the United States increased by 7.2% to 132 million (from 123 million), the lowest decade-to-decade percentage increase during the century. In the late 1930s and early 1940s, U.S. economists and demographers alike predicted the U.S. population would stabilize by 1950 at about 140 million. The post World War II baby boom, perhaps the demographic surprise of the century, significantly altered U.S. population growth rates and fertility patterns. The U.S. population grew by 18.5% during the 1950s and 14.5% during the 1960s, but growth rates fell to 11.4% during the 1970s and fell again to 9.8% during the 1980s.

The first results of the latest U.S. census have been released. The U.S. population of 281 million reported by the U.S. Bureau of the Census was 6 million higher than the bureau's estimates for 2000. The U.S. population growth rate, which most observers had expected to remain constant, increased to 13.6% during the 1990s from 9.8% in the 1980s. Apparently the higher growth rate is due to higher than anticipated migration, much of it from Mexico.

Population projections (United Nations 1998) for the United States and Mexico to the year 2050 are presented in Table 1. The projections for both nations exhibit considerable variation. By 2050 the difference in the high and low projections for the United States is 127 million, while for Mexico the corresponding figure is 104 million. The U.N. high projection for Mexico of 223.5 million in 2050 is nearly 75% of the U.S. low projection of 292.8 million. All three population projections depend critically on migration flows, mainly from Mexico to the United States. For the United States, population flows from Mexico could provide a solution to a slow-growing and rapidly aging U.S. labor force, the so-called "social security problem," and any number of other economic ills. For Mexico, significant out-migration provides one solution for absorbing more than a million new entrants into the labor market each year. Because migration is so important, the actual population of the two nations in the year 2050 will be influenced by national economic conditions and immigration policies.

Table 1. U.N. Population Projections for the United States and Mexico (in millions)

	2000	2020	2030	2040	2050
United States					
High	280	335.6	364	391	419
Medium	280	317.1	333	343	349
Low	280	301.5	306	302	292
Mexico					
High*	98.8	142.4	167	194	223
Medium	98.8	125.0	135	142	146
Low	98.8	117.9	122	123	119

*Constant Variant

Source: United Nations

These national trends will directly affect border region population growth rates. For more than 50 years, population growth in the border region's urban areas has been high by national standards. Projections of border region population to the year 2020 (Peach and Williams 2000) reflect these historically high growth rates and exhibit considerable variation. These projections imply a combined population of the 25 U.S. border counties and 38 border *municipios* ranging from 15 million to 24.4 million by the year 2020.

Such population projections, together with assumptions about per capita income, are building blocks for border region energy projections. The increase in border region energy demand from these projections is genuinely large. But projections of future national or border region populations should not lead to a Malthusian gloom-and-doom scenario regarding border energy or other environmental issues.

Malthus became famous for his simplistic dictum that population would always grow faster than the food supply and that, as a result, the future would inevitably be clouded by starvation and other resource shortages. It is probably true there would be very little interest in border region environmental or energy issues if the border population were decreasing or even stable. However, there are many reasons to reject the Malthusian perspective. First, there is no justification, in the border region or elsewhere, to adopt the Malthusian assumption of exponential population growth rates. At the national and regional levels, there is a great deal of evidence to suggest population growth rates have been highly variable historically and are likely to be highly variable in the future. Rational energy sector planning in the border region should make the uncertainty of future population growth rates a fundamental axiom.

Second, the Malthusian perspective is not meaningful at the regional level. Other things remaining equal, a growing regional population does imply a greater demand for energy consumption. But, a growing regional population does not imply inevitable regional energy shortages. In economic terms, the concept of a shortage has meaning only in relation to a given price. Border region energy markets are not independent of national and international energy markets. The borderlands could experience region-specific energy problems such as those already occurring in California, but these will not occur primarily because of population growth.

Third, the Malthusian population perspective is unwarranted because national population growth rates are affected by national policies. In the 20th century, Mexico's national population policies were associated with rapid population growth from the 1930s to the mid-1970s and an equally dramatic decrease in population growth rates since the mid-1970s. While the United States has no explicit population policy, it does have immigration laws and various other policies (such as income tax deductions for dependents) that influence population growth.

Finally, the basic Malthusian proposition should not be applied to border region energy issues because it fails to account for other significant variables such as technological change, levels of per capita income, the regional structure of industry, and regional patterns of non-energy consumption.

Long-Term Economic Growth in Mexico and the United States

As suggested earlier, per capita income is a primary determinant of per capita energy consumption in the border region. Policy options for addressing border region energy and environmental issues are also constrained by relative income levels on the two sides of the border. On the Mexican side of the border, per capita income as measured by per capita GDP is higher in each of the six border states than the average for Mexico as a whole (Figure 3). Among U.S. border counties, per capita income is generally low compared to the United States as a whole (Figure 4). Nevertheless, large cross-border differences in border region per capita incomes largely reflect national averages. The best place to find indicators of future border region income patterns is to examine long-term economic growth trends at the national level.

Figure 3. Income Per Capita (1999 US$)

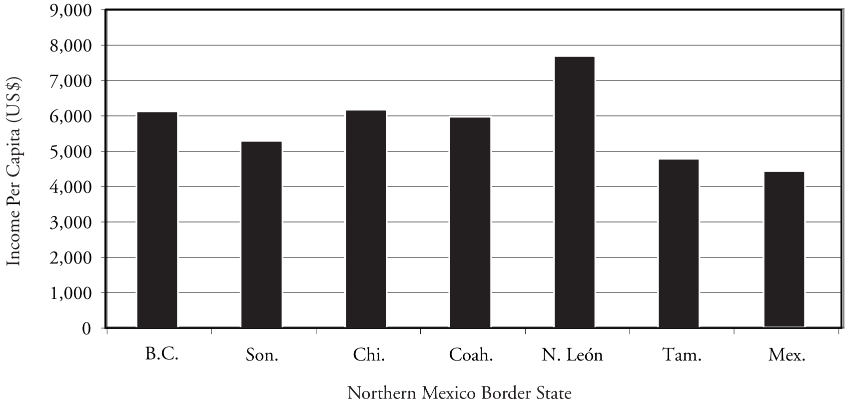
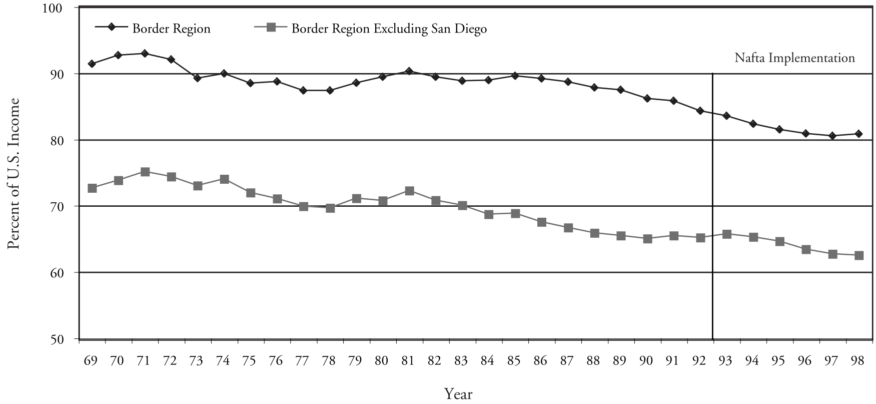


Figure 4. Border Region Per Capita Income as Percent of U.S. Income



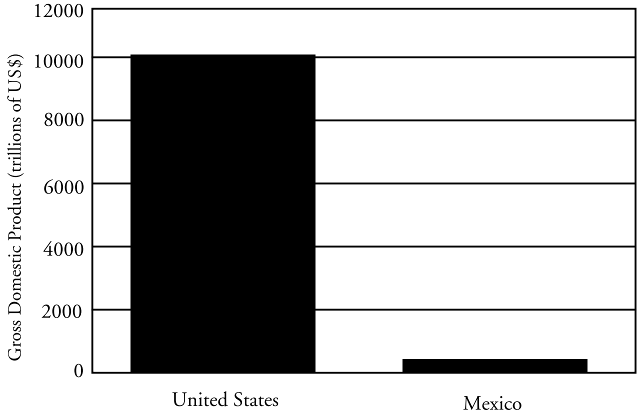
During the 20th century, U.S. real (inflation adjusted) GDP per capita has increased by approximately 2.1% year (Economic Report of the President 2001). Over the course of a century this 2.1% per year growth rate meant that U.S. residents on average enjoyed an eight-fold increase in their standard of living. Only the Great Depression of the 1930s seriously interrupted the long-term growth of real GDP per person.

The Mexican economy also experienced periods of very rapid economic growth during the twentieth century. The four decades beginning in the early 1940s were justifiably known as the “Mexican Economic Miracle.” Yet, economic growth rates in Mexico, particularly over the last two decades, have also been highly variable. The result has been a widening income gap between Mexico and the U.S. GDP per person; in Mexico in 2000 it was $4,500, or roughly one-eighth of the comparable U.S. figure. A century earlier Mexico’s GDP per capita was approximately one-fourth of the comparable U.S. figure ($1,028 measured in 2000 dollars). The 1900 GDP per capita figures for both the United States and Mexico are very rough approximations. Neither nation had a system of national accounts in 1900. The U.S. estimate is consistent with figures cited in the 2001 Economic Report of the President. The 1900 figure for Mexico has been estimated from the GDP per capita figure of 2,529 (1970) pesos given in *Estadísticas Históricas de México* (INEGI 1991). This figure is approximately the same as that found in Coatsworth (1981).

The relative sizes of the two economies help to shape economic and political relations between the two nations and affect the border economy in a variety of ways. First, the United States is a large market for Mexican exports. In 1999 the United States was the destination for 86% of Mexican exports. Fluctuations in the U.S. economy are transmitted rather quickly into changes in demand for Mexican products. Since many of these products enter the United States through ports of entry located in the borderlands, border region economic activity is also affected. In addition, labor market conditions in the U.S. portion of the border region are extremely sensitive to national economic conditions.

The U.S. GDP in the fourth quarter of 2000 was $10.1 trillion compared to Mexico's GDP of $450 billion (Figure 5). Even with the slowdown in growth during the fourth quarter of 1999, the U.S. GDP increased by $663.5 billion from 1999 to 2000. Stated differently, the increase in U.S. GDP was approximately 50% greater than Mexico's entire GDP of $450 billion. This is not unusual. In 15 of the last 20 years U.S. GDP growth has been greater than Mexico's entire GDP. In 1999 there were three U.S. states—California, New York, and Texas—with a larger GDP than Mexico's GDP (U.S. Department of Commerce 2000). California's GDP is more than double Mexico's total output.

Figure 5. Gross Domestic Product in the United States and Mexico (2000)



Closing the U.S.-Mexican income gap in per capita terms is a monumental task but one that is critical in the context of border environmental and energy issues. Yet, the simple arithmetic of compound annual growth rates effectively prohibits income convergence between the two nations during the next century. Using 2000 as a base year, U.S. GDP per capita was $36,000 while Mexico's GDP per capita was $4,500. Assuming no growth in U.S. GDP per capita and a 2% compound annual growth rate for Mexico's GDP per capita, it would take 108 years for Mexico to reach the current level of U.S. GDP per capita. Under these assumptions it would take 36 years for Mexico's GDP per capita to reach just $9,000 per year. Obviously if U.S. GDP per capita were growing at the same time, it would take much longer for Mexico's GDP per capita to "catch-up" to U.S. levels.

The selection of a 2% growth rate for Mexico in this exercise is not entirely arbitrary. While the 2% per year growth rate in per capita GDP is lower than the Fox Administration's goal of 5% per year, it is a more plausible figure for long-term economic growth. The 2% figure corresponds very closely to the twentieth century performance of the U.S. economy. If Mexico were able to achieve such a per capita growth rate for an entire century, no one would argue about the success of its economic policies.

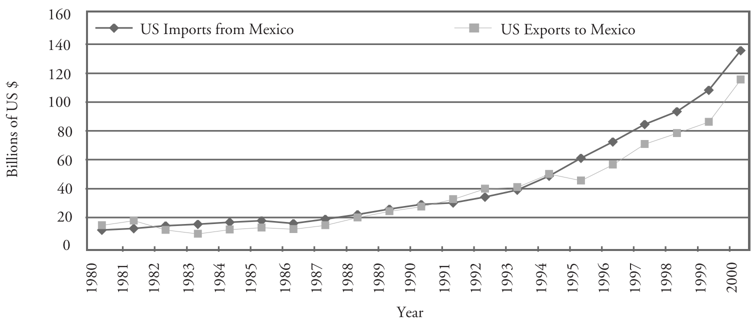
There is another reason to suspect Mexico's per capita income will not reach U.S. levels anytime soon. Starting in the mid-1980s, Mexico abandoned its traditional Import Substitution Industrialization (ISI) policy in favor of an export-led growth policy. Mexico joined General Agreement on Tariffs and Trade (GATT) in 1986 and has signed numerous trade agreements (such as NAFTA in December 1993) on a bilateral and multilateral basis since then. Adopting export-led growth may have been the right decision for Mexico at the time. Many would argue that the old ISI approach was failing and that Mexico had no choice.

Export-led growth is the currently fashionable formula for achieving long-run economic growth. Free trade, it is argued, increases the efficiency of domestic industries and reduces domestic inflationary pressures because local firms must compete with international sources of supply. Export-led growth also means domestic industries must adopt more modern technology, resulting in increased productivity per worker.

Export-led growth is not, however, without its dangers. For exports to lead the growth process, they must grow every year at a very high rate. Suppose the desired rate of GDP growth in Mexico is 4% per year. A 2% per year increase in population would produce a growth rate of 2% per year per capita GDP. Assume also that exports constitute one-third of GDP, as is currently the case in Mexico. If the non-export sector were not growing, this situation would require exports to grow at the rate of 12% per year every year. For any long time period this is a most unlikely scenario. Could a U.S. economy growing 3% per year sustain increases in imports of 10% to 12% per year from Mexico?

Second, export-led growth means dependence on foreign markets. For Mexico this means dependence on the U.S. market. A downturn in foreign economies that translates into a decrease in the demand for Mexican products means exports cannot "lead" the domestic economy. Dependence on export-led growth also leaves the domestic economy vulnerable to changes in the exchange rate and to changes in the structure of international demand. Further, dependence on international markets may imply a loss of domestic macroeconomic policy independence. In the long run, as many Mexican policymakers realize, export-led growth is merely a stopgap measure. Long-run economic growth in Mexico must depend on significant increases in domestic demand. Nevertheless, the growth of U.S.-Mexican trade and Mexican trade with other nations is impressive. Mexican exports to the United States doubled in the five years preceding NAFTA's implementation and doubled again in the first five years after NAFTA (Figure 6).

Figure 6. U.S. Imports from and Exports to Mexico



Policy Speculation and Conclusions

Income convergence between the United States and Mexico is not impossible, but current national policies in the two nations will not produce that result. Income convergence is not a zero-sum game in which the gains of one nation must be accompanied by losses in the other nation. What is needed most is a permanent increase in the rate of growth of Mexico's per capita GDP, a goal heartily endorsed on both sides of the border.

NAFTA and Mexico's adoption of an export-led growth model will not produce income convergence. U.S.-Mexican trade has increased dramatically since NAFTA was adopted, but that trade was already increasing in the five years before NAFTA was implemented. In any case, it is clear exports must grow continuously at very high rates for export-led growth to narrow the U.S.-Mexican income gap substantially. The maquiladora industry, often described as Mexico's most dynamic economic sector, is far too small and pays wages that are generally far too low to close the income gap. Greater reliance on the private sector in Mexico and the United States may produce gains in efficiency in some sectors in both nations, but will not result in U.S.-Mexican income convergence. Greater sophistication among central bankers and the possibility of monetary policy stability in the two nations will not result in income convergence.

There are a number of policies that could be effective in narrowing the U.S.-Mexican income gap. The United States, Mexico, and Canada could agree to complete labor mobility among the three nations as an extension of NAFTA. Such a labor mobility pact would go a long way toward eliminating wage and income differences among the three nations. Another possibility could be for the three nations to agree on a common North American minimum wage set at the highest minimum wage, that of the United States. A North American minimum wage would not affect many workers in either the United States or Canada, but would boost the incomes of a large portion of Mexico's labor force. It would also increase (domestic) aggregate demand in Mexico considerably, offering expanded markets and many new business possibilities. Labor mobility and a common minimum wage could also be implemented gradually.

Another interesting policy possibility is the North American

Common Market (NACM) proposed by Mexico's President Fox. A free trade agreement such as NAFTA is a weak form of economic integration, requiring only the elimination of trade barriers among participating nations. A common market, such as the proposed NACM or the European Union, is a much stronger form of economic integration. A common market requires the elimination of trade barriers, a common trade (tariff) policy toward non-members, and the removal of barriers to the cross-border movement of capital and labor among member nations. The proposed NACM could result in more rapid income convergence.

There are a number of reasons why the proposed NACM may be given serious consideration. First, major political figures and parties in the United States and Mexico are openly receptive to the idea that markets promote economic efficiency. Second, there is historical precedent. The United States may be viewed as a giant common market. The European Union provides another reasonably successful example. Third, a common market consisting of the three NAFTA nations offers a much larger market size. Fourth, NACM offers at least a partial solution to the immigration problem. Fifth, long-run demographic and economic trends imply the need for greater economic integration. For example, the United States faces a potential labor shortage in coming decades due to its aging population, while job creation for a growing labor force is a major problem in Mexico.

NACM and other policy options offering the potential to reduce the U.S.-Mexican income gap may appear to be politically impossible. However, a decade ago NAFTA was not even being discussed. Perhaps NACM will never exist. But without a major policy shift, large differences in per capita income will persist at the national level and in the U.S.-Mexican borderlands.

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II

Energy Issues in the U.S.-Mexican Binational Region: Focus on California-Baja California

Alan Sweedler, Margarito Quintero Núñez, and Kimberly Collins

Abstract

Energy is the indispensable lifeblood of the U.S.-Mexican binational region. It makes homes and businesses comfortable, moves people and goods, operates the machinery of industry, and powers the infrastructure that underpins the region's communities. This pervasive role makes energy a key issue in the binational region's future. Energy choices made today will have significant effects on tomorrow's economy, environment, and quality of life. Without secure, reliable, and reasonably priced sources of energy, the border region cannot develop to its full potential.

The energy sectors in the United States, Mexico, and Canada are undergoing major changes that will affect the way energy is produced, transmitted, distributed, and sold throughout North America. These changes will directly influence energy use and energy-related infrastructure in the U.S.-Mexican binational region.

Some of the important energy issues confronting the binational region are:

- Meeting the demand for electricity services in northern Mexico and the southwestern United States, which are expected to grow

significantly over the next 10 years

- Meeting the rapidly increasing need for natural gas in the border region
- Understanding the complex array of different regulatory structures in the United States and those evolving in Mexico
- Developing cross-border infrastructure associated with natural gas and power transfers
- Creating the necessary administrative and regulatory mechanisms to plan and coordinate issues related to the energy sector in the binational region
- Developing environmentally sensitive and sustainable sources of energy for the region

This chapter discusses these issues and makes recommendations for improving cross-border collaboration to meet the future energy needs of the region. It will first focus on national energy issues in the United States and Mexico, then move on to border-wide topics, and finally focus on the California-Baja California section of the border, where 42% of the border population is currently located. While many of the problems and opportunities facing the energy sector of California-Baja California region are similar to other portions of the border, there are unique characteristics as well.

Increasing population and economic growth are the driving forces leading to increased demand for energy services in the border region during the next 20 years. The current population of the cross-border region is 13 million people. By the year 2020 it is expected to reach nearly 24 million. In the California-Baja California region alone, the population is expected to reach 9.2 million by 2020. In fact, the number of people added to this region in the next 19 years will be equal to the total population that existed in 1990 and 80% of the 2000 population.

In addition to population growth, the expanding economy—especially the growing number of maquiladoras—and the expected increase in the numbers of cars and trucks associated with increased U.S.-Mexican trade are also important factors influencing the energy needs of the binational region. Maquiladoras are major users of electricity and water, while the transportation sector depends on liquid fuels, most often in the form of gasoline and diesel fuel. Since natural gas is likely to be the fuel of choice for new power generation in the region, significant shortfalls of this versatile fuel can be expected unless measures are taken in the near future to meet projected demand.

The treatment of the energy sector in the North American Free Trade Agreement (NAFTA) is perhaps most significant for what it lacks. Nevertheless, NAFTA does provide new opportunities for private energy companies, particularly those in the electricity industry. NAFTA aims for more open markets in the energy sector, but it remains unclear whether those markets will provide sufficient returns to support increased investment. Still to be addressed are the:

- Rates the Comisión Federal de Electricidad (Federal Electricity Commission, in Spanish, CFE) will pay for electricity sold by the foreign-owned facilities
- Extent to which the Mexican government may regulate and modify the rates and terms of power sale agreements with the CFE, since deals will be limited or impossible without a guaranteed payment stream to cover the debt service
- Level of taxes that may be imposed on such operations in Mexico
- Role of state-run oil and gas monopoly Petróleos Mexicanos (Pemex) in importing gas for gas-fired electricity facilities

Compared to other regions in the United States and Mexico, both the southwestern United States and northern Mexico are experiencing large population increases and high economic growth that are expected to continue for at least the next decade. These factors have led to a greater demand for energy services in the border region than is expected for other areas of North America. For example, demand for power in northern Mexico is expected to grow by 7% per year for the next 10 years, compared to 5% for the rest of the country. To meet the expected demand in northern Mexico, new and upgraded interconnections of the transmission system with the United States will be needed.

In addition to the increased need for power, there will be significant pressure on supplies of natural gas and associated infrastructure, such as high-pressure gas pipelines, distribution systems, and pumping stations. Now more than ever, there is a close relation between natural gas and power generation, since all of the new power plants in the border region are expected to be of the high-efficiency, combined-cycle design, which requires natural gas for the primary fuel. Aside from fossil fuels, renewable resources such as geothermal energy and wind power also play a role in the border region. As prices for fossil fuels and electricity continue to rise, it is expected that solar energy (both thermal and electric) will also play a larger role in the binational region.

In Baja California, installed capacity is 1,455 megawatts (MW), and there are plans to add between 1,262MW and 3,879MW of additional capacity during the next decade. One large 750MW plant proposed near Mexicali is planned to serve the California market and up to 300MW from other proposed plants are slated for export to California and other parts of the United States. Thus it is expected that Baja California could become a supplier of power to California and other western states. One reason for locating power plants in Baja California is the shorter permitting time required for new power plants in Mexico compared to California. The environmental impacts of siting plants in Mexico could become an issue in the border region, but in Baja California all new plants are efficient combined-cycle, gas-burning facilities and are expected to meet all Mexican environmental regulations. One critical bottleneck, however, is obtaining a secure and reliable supply of natural gas.

A secure supply of reasonably priced energy with a minimal environmental impact will be needed for the U.S.-Mexican border region if it is to remain competitive in the global economy. Given the high population growth expected over the next 10 to 20 years, meeting increased demand for energy services will be one of the most important challenges facing the binational region. The large increase in energy demand projected over the next 20 years for the border region is not a foregone conclusion, however. Although total energy demand per capita may decrease as the economy becomes more efficient, a trend dictates that electricity use grows faster than the population. Therefore unless vigorous and consistent power efficiency and conservation programs are put into place in the border region, the very high growth rates discussed in this chapter will result.

Even with such a conservation program, given the expected increase in population and living standards on the Mexican side of the border, it is difficult to see how power demand can be met without the construction of new generating facilities in the binational region. If environmental degradation is to be avoided and quality of life standards improved, the type of generation will be very important. Heavy reliance on fossil fuels, even natural gas, will inevitably degrade air quality and stress limited water supplies. Since transportation is the most polluting sector, plans to use fuels other than gasoline and diesel will ultimately pave the way for a cleaner environment in the next 20 years.

Meeting this challenge will require effective cooperation and coordination between the privatized energy market players and the local and state agencies responsible for regulating the energy sector both in the United States and Mexico. Complicating the planning for future energy-related infrastructure is the lack of formal cross-border energy planning, coordination, and cooperation. The impediments to creating a healthy energy supply system in the binational region are not mainly technical or financial, but grow out of the absence of planning, forecasting, and coordination at the binational and regional level.

Some ways to enhance cross-border cooperation in the energy field and provide the energy services needed for border residents in the future include:

- Creating a binational collaborative effort to examine the future energy needs of the binational region and surrounding areas. This group should have representatives from all the major stakeholders in the region: energy service companies, major energy consumers, relevant local and state agencies, environmental groups, appropriate non-governmental organizations (NGOs), ratepayer advocates, and the general public. It is critical that broad representation from both sides of the border be present. One example of such an effort is the California-Baja California Binational Energy Strategy Committee (BESC). Another example based on efforts to control air pollution is the Air Alliance for the El Paso-Ciudad Juárez region and the Binational Air Quality Alliance (BAQA) in the San Diego-Tijuana area.
- Developing needed infrastructure to handle the increased use

of natural gas in the border region, especially the western sections. A secure supply of natural gas for industry and power generation will go a long way toward meeting the energy needs of the binational region in a manner less harmful to the environment than fuels currently in use, such as oil and coal. One way to assist the transition to natural gas in the California-Baja California region is to consider a gas exchange program between Mexico and the United States. Mexican natural gas could be imported to the United States via Texas and equivalent amounts of U.S. gas exported to Baja California by extending San Diego pipelines into Tijuana. This could reduce the burden on Mexico of having to use its foreign currency reserves to purchase U.S. natural gas. Other issues that need to be addressed are the safety and security of the supply.

- Preparing and maintaining a comprehensive energy database for the cross-border region. The region has no central database related to energy, and no entity is collecting and distributing such information.
- Investing in renewable sources of energy. Although the cross-border region will likely remain dependent on non-renewable energy sources imported from outside the region, more could be done to encourage and use the existing renewable energy resources found on both sides of the border. The region has yet to take full advantage of the combination of solar, wind, geothermal, and biomass energy resources. Greater use of renewable sources of energy will not only reduce air pollution, but could also form the basis of a new high-tech research, development, and manufacturing sector in advanced energy technology.

The underlying logic of electricity restructuring in the United States, the opening of the energy sector in Mexico to private investment, and the growing economic interdependence of the United States and Mexico will inevitably lead to greater cross-border trade in energy services. This trade is likely to take place through the purchase and sale of electricity by local and state agencies responsible for supplying power, and through private industries located on either side of the border. In the open market for energy services emerging on both sides of the border, the final price to consumers will be the most important element in deciding where to purchase energy; the location of the energy source will become less relevant than it is today. Over time, the international border will become less of a barrier to energy flows—a consequence of the continued integration of the cross-border region.

Temas de Energía en la Región Binacional de México-Estados Unidos: Un Enfoque en California-Baja California

Alan Sweedler, Margarito Quintero Núñez y Kimberly Collins

Resumen

La energía es un elemento vital de la región binacional de México-Estados Unidos. Hace que los hogares y negocios sean cómodos, mueve a las personas y a los bienes, opera las maquinarias de la industria y genera la potencia para la infraestructura que sostiene a las comunidades de la región. Esta función penetrante hace de la energía un tema clave en el futuro de la región binacional. Las opciones de energía que se tomen hoy van a tener efectos significativos en la economía, medio ambiente y calidad de vida del mañana. Sin una fuente de energía que sea segura, confiable y a un precio razonable, la región fronteriza no se puede desarrollar en su potencial máximo.

Los sectores de la energía en los Estados Unidos, México y Canadá están experimentando grandes cambios que van a afectar la manera en que la energía es producida, transmitida, distribuida y vendida a lo largo de Norteamérica. Estos cambios van a influir directamente el uso de la energía y la infraestructura vinculada a la energía, en la región binacional de México-Estados Unidos.

Algunos de los temas importantes sobre la energía que enfrenta la región binacional son:

- La satisfacción de la demanda de servicios eléctricos en el norte de México y el suroeste de los Estados Unidos, que se espera crezca de manera significativa en los próximos diez años
- La satisfacción de la necesidad que aumenta rápidamente de gas natural en la región fronteriza
- La comprensión del complejo conjunto de estructuras regulatorias diferentes en los Estados Unidos y los que se están desarrollan do en México
- El desarrollo de la infraestructura transfronteriza asociada con las transferencias de gas natural y energía
- La creación de los mecanismos administrativos y regulatorios necesarios para planificar y coordinar temas relacionados al sector de energía en la región binacional
- El desarrollo de fuentes de energía sensibles y sostenibles al medio ambiente para la región

Este ensayo discute estos temas y hace recomendaciones para mejorar la colaboración transfronteriza para satisfacer las necesidades futuras de energía de la región. Primero nos centramos en temas nacionales de energía en los Estados Unidos y México, proseguimos hacia los temas de inquietud fronteriza, y luego nos enfocamos sobre la sección de la frontera de California-Baja California en donde se encuentra ubicado el 42% de la población fronteriza. En tanto que muchos de los problemas y oportunidades que enfrentan al sector de energía en la región de California-Baja California son similares a otras partes de la frontera, también existen características singulares.

El aumento poblacional y el crecimiento económico son los principales impulsos que conducen a un aumento de la demanda de servicios de la energía en la región fronteriza durante los próximos 20 años. La población actual de la región transfronteriza es de 13 milllones y, para el año 2020, se espera que llegue a 24.1 millones. Tan solo en la región de California-Baja California se espera que la población llegue a los 9.2 millones para el año 2020. De hecho, el número de personas apenas sumadas a esta región en los próximos 19 años será igual al total de la población que existía en 1990 y al 80%

de la población de 2000.

Además del crecimiento poblacional, la economía en expansión–especialmente el número creciente de maquiladoras–y el aumento esperado de automóviles y camiones asociado al aumento del comercio México-Estados Unidos, son también factores importantes que influyen en las necesidades de energía de la región binacional. Las plantas maquiladoras son los usuarios primordiales de electricidad y agua, mientras que el sector de transporte depende de los combustibles líquidos, principalmente en la forma de gasolina y diesel. Dado que el gas natural es el combustible de opción probable para la nueva generación de energía de la región, se pueden esperar limitaciones importantes de este versátil combustible, salvo que se tomen medidas en el futuro inmediato para satisfacer la demanda proyectada.

Introduction

Energy is the lifeblood of the U.S.-Mexican binational region. It makes homes and businesses comfortable, moves people and goods, operates the machinery of industry, and powers the infrastructure that underpins the region's communities. This pervasive role makes energy a key issue in the binational region's future. Energy choices made today will have significant effects on tomorrow's economy, environment, and quality of life. Without secure, reliable, and reasonably priced sources of energy, the border region cannot develop to its full potential.

The energy sectors in the United States, the four U.S. border states, Mexico, and Canada are undergoing major changes that will affect the way energy is produced, transmitted, distributed, and sold throughout North America. These changes will directly influence energy use and energy-related infrastructure in the U.S.-Mexican binational region.

Some of the important energy issues confronting the binational region are:

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This chapter discusses these issues and makes recommendations for improving cross-border collaboration to meet the future energy needs of the region. It will first focus on national energy issues in the United States and Mexico, then move on to border-wide topics, and finally focus on the California-Baja California section of the border, where 42% of the border population is located. While many of the problems and opportunities facing the energy sector of California-Baja California region are similar to other portions of the border, there are unique characteristics as well.

Overview of Region

To understand the energy sector in the cross-border region, it is important to examine the context within which energy services are used. The most important elements are the region's population and its expected growth; the region's economic activities; and the environmental impacts of energy production, transmission, and end use. Although this chapter is focused on the U.S.-Mexican border region, energy systems are integrated over much larger areas than just the border zone. In fact, today's energy markets are truly global, and a comprehensive analysis must recognize the global context of energy.

Although widely used, the term "border region" is not precisely defined. The La Paz Agreement between the United States and Mexico in 1983 defined the U.S.-Mexican border region as a zone stretching 100 kilometers on either side of the international boundary. However, for the purpose of analyzing energy flows and related environmental issues like air pollution, this definition is not particularly meaningful. Energy and transportation systems are not localized within a narrow region, and the cities in the border area all have important links to other regions throughout the United States, Mexico, and Canada.

Population growth is the main driving force behind the increasing demand for energy services in the binational region. The current population of the cross-border region is 13 million people, and by 2020 it is expected to reach nearly 24 million (Peach and Williams). In the California-Baja California region alone, the population is expected to reach 9.2 million people by 2020. In fact, the number of people added to this region in the next 19 years will be equal to the total population that existed in 1990 and 80% of the 2000 population.

In addition to population growth, the expanding economy—especially the growing number of maquiladoras—and the expected increase in the number of cars and trucks associated with increased U.S.-Mexican trade are also important factors influencing the energy needs of the binational region. Maquiladora plants are major users of electricity and water, and the transportation sector depends on liquid fuels, most often in the form of gasoline and diesel fuel. Since natural gas is likely to be the fuel of choice for new power generation in the region, significant shortfalls of this versatile fuel can be expected unless measures are taken in the near future to meet projected demand. Details of population growth and economic trends are covered in other chapters.

The United States and Mexican Energy Sectors

As noted above, the production, transmission, distribution, and use of energy in the U.S.-Mexican border region takes place within the framework of the larger energy markets of the southwestern United States, Mexico, and to some extent, Canada. Power transmission grids and natural gas pipelines crisscross the North American continent and link the energy systems of the three North American countries. High-power transmission lines routinely transmit electricity generated in Canada or Mexico for use in the United States, and vice versa. Natural gas produced in Canada is transported to U.S. markets by transborder pipelines, and trade in natural gas has begun to take place between the United States and Mexico. To analyze the energy sector in the border region, it is necessary to discuss briefly the larger North American energy context, focusing on the United States and Mexico.

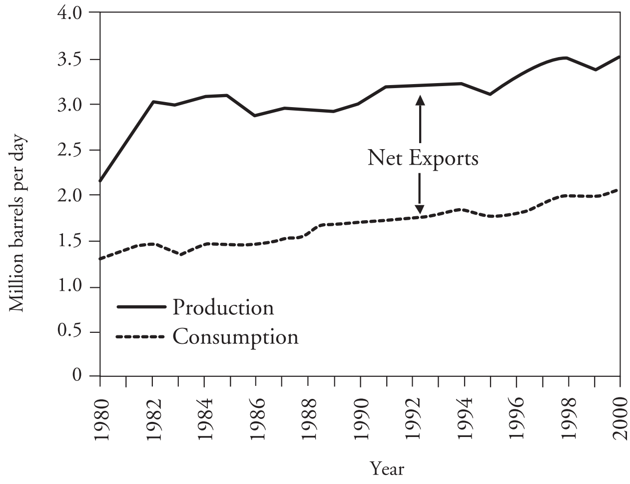
Energy Sources and Uses in the United States and Mexico

The structure of the energy sector and the use of energy in the United States and Mexico differ significantly. The United States uses a broader spectrum of energy resources than Mexico, drawing on coal, oil, natural gas, nuclear, and hydropower, as well as a small number of renewable resources. Mexico, by contrast, is heavily dependent on oil and natural gas, with the notable exception of geothermal resources in the state of Baja California.

Petroleum

The United States is the world's largest oil consumer, consuming 19.4 million barrels per day (bbl/d) in 1999 or 6.9 billion barrels per year. Of these, 10.6 million bbl/d were imported, including 1.3 million bbl/d from Mexico (U.S. Energy Information Agency [EIA] 2001). Mexico, by contrast, is self-sufficient in petroleum. Mexico has the second largest proven crude oil reserves (28.3 billion barrels) in the western hemisphere. In 2000 Mexico produced about 3.5 million bbl/d, with net oil exports of roughly 1.5 million bbl/d. Mexico ranked as the world's fifth-largest oil producer and tenth-largest oil exporter in 2000, with about 1.4 million bbl/d bound for the United States. The value of Mexican oil exports increased from $6.4 billion in 1998 to an estimated $10.4 billion in 2000. Oil exports account for about one-third of government revenues (EIA 2001). Mexico's petroleum production and consumption from 1980 to 2000 are shown in Figure 1.

Figure 1. Mexican Oil Production and Consumption 1980-2000 (data for 2000 are estimated)



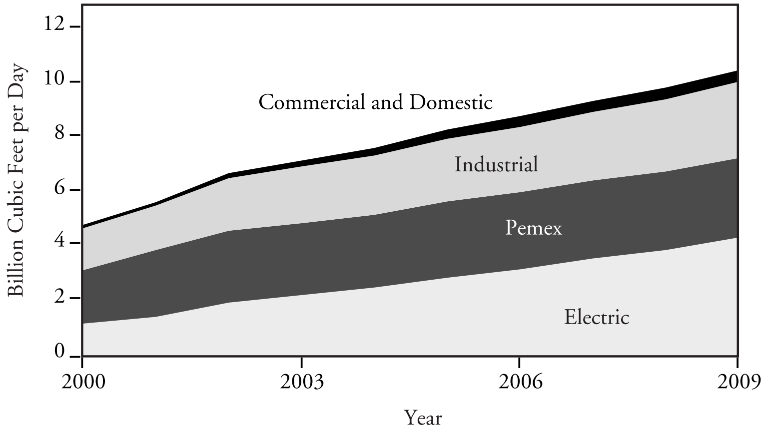
Source: EIA

Natural Gas

Mexico has proven natural gas reserves of 30.4 trillion ft^3, with 1999 production of about 1.29 trillion ft^3 and consumption of about 1.26 trillion ft^3. Mexico has not emphasized natural gas development and exploration until recently. Most of the gas now produced is "associated" gas, which occurs as a co-product of oil production. Mexico is a small net importer of U.S. gas, a trend that is expected to continue in the coming decades. The tariff on Mexican imports of U.S. gas was eliminated in mid-1999, which will encourage continued and growing volumes of imports in the future.

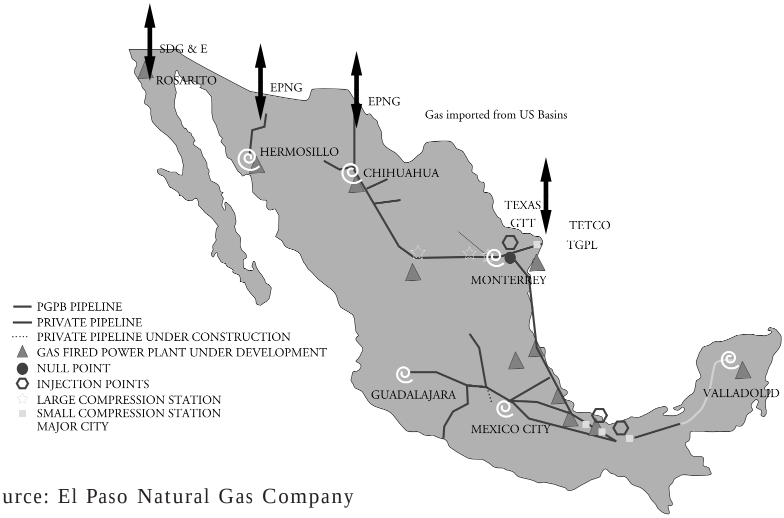
Natural gas is slated to play a more important role in the future as demand rises in the power sector and in the northern Mexican states. In response to anticipated demand growth, Pemex plans to increase U.S.-Mexican border infrastructure and capacity and to focus more on gas exploration activities. The Burgos field, located in northeastern Mexico, is expected to contain massive volumes of largely non-associated, recoverable natural gas resources. The Cantarell fields hold significant gas reserves in association with oil deposits, most of which is flared. Pemex predicts gas production will increase more than 50% by 2008. Pemex will invest nearly twice as much capital in gas exploration and development activities in 2001 as it did in 2000. Figures 2 and 3 give the projected natural gas demand for Mexico and the major cross-border corridors. Demand for natural gas in Mexico is expected to double in the next nine years.

Figure 2. Projected Demand of Various Users



Source: Pemex

Figure 3. Major U.S. and Mexican Gas Corridors



Source: El Paso Natural Gas Company

Mexico's growing reliance on natural gas is coinciding with historically high prices for the fuel and growing demand in North America. The Mexican gas price was fixed to the Houston Ship Channel price in Texas in the early 1990s. As U.S. natural gas prices spiked in early 2001, Mexican President Vicente Fox came under pressure from Mexican industry and labor unions, which claimed high prices were causing irreversible damage to Mexican industry. In the wake of industrial plant closures in early January 2001, Pemex reached an agreement to sell natural gas to businesses at a fixed price of $4 per million Btu (or British thermal units) for the next three years. In comparison, the U.S. Houston Ship Channel price reached more than $9 per million Btu in January 2001. Pemex will cover the difference when gas prices are above $4 per million Btu, but companies will continue to pay that price even if international prices drop below $4. The $4 per million Btu price is retroactive to January 1, 2001 (EIA 2001).

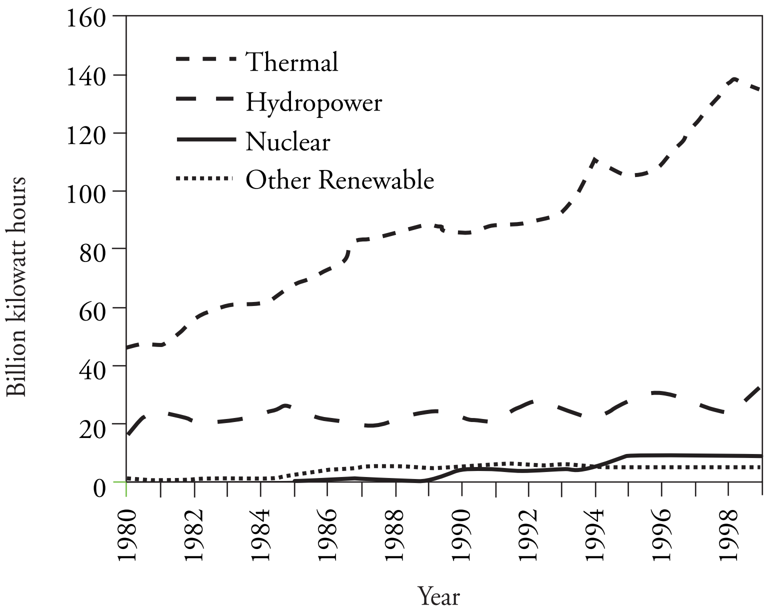
Natural gas consumption for the United States was 21.4 trillion ft^3 in 1999, which is 17 times greater than Mexico's. Of this amount, 3.6 trillion ft^3 or 17%, was imported, mostly from Canada. The availability and price of natural gas will be one of the most important energy issues in the border region during the next 20 years. El Paso Corporation, the leading producer, processor, and transporter of natural gas, has banked on natural gas prices remaining high for most of this decade. In February 2001, it announced plans to invest up to $1.5 billion to build six liquefied natural gas (LNG) facilities over the next five years in the United States, Mexico, and the Caribbean. It expects prices to be in the range of $3.50 to $4 per million Btu, which would be double the price of the preceding 15 years, yet still below the current natural gas prices of $6 or more (Los Angeles Times 2001).

Electricity

Mexico has installed electricity capacity of 38.5 million kilowatts (kW) (or 38,500MW) and in 1999 it generated 182.5 billion kilowatt-hours (kWh). Oil-fired plants make up the largest share of electricity generation, and thermal (oil, gas, and coal) electricity generation in 1999 accounted for 74% of total generation. As well, hydropower accounted for 18%, nuclear power for 5%, and other renewable sources (wind, solar, biomass) accounted for 3% of total generation. Mexico's industrial energy policy calls for conversion of many oil-fired power plants to natural gas by 2005. Most new power plants will be run on natural gas and all proposed plants in the northern Mexico border region are slated to use natural gas.

Mexico's electricity sector is at a crossroads. Although generation has increased rapidly over the past decade, supply is not expected to meet demand growth over the next two decades, especially in northern Mexico. Given current grid capacity constraints, shortages could result. Regular shortfalls resulting in nationwide blackouts are predicted within the next two years. Failure to make substantial investments in generation capacity and infrastructure could adversely affect the international competitiveness of key northern industrial regions. Although about 95% of Mexican households have electricity, there are still many thousands of rural towns without it (EIA 2001). Mexican electrical generation from 1980 to 1999 is shown in Figure 4.

Figure 4. Mexican Electricity Generation 1980–1999



Source: EIA

Structure of Energy Sectors in the United States and Mexico

The U.S. energy sector is, for the most part, owned and operated by private companies. Although in private hands, energy companies are regulated by state and federal agencies. The prices of coal, oil, and natural gas are largely determined by market factors, and relatively uniform prices exist across the United States. The price for electricity, however, has until recently been established by state regulatory agencies and has not been determined directly by market forces. The retail price for electricity can vary by up to a factor of four across the country. The complex issues related to power deregulation—or more accurately, restructuring—will be discussed later in the context of the California experience. Some of the agencies responsible for regulating the energy industries in the United States are the Federal Energy Regulatory Commission (FERC), the U.S. Department of Energy (DOE), the Nuclear Regulatory Commission (NRC), and state public utilities commissions. In California, the California Public Utilities Commission (CPUC) and the California Energy Commission (CEC) are the principal agencies that oversee the energy sector. At the local level, city and county jurisdictions may have to grant approval for energy-related construction such as gas pipelines and power transmission lines.

In contrast to the United States, the production, distribution, and management of energy supplies in Mexico are, by and large, under the control of the federal government. The federal government also sets energy prices. The Secretaría de Energía (SE) is the key government ministry responsible for formulating energy policies. SE has direct oversight over the CFE, Pemex, the Comisión Nacional Para el Ahorro de Energía (the national energy conservation commission, in Spanish CONAE) and several energy-related research institutes. A relatively new agency, the Comisión Reguladora de Energía (Energy Regulatory Commission, in Spanish CRE), was established in 1993.

The power sector in Mexico is dominated by the state-controlled CFE. Like Pemex in the oil and gas industry, CFE has enjoyed a monopoly in the electricity sector for decades, although reforms instituted in 1992 allow independent power producers (IPPs) and cogenerators to sell power to CFE.

Deregulation of the electricity sector is a contentious issue in Mexico. President Fox has made privatization of the industry a top priority, as private investment will be needed to meet the country's rapidly increasing electricity demand. His reforms already have met strong resistance. Fox had planned to submit a reform bill for electricity privatization before the end of 2000, but it was then pushed back to March 2001. The bill was expected to call for a change in the constitution to allow private generators to sell electricity in a wholesale market and to establish a separate electricity regulatory body. At the time, only the state power companies could distribute and sell electricity to the general public. Fox has pledged not to privatize CFE during his presidency.

IPPs are allowed to build and own power generation facilities, and the power can be used at related industrial companies or sold under long-term contracts to CFE. As of February 2001, 12 IPP permits had been issued for a total investment of $3 billion. The projects are expected to add more than 6,000MW of capacity by 2004, although the natural gas and electricity shortages in the United States are having a negative effect on IPP development in Mexico. Of the 12 IPP projects in progress, 10 are in northern Mexico—five are totally dependent on natural gas imports from the United States, while the other five are partially dependent on U.S. imports. Uncertainty regarding import sources could explain the low level of interest in new projects offered by CFE.

Subsidies paid to agricultural and residential electricity consumers and lack of an open power market are blamed for escalating industrial electricity costs, which are now above average international industrial costs. Mexican industry has warned that these costs will make Mexican industry internationally uncompetitive.

NAFTA and Energy

The treatment of the energy sector in NAFTA is perhaps most significant for what it lacks. Pursuant to the restriction in the Mexican constitution that reserves for the Mexican federal government all ownership of Mexico's basic energy resources, NAFTA does not create significant new opportunities for private investment in oil, gas, refining, basic petrochemicals, or direct delivery of electricity. These activities remain controlled by Pemex and CFE. Nevertheless, NAFTA does provide new opportunities for private energy companies, particularly those in the electricity industry.

Under NAFTA, foreign companies can acquire, establish, and operate electricity generation facilities in Mexico. Electricity generated at these facilities can only be used at the site or sold to CFE. Moreover, the opening of the Mexican government procurement market will create opportunities for foreign companies to compete with Mexican entities for supply and service contracts with Pemex and CFE.

The Mexican state, also under NAFTA, controls goods, activities, and investments in the oil, gas, refining, basic petrochemicals, nuclear, and electricity sectors. Consistent with Mexico's move to greater privatization of industries and resources, however, NAFTA opens many downstream activities in the energy sector to greater private investment, both foreign and domestic. NAFTA also expands on Mexico's current Build-Lease-Transfer (BLT) program, which permits foreign companies to build an energy facility while leasing the site during construction and then to transfer the plant back to the government shortly before commercial operation. With the full implementation of NAFTA, foreign companies will be able to own the plants and earn profits on sales of power back to CFE for the life of the facility. In addition, NAFTA's gas provisions potentially enable U.S. owners of gas-fired cogeneration facilities and other gas-fired facilities in Mexico to arrange for competitive gas supplies from U.S. gas companies.

NAFTA aims for more open markets in the energy sector, but it remains unclear whether those markets will provide sufficient returns to support increased investment. Still to be addressed are the:

- Rates CFE will pay for electricity sold by the foreign-owned facilities
- Extent to which the Mexican government may regulate and modify the rates and terms of power sale agreements with CFE, since deals will be limited or impossible without a guaranteed payment stream to cover the debt service
- Level of taxes that may be imposed on such operations in

Mexico
- Role of Pemex in importing gas for gas-fired electricity facilities

Genuinely open oil and gas markets are not created under NAFTA, and the effect of the agreement's electricity provisions will depend greatly on how they are implemented. This will depend on the extent to which Mexican administrations succeed in bringing reform and a market-oriented spirit to Pemex and CFE.

Energy Sector of the U.S.-Mexican Border Region

The four U.S. states and the six Mexican northern border states confront some energy issues different from, but related to, the general energy situation in the whole of North America. Compared to other regions in the United States and Mexico, the southwestern United States and northern Mexico are experiencing large population increases and high economic growth, which are expected to continue for at least the next decade. These factors have led to a larger increase in demand for energy services in the border region than is expected for other areas of North America. For example, demand for power in northern Mexico is expected to grow by 7% per year for the next 10 years, compared to 5% for the rest of the country. To meet the expected demand in northern Mexico, new and upgraded interconnections of the transmission system with the United States will be needed.

In addition to the increased need for power, there will be significant pressure on supplies of natural gas and associated infrastructure, such as high-pressure gas pipelines, distribution systems, and pumping stations. There is a close relationship between natural gas and power generation, since all the new power plants in the border region are expected to be the high-efficiency, combined-cycle design that requires natural gas as its primary fuel.

Like the rest of North America, the energy sector of the border region is primarily dependent on fossil fuels. The three main fossil fuels—petroleum, natural gas, and coal—account for the main sources of energy in the binational region. Gasoline and diesel, which are derived from petroleum, are used as the main transportation fuels. Liquid petroleum gas (LPG) is used extensively in place of natural gas on the Mexican side of the border for cooking, heating, and industrial processes, and where available, natural gas is used for heating and industrial process heat. Current power production is dependent on oil, coal, and some natural gas in Mexico. In the U.S. portion of the binational region, natural gas and nuclear make up the bulk of fuels used for power generation. As noted earlier, this fuel mix will change during the next decade as natural gas replaces oil, coal, and nuclear as the most preferred fuel for power generation on both sides of the border.

Aside from the fossil fuels, renewable resources, especially geothermal energy and wind power, play a role in the border region. The use of wind power is growing rapidly in Texas. And, as prices for fossil fuels and electricity continue to rise, it is expected that solar energy (both thermal and electric) will also play a larger role in the binational region.

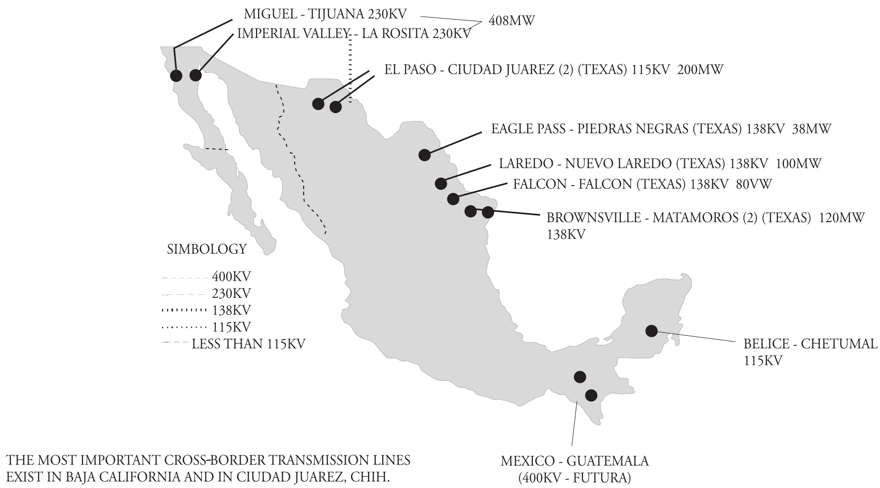
Electricity in the Border Region

Figures 5 and 6 show the main electricity transmission system of Mexico and the cross-border connections. There are 11 transmission lines that cross the border, two into California, two into Arizona, and seven into Texas. Of these, only two are 230 kilovolts (kV), the others are in the 115kV-range or lower. The two high-voltage lines are located in the California-Baja California region. One important issue facing the border region is the need to increase the capacity of the cross-border transmission system by upgrading existing lines or developing new lines. Since this involves the international transfer of energy, FERC and DOE would have to be involved, as would state and local agencies. In Mexico, CFE and SE would be the main entities involved, with possible input from the growing influence of state and municipal authorities.

Figure 5. Main Power Transmission Lines in Mexico as of 1999

Source: CFE

Figure 6. Cross-Border Power Transmission Lines in 1999

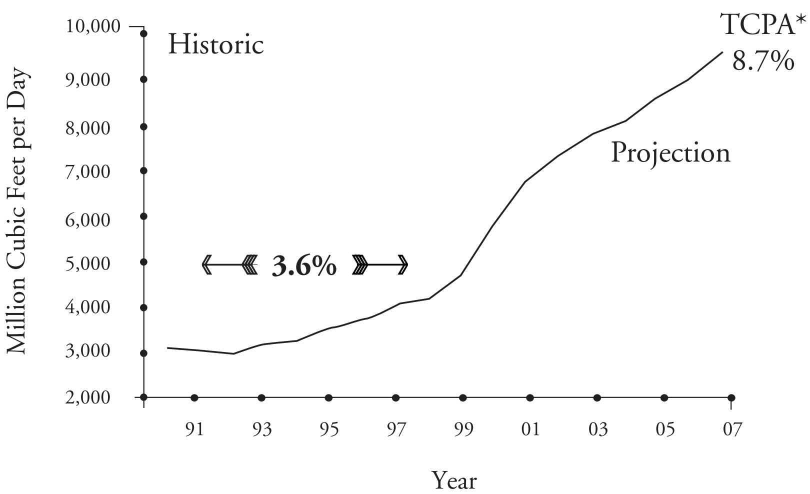


Source: CFE

Natural Gas
As previously noted, natural gas will become an important element in the fuel mix for the border region in the future. Natural gas is relatively clean-burning compared to coal or oil, and it is the best fuel for the new, efficient, gas turbine-steam generator (combined-cycle) power plants to be constructed in the border region. Therefore, developing a secure and reasonably priced supply of natural gas will be one of the main challenges facing the region.

The use of natural gas in the Mexican power sector will result in an unprecedented increase in the annual growth rate from an average of 3.6% from 1991 to 1999 to an average of 8.7% from 2000 to 2008, as shown in Figure 7.

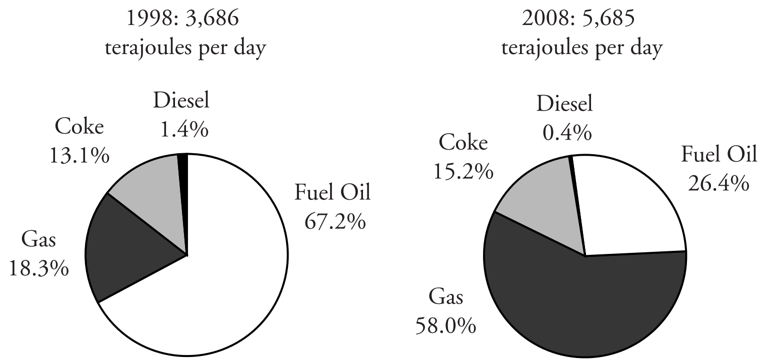
Figure 7. Historical and Projected Mexican Natural Gas Demand 1991 to 2008



*TCPA = average annual growth rate
Source: SE

In 1998 natural gas accounted for just 18% of total power generation in Mexico, but it is expected to account for 58% in 2008 (CRE 2000), as seen in Figure 8.

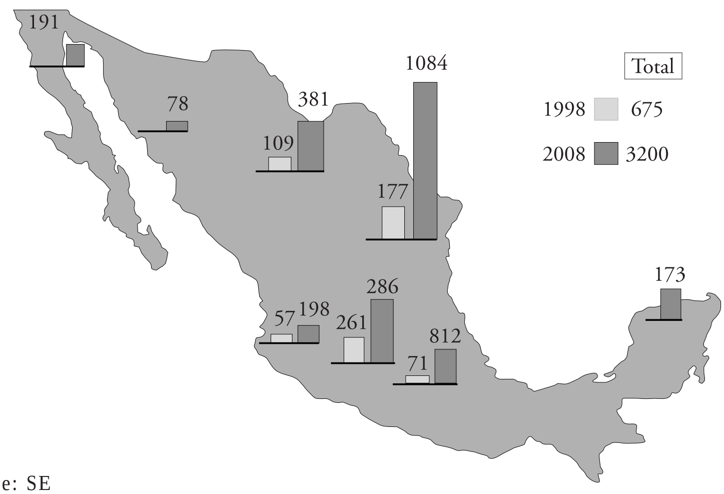
Figure 8. Projected Evolution of Fossil Fuel Consumption in Electricity Generation



Source: CRE

Much of the projected consumption of natural gas will take place in northern Mexico, as seen in Figure 9.

Figure 9. Consumption of Natural Gas for the Generation of Electricity in Mexico



Source: SE

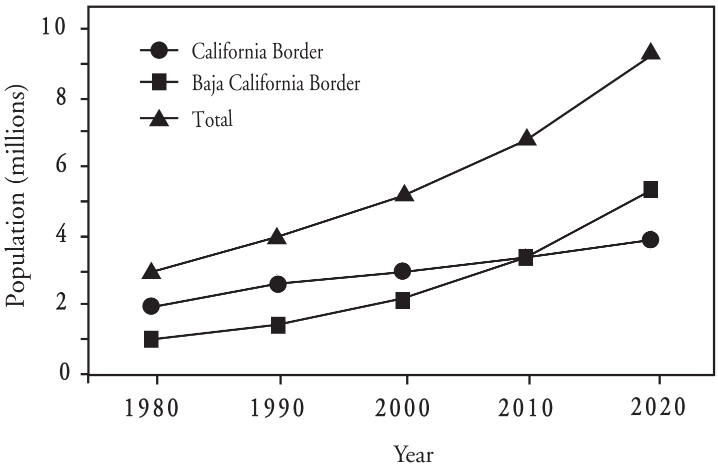
Geothermal Energy
Geothermal sources of energy for power production are important in the California-Baja California area, where significant geothermal resources are located, specifically in the Imperial-Mexicali Valley.

California-Baja California Border Region

The California-Baja California area is an especially important section of the U.S.-Mexican border region. Some 42% of the total border population and the largest United States and Mexican cities—San Diego and Tijuana—are located in this western section of the border zone. The energy issues here differ from other border regions because of the complex energy situation in California and the fact that Baja California is somewhat physically isolated from the rest of Mexico. Baja California's power grid is not connected to the main Mexican transmission system, but two of the largest cross-border connections are in this region (Figure 6). The Mexican natural gas pipeline system also does not reach Baja California, and any gas supplies would have to come across the border through California or Arizona.

As is the case in the entire border region, population growth is the principal driving factor for projected increases in energy services. Figure 10 gives the expected population growth to 2020, at which time more than 9 million people are expected to reside in the region, an 80% increase from 2000. The San Diego-Tijuana metropolitan region is expected to have 5.8 million people by the year 2020.

Figure 10. California-Baja California Border Population 1980 to 2020



Source: Ganster

In addition to population growth, the number of maquiladora plants is expected to grow significantly from the current number of 2,524. These plants employ 881,061 people. As U.S.-Mexican trade increases, there will also be a large increase in cars and trucks. This will lead to a greater demand for liquid fuels such as unleaded gasoline and diesel fuel.

Electricity in Baja California

Demand for power in Baja California is expected to grow by 7% per year over the next decade, resulting in a doubling of demand by 2010. This translates to more than 1,400 additional megawatts just to meet the needs of the Mexican population, leaving nothing left over for export to California. San Diego's power needs are also expected to grow by 3% per year for the next decade. Although a lower growth rate, San Diego's demand will grow from a higher base load. Electricity consumption for San Diego is projected to increase 33% by 2010.

Baja California's electrical energy infrastructure consists of two large power-generating facilities, several smaller generating plants, and appropriate transmission lines. The power grid is connected to San Diego via two 240kV lines, one near Tijuana and the other near Mexicali. Installed capacity for Baja California is shown in Table 1.

Table 1. Baja California Generating Facilities

Municipality	Site	Fuel	Capacity in MW
Tijuana	Tijuana	Diesel	60
Rosarito	Rosarito	Fuel oil & Natural gas	620
Mexicali	Cerro Prieto I	Geothermal	180
	Cerro Prieto II	Geothermal	220
	Cerro Prieto III	Geothermal	220
	Cerro Prieto IV	Geothermal	100
Ensenada	Cipres	Diesel	55
Total			1455

Source: Secretaría de Desarrollo Económico del Estado de B.C., Estadísticas Básicas del Estado.

The main power plant supplying power to Tijuana—the 620MW facility in Rosarito 24 kilometers from the border—currently burns heavy oil and is the largest fixed-source of air pollution in the region. One of the most important energy-related issues facing the San Diego-Tijuana region is to complete the conversion this power plant to natural gas, which was scheduled to happen by 2003.

The only indigenous energy source used on a large scale in Baja California is geothermally generated electricity from a facility located south of Mexicali at Cerro Prieto. Until a few years ago, power from Cerro Prieto was exported to Southern California under a contract with Southern California Edison (SCE) and San Diego Gas & Electric (SDG&E). These exports peaked in 1987 and 1992 and accounted for 12% and 10%, respectively, of San Diego's electricity supply in those years. Importing electricity from Mexico to San Diego ended in 1996 because supply in Baja California barely kept up with growing internal demand. The balance of trade in electricity for all of Mexico is given in Table 2. The growing level of power imports from the United States beginning in 1995 is clear.

Table 2. Balance of Trade for Electricity (thousands $US)

Year	Exports	Imports	Balance
1990	687	193	493
1991	763	209	554
1992	820	385	435
1993	839	448	390
1994	996	593	402
1995	3,118	1,926	-1,192
1996	2,677	3,220	-542
1997	132	2,957	-2,825
1998	219	5,121	-4,901
1999	382	2,864	-2,482
2000	351	7,972	-7,620

Source: SE

Between 1996 and 1998, electricity consumption increased 22% for the state of Baja California and 25.8% for Tijuana. These are very large increases and have put a significant strain on CFE's generating capacities in Baja California. By comparison, electricity use in San Diego County increased by only 7.4% in the same two-year period. In Tijuana the industrial and residential sectors are the major users of electricity. This is different from electricity use patterns in San Diego, where the commercial and residential sectors consume more electricity than the industrial sector. The difference in electricity use between Tijuana and San Diego reflects the fact that manufacturing and assembly activities form a larger part of the economy in Tijuana than in San Diego.

In Mexicali, residential electricity consumption is more than twice that of Tijuana, even though Mexicali's population is less than Tijuana's. In fact, Mexicali has the highest per capita residential energy use in Mexico. Mexicali has some of the highest temperatures in Mexico, with daily average outdoor temperatures well above 90°F in July and August. It also has energy-inefficient housing infrastructure due to the poor shell characteristics of the housing stock and the low efficiency of the electric devices used for air conditioning.

Inefficient air conditioning in Mexicali is an obvious area where improvements could be made. Reduced air conditioning loads would result in a reduction in demand for electricity in Baja California. Several programs are under way that address the energy efficiency in the housing stock and reducing air conditioning loads in Mexicali.

Although per capita electricity use in Baja California is greater than the Mexican average, it is still much less than in San Diego. For Baja California as a whole, per capita electricity use in 1996 was 2,147kWh, which was one-third that of San Diego (6,333kWh). For Tijuana, per capita electricity use was 1,608kWh, or one fourth of San Diego's. Mexicali, with 3,268kWh per capita, is the highest per capita consumer in Baja California.

Future Power Needs of Baja California

The process of estimating future energy needs and planning to meet those needs in Mexico is quite different from the process in California. In Mexico there are no counterpart state or local agencies to the CPUC, CEC, or the San Diego Association of Governments (SANDAG). Future electricity demand has traditionally been estimated by CFE, based more or less on historical growth patterns, rather on than a detailed analysis of the different electricity-consuming sectors.

Estimates of future annual growth rates for power for the next decade are in the range of 5% to 7% for Baja California. This means that between 910MW and 1,400MW of additional capacity will be needed by 2010. New power plants proposed for the region are outlined in Table 3. There is a total firm capacity of 1,262MW and potentially committed capacity of 3,879MW. If all these plants are completed within the next decade, the power needs of Baja California can be met. However, it is doubtful all the proposed plants will be built in this time, primarily due to lack of capital and secure supplies of natural gas.

Table 3. Proposed Power Plants in Baja California

Facility	Location	Capacity	Estimated Online Date	Technology	Fuel Type	Company	Notes
La Rosita I	Mexicali	750	2003	CC*	Natural Gas	InterGen	255MW for export to U.S.
La Rosita II	Mexicali	750	2005	CC*	Natural Gas	Sempra	All export to U.S.
	Mexicali	257	2005	CC*	Natural Gas	American Electric Power	Portion for sale to U.S.
Rosarito IV	Bajamar, near Rosarito Beach	450	2001	CC*	Natural Gas	American Electric Power	
	Ensenada	40	2005	Fuel Oil		CFE	Added to existing plant
	Tecate	22	2002	Small Hydro	Water	Baja California Government	Public lighting
Total		3879					
Firm		1262					

*CC = Combined Cycle

Instead of increasing generating capacity within Baja California, expected demand might be met by purchasing more electricity from the North American power system and integrating Baja California more fully into the electricity transmission system of the United States. As noted earlier, the Baja California power grid is isolated from the Mexican national system but is connected to the California system at two points. This permits a limited amount of power transfers between the western North American system and Baja California. Whatever the ultimate fate of restructuring efforts in California, there is little doubt that a regional market for power will develop in the western United States, and there is no reason why Baja California and northern Mexico will not be part of that power pool. This being the case, electricity customers and energy brokers will be searching all over North America for the cheapest power available. It may prove cost-effective for CFE in Baja California to both buy and sell power within this very large electricity market. Large consumers of power in Baja California, such as industrial parks, may find it cheaper to purchase power from the United States rather than from CFE. Similarly, customers in San Diego may find it less costly to obtain power from CFE in Baja California or from IPPs in Mexico rather than from local generators in the United States.

Baja California's Natural Gas Market

As mentioned earlier, Baja California has no direct access to the abundant natural gas resources of Mexico because of its location. There is, however, a growing recognition that natural gas would be an ideal fuel to meet the region's growing demand for industrial heat and electricity generation and that the United States, and perhaps Canada, could serve as sources of natural gas for Baja California if appropriate cross-border pipelines were constructed.

Baja California's dependence on U.S. natural gas supplies can have drawbacks, however. The Mexican government is guaranteeing a price of $4 per therm, except for users in Baja California. This is because Baja California's gas comes from the United States and not from Pemex. Marcos Ramírez Silva, Pemex's director of gas and petrochemicals, has been quoted saying, "We don't have any infrastructure there … Nothing. Well, (Baja California is) more like the

United States. They should be burning fuel oil" (Lindquist 2001a). Of course, if the price of U.S. natural gas falls below Mexico's price, Baja California could benefit.

The use of natural gas for power generation in Baja California is of particular importance to the San Diego-Tijuana region. Since the principal thermal power plant in Baja California is just 24 kilometers south of the border and burns heavy fuel oil, supplying that plant and its planned additions with natural gas will improve air quality in the region. At the same time, it will provide natural gas to industries and residents of Tijuana. Gas-fired electrical generation produces almost no sulfur oxides and is generally more efficient than an oil-fired plant because combined-cycle technology can be used.

In July 1997, a Swedish-Japanese joint venture won a $244 million contract to build a 450MW expansion to the Rosarito power plant. When completed, the total installed capacity at the site would be 1,160MW. The plans call for the plant to use natural gas. In August 1998 Sempra Energy (formed by the merger of SDG&E and Southern California Gas) won the contract to supply natural gas to the Rosarito site. Sempra Energy expects to spend about $40 million to build the 23-mile pipeline and hopes to generate about $1 billion in revenues by supplying natural gas over the next 10 years. As of March 2001, Sempra was in the process of obtaining right-of-way permits to complete construction of the pipeline.

A similar project has been completed to bring natural gas from California to Mexicali. In March 1996 the Mexican government, through CRE, called for bids to construct a pipeline system to supply natural gas to Mexicali. The project was awarded to a consortium of three companies: Sempra Energy, Pacific Enterprises, and Proxima, a Mexican company based in Mexicali. The consortium, known as Distribuidora de Gas Natural de Mexicali (DGN), has a 12-year exclusive contract for the distribution of natural gas to more than 25,000 users in Mexicali.

For the first time in Baja California, natural gas is now available via a pipeline crossing the border east of Calexico near the recently opened truck-crossing facilities. As of May 1999, 70 industrial customers, 80 commercial businesses, and 10,308 residences have been connected to this distribution system. Contracts have been signed for an additional 78 industrial customers, 127 commercial businesses, and 15,700 residences. In addition, a new pipeline is planned to supply natural gas to a new power plant at La Rosita near Mexicali.

A joint venture between Phillips Petroleum and El Paso Corp. was announced recently. It would bring LNG from Australia to California or Baja California, where it would be regassified for distribution on both sides of the border. The $3 billion project would be one of the largest in the world, and would produce an average of 680 million cubic feet of natural gas per day beginning in 2005. This would be enough to satisfy 12% of California's 10 million natural gas customers. The companies have not yet indicated where the LNG facility would be located, but Baja California would be a possible site. Still to be resolved are potential safety issues related to locating large LNG facilities near population centers (Lindquist 2001b).

Renewable Sources of Energy in Baja California

Both San Diego and Baja California are heavily dependent on fossil fuels (petroleum products and natural gas) that originate far from the region. This dependence represents an outflow of regional capital. In addition, the burning of fossil fuels is a major source of air pollution. Therefore it is important to consider potential development of indigenous and renewable sources of energy in the border area as a replacement for fossil fuels.

Although Baja California has an impressive array of renewable energy resources, very few of these have been developed to produce significant amounts of energy. The main reasons for this lack are the same that plague renewable energy development everywhere: Relatively low costs for oil and natural gas coupled with relatively high initial capital costs for renewable energy projects. These factors present significant impediments to the development of renewable projects in Mexico because of the plentiful supply of oil and gas and the lack of capital. However, with the current upsurge in natural gas prices, the continuing high price of oil, and the shortage of power in California and the western United States, development of renewable energy resources has never looked better.

Renewable energy resources in Baja California consist of geothermal, microhydroelectric, biomass, wind, solar, and tidal. With the exception of geothermally generated electricity, none of these renewable resources has been used significantly to date.

Geothermal

Baja California is home to some of the largest geothermal reserves in Mexico. These considerable resources are located at Cerro Prieto in the Valley of Mexicali, about 30 kilometers from the international border. An intriguing potential source of even greater geothermal energy might be in the form of geopressurized deposits (high-temperature, high-pressure water located beneath the sea bed) located in the northern part of the Gulf of California. This region displays characteristics for the development of marine geothermal resources found nowhere else in the world. The initial geothermal potential has been estimated to be tens of times greater than that of Cerro Prieto.

Geothermal Binary Cycle

There is the potential to use heat from the residual brine that results from the operation of the geothermal fields at Cerro Prieto. The fields have an installed capacity of 720MW, and when in full operation they produce 12,000 tons of residual water per hour with a temperature range of 120^{o}C to 135^{o}C. This represents an important amount of useful energy for a binary cycle operation. Estimates suggest that as much as 246MW of additional power could be produced in this fashion.

Microhydroelectric Power

An interesting renewable technology that could prove practical in Baja California is microhydroelectric power generation in the Valley of Mexicali. This is based on capturing the energy in the flow of water from the extensive irrigation system that exists in the agricultural region surrounding the city of Mexicali. Estimates as high as 80MW have been suggested for microhydroelectric generation potential.

Solar, Wind, and Biomass

Table 4 lists an estimate of renewable and alternative energy resources for Baja California. These sources of energy could play a significant role in the region's energy portfolio. Although the potential contribution to the region's energy mix from solar (thermal and electric), wind power, and biomass could be substantial, there are no studies that examine in a comprehensive fashion the potential of these resources.

Table 4. Estimated Renewable and Alternative Energy Resources for Baja California

Energy Source	Potential
Geothermal	1,000 MW proven reserves (Mexicali)
Solar / Wind	3.3-6.9 kWh/m^2
Biomass:	100-250 watts per m^2
Agricultural waste	3,600m^3 (Mexicali)
Solid urban waste	25-30 MW + heat
Seaweed	~75,000 Barrels of Oil Equivalent per year
Fuel wood	Negligible
Mycrohydroelectric	~80 Megawatts (Mexicali) ~20 Megawatts (Tecate)
Tidal Power	~1,200 Megawatts (Gulf of Cortez)

Source: Huacuz

San Diego's Energy Sector

Overview

The last comprehensive analysis of the energy sector in San Diego was completed by SANDAG in 1995, and a revision of that study is currently underway. Although the regulatory framework of the energy sector has changed dramatically since 1995, the underlying energy supply, distribution, and end-use for the region are about the same as they were when that SANDAG study was completed.

The main features of the energy sector in San Diego are the dominance of the transportation sector in energy consumption, the high proportion of electricity imported from outside the region, and the relatively high electricity and gasoline prices. Transportation accounts for more than 60% of end-use energy consumption in San Diego, followed by the residential, commercial, and industrial sectors. This energy consumption pattern reflects the structure of the San Diego economy; most San Diego residents commute to work in private automobiles with one or two occupants. Moreover, most of the rapid population growth during the last 10 years has occurred in the northern sections of the county, resulting in longer commutes between home and work.

Power Sector

San Diego is more dependent on power imports from outside the region than the state as a whole, importing 52% of its power compared with 18% for the state in 2000. San Diego's commercial sector uses more electricity proportionally than the rest of the state, reflecting San Diego's concentration of high-tech businesses, tourist activities, and retail trade. This is important because these sectors are growing rapidly in both San Diego and Tijuana. However, at the present time industrial use of power is still greater than commercial activities in Tijuana and Mexicali, compared to San Diego.

The major power infrastructure elements in San Diego consist of two large thermal power plants located in Carlsbad (Encina) and Chula Vista (South Bay) plus the San Onofre Nuclear Generating Station (SONGS) located just south of San Clemente. All thermal power plants operating in the county use natural gas. There are only two high-voltage (500kV) transmission lines, one to the north and the other to the east, responsible for carrying all the imported power into the region.

Demand for power has grown faster than population and housing since 1995, a trend that is expected to continue through 2010. The main reason for this is the large amount of power consumed in office buildings, internet centers, and information processing sectors, all of which play an important role in the San Diego economy.

To meet this projected demand for power, San Diego and the binational region as a whole have several choices:

- Increase in-region generation capability
- Increase electricity imports from outside the region
- Reduce demand
- Some combination of the above three

For San Diego the only new power plant likely to have any impact in the near future is the proposed 500MW facility located on the border at Otay Mesa. This combined-cycle, natural gas fired plant is through the approval process and construction may begin in 2003. One of the interesting features of this plant is the use of mobile offsets for it to comply with air emissions requirements. This means the plant owners intend to replace diesel buses with natural gas burning vehicles, thereby reducing mobile emissions in the region. This is the first time this has been approved, and it could represent a creative approach to reducing air pollution while increasing energy production. A natural extension of this concept would be to consider cross-border air emissions trading in regions such as San Diego-Tijuana, Imperial-Mexicali Valley, and El Paso-Ciudad Juárez.

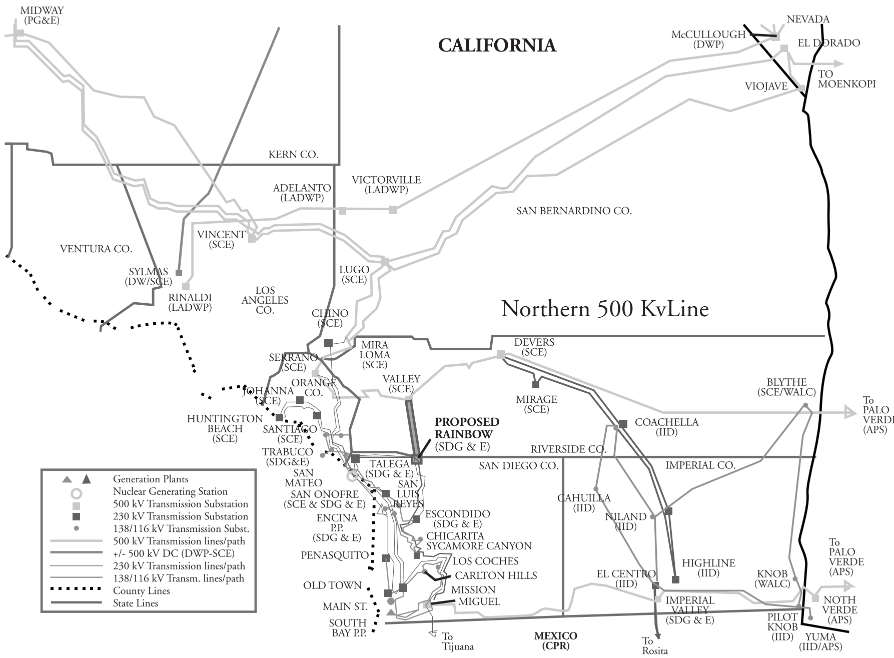
In addition to large central power plant construction, other ways to increase in-region capacity are to encourage distributed generation and increase the use of renewable resources, such as solar and wind.

Importing more electricity into San Diego is currently difficult because of limited transmission capacity into the region. Figure 11 shows the grid system for San Diego.

There is a proposal to build a 500kV connecting line that would allow more power to be brought into the region from the north. However this has not been approved and there is considerable opposition to its construction. There is also discussion about increasing the capacity of the two 240kV lines that cross the border into Baja California.

Reducing energy demand is a tried and true approach that complements increasing energy supply. Any comprehensive energy plan for the binational region should include energy reduction programs such as increasing energy efficiency in buildings, appliances, and lighting; economic incentives for installing energy efficient devices; and tiered pricing structures that encourage lower energy consumption.

Figure 11. Electricity Transmission for the San Diego Region



Source: Center for Energy Studies

Binational Energy Strategy Committee

Recognizing the need for better planning and coordination between California and Baja California in the energy sector, SANDAG's Committee for Binational and Regional Opportunities (COBRO) established the Binational Energy Strategy Committee (BESC) in 2001. The BESC serves as the only public forum that discusses energy issues of importance to the binational area; it is also an information resource where new projects can be vetted, as well as a communication link among stakeholders. Members of BESC represent the major energy interests from both sides of the border. In 2002, the BESC successfully evolved into a policy-recommending body and was renamed the Border Energy Forum (BEF).

Impact of Restructuring the California Power Sector on Binational Energy Issues

The full impact of the 1996 restructuring of the California electricity sector has not yet been felt either in California or the binational region. Originally conceived as a means to lower electricity rates in the state, the experience of the last 10 months has left most policy makers, legislators, politicians, and ratepayers somewhat confused as to the future of deregulation. The very high cost of wholesale power in California beginning in June 2000 in San Diego—coupled with sporadic blackouts, more than 30 days of Stage 3 alerts called when power reserves are less than 1.5% of demand, and the near bankruptcy of the state's investor-owned utilities—have changed significantly the way the power sector is organized in California. The whole enterprise of restructuring and deregulating the power industry is, at this time, quite uncertain.

Because of this uncertainty, the impact of restructuring on the energy sector in the binational region is difficult to ascertain with any degree of accuracy. Nevertheless, the underlying energy needs of the region will continue to drive greater energy transfers across the border, as evidenced by the planned power plants in Mexico, several of which expect to export to the United States

Restructuring efforts that began in 1992 at the U.S. federal level, 1995 in Mexico, and 1996 at the California state level have opened several new possibilities. For example, IPPs can generate electricity for their own use or for sale to CFE. They can also build power plants whose output can be sold to CFE or to the United States. As well, generating facilities could be constructed on the U.S. side of the border to supply electricity services to customers in Tijuana. The local utility that controls transmission and distribution would have to allow equal access to all qualifying generators to transmit power over its transmission and distribution system, at least up to the border connections. Beyond that point, power would flow in CFE-controlled lines. For example, U.S. Generating (a subsidiary of Pacific Gas and Electric) expects to complete a 500MW plant in Otay Mesa that could supply customers in both San Diego and Tijuana within the next few years.

Generating facilities, such as the planned Rosita plant near Mexicali, can be built in Baja California to supply customers on both sides of the border. When CFE had excess capacity in the 1980s and early 1990s, San Diego routinely purchased power from Mexico. Now the situation is reversed. As the Mexican energy sector continues to open to private investment, the possibility exists for IPPs, Mexican or foreign, to build plants in Mexico and export their power to San Diego and other parts of the western United States. Finally, renewable energy resources such as solar and wind are a source of future energy production in the binational region. Wind farms and solar facilities could be located in Baja California, where land and labor costs are less than in San Diego, and power sold to users on both sides of the border.

Challenges and Opportunities: Issues For Discussion

A secure supply of reasonably priced energy with a minimal environmental impact will be needed for the U.S.-Mexican border region if it is to remain competitive in the global economy. Given the high population growth expected over the next 10 to 20 years, meeting increased demand for energy services will be one of the most important challenges facing the binational region.

The large increase in energy demand projected over the next 20 years for the border region is not a foregone conclusion, however. As a society develops and its standards of living rise, per capita energy demand can actually decrease. This has been the experience of many industrialized countries during the period of 1975 to 1998. Although total energy demand per capita may decrease as the economy becomes more efficient, there is also a trend that electricity use grows faster than the population. Therefore, unless vigorous and consistent power efficiency and conservation programs are put into place in the border region, the high growth rates discussed in this chapter will result.

Even with such a conservation program, given the expected increase in population and living standards on the Mexican side of the border, it is difficult to see how power demand can be met without construction of new generating facilities in the binational region. If environmental degradation is to be avoided and quality of life improved, the type of generation will be very important. Heavy reliance on fossil fuels, even natural gas, will inevitably degrade air quality and stress limited water supplies. Since the most polluting sector is the transportation sector, plans to use fuels other than gasoline and diesel will pave the way for a cleaner environment.

Meeting this challenge will require effective cooperation and coordination among the privatized energy market players and the local and state agencies still responsible for regulating the energy sector in both the United States and Mexico. The lack of formal cross-border energy planning, coordination, and cooperation complicates the development of planning for future energy-related infrastructure. The impediments to creating a healthy energy supply system in the binational region are not mainly technical or financial, but grow out of the absence of planning, forecasting, and coordination at the binational and regional levels.

Some ways to enhance cross-border cooperation in the energy field and provide the energy services needed for border residents in the future include creating a binational collaborative effort to examine the future energy needs of the border region and surrounding areas. This group should have representatives from all major stakeholders in the region, which include energy services companies, major energy consumers, relevant local and state agencies, environmental groups, appropriate NGOs, ratepayer advocates, and the general public. It is critical that broad representation from both sides of the border be present. This group could be structured like BESC, discussed above. Another model is the Air Alliance for the El Paso-Ciudad Juárez region or the Binational Air Quality Alliance (BAQA) in the San Diego-Tijuana area.

Another way to enhance regional cooperation is by developing needed infrastructure to handle increased use of natural gas in the border region, especially the western sections. A secure supply of natural gas for industry and power generation will go a long way toward meeting the energy needs of the binational region in a manner less harmful to the environment than the oil and coal currently in use. One possible way to assist the transition to natural gas in the California-Baja California region is to consider a gas exchange program between Mexico and the United States. Mexican natural gas could be imported to the United States via Texas and equivalent amounts of U.S. gas exported to Baja California by extending San Diego pipelines into Tijuana. This could reduce the need for Mexico to use its foreign currency reserves to purchase U.S. natural gas. Other issues that need to be addressed are the safety and security of the supply. Preparation and maintenance of a comprehensive energy database for the cross-border region is also needed. The region has no central database related to energy, and no entity is collecting and distributing such information.

Finally, investment in renewable sources of energy can be planned and implemented regionally. Although the cross-border region will likely remain dependent on non-renewable energy sources imported from outside the region, more could be done to encourage and use existing renewable energy resources found on both sides of the border. The region has yet to take full advantage of energy resources like solar, wind, geothermal, and biomass. Greater use of renewable sources of energy would not only reduce air pollution, but could form the basis of a new high-tech research, development, and manufacturing sector in advanced energy technology.

The electricity restructuring in the United States, the opening of the energy sector in Mexico to private investment, and the growing economic interdependence of the United States and Mexico will inevitably lead to greater cross-border trade in energy services between the two countries. This trade is likely to take place through the purchase and sale of electricity by local and state agencies responsible for supplying power and through private industries located on both sides of the border. In the emerging open market for energy services, the final price to consumers will be the most important element in deciding where to purchase energy. The location of the energy source will become less relevant than it is today. Over time, the international border will become less of a barrier to energy flows, a consequence of the continued integration of the cross-border region.

APPENDIX

Restructuring the Power Sector: California's Experience

The impetus for restructuring, and ultimately deregulating, the power sector in the United States came from Federal Energy Regulatory Commission (FERC) decisions made in 1992. The Energy Policy Act of the same year allowed generators to sell power nationwide, subject only to FERC—not state—authority. In December 1995, the California Public Utilities Commission (CPUC) responded to FERC with its own decision to deregulate. The CPUC mandated that the main investor-owned utilities (San Diego Gas and Electric [SDG&E], Pacific Gas and Electric [PG&E], and Southern California Edison [SCE]), which serve more than 70% of the ratepayers in the state, must sell their power plants, purchase power on the national market, establish a power exchange in California, and buy power on the spot market. California Governor Pete Wilson and the legislature felt it would send stronger signals to the market about California's intent to deregulate the power market if complementary legislation were also passed. On Sept. 23, 1996, Wilson signed legislation that dramatically changed the regulatory system governing electricity utilities in California. The law, commonly known as AB 1890:

- Recognized that new technology and new federal laws allow change from the existing highly regulated market structure to one that relies on competition to set the price of the generation component of electricity bills
- Created two new market entities, one to oversee the high volt age transmission system (Independent System Operator, or ISO) and one to create an auction market for the buying and selling of electricity (Power Exchange, or PX)
- Authorized retail competition, allowing customers to choose their electricity supplier beginning in April 1998
- Permitted new business opportunities for buying, selling, or brokering electricity for individual customers or customer groups

- Permitted utilities to recover their transition costs from ratepayers, the so-called “stranded costs”
- Mandated a 10% rate reduction for small residential and commercial customers beginning on Jan. 1, 1998 and expiring in 2002
- Provided funds for continuation of utility energy conservation; research, development, and demonstration (RD&D); public assistance; and renewable energy-based electricity generation activities
- Allowed customers to continue to rely on service from local utility companies as they had in the past, if they chose not to participate in the competitive market

AB 1890 effectively separated, or “unbundled,” the generation of electricity from its transmission and distribution. Power plant owners had the opportunities to sell electricity to customers with whom they had negotiated sales contracts, sell electricity into a general “pool” (the now-defunct PX) from which large customers and distribution utilities could draw to meet their needs, or sell to “aggregators,” companies that have signed contracts with many small customers to provide their electricity needs. The transmission and distribution of electricity still was a regulated monopoly under control of the local utility. However the utility could not refuse to transmit and distribute power from qualified generators, and it was required to charge the same tariff to all generators. The intent of the legislation was to create competition among potential generators of electricity, thereby letting the electricity market set the price for the generating component of electricity bills. Regulators would ensure competition was allowed to flourish and no companies could dominate the market and set prices.

AB 1890 created three new entities: ISO, the PX, and the Oversight Board. The ISO oversees the operation of the high-voltage electricity transmission system in California. Western North America is interconnected by many high-voltage electricity lines. These lines allow electricity to be generated in one area and used in another over a geographic region that extends from Colorado to the Pacific Ocean and from Canada to northern Mexico. The major responsibility of the ISO is to ensure fair and impartial access to the transmission system for all generators while maintaining reliable operation. Since the high-voltage lines are the electrical “highways of commerce,” the ISO ensures that no particular buyer or seller of electricity can block access by others.

The governing board for the ISO is composed of individuals involved in the generation, transmission, distribution, purchase, sale, and use of electricity. Appointments are drawn from public interest groups and individuals not directly involved in the electricity market. The objective of having such a wide representation is to ensure no one interest can dominate the market and that robust competition prevails.

The PX, which ceased operations in February 2001, accepted requests to buy a quantity of electricity at a given price. In theory, the PX functioned like an auction, matching total demand for power with generation of power. The PX created a “pool” or “spot market” where price information was publicly available. The PX solicited bids from electricity generators and chose the lowest bidders until it had enough supply to meet the requests to buy power. PX prices changed on an hourly basis. Customers paid for electrical power based on this price, either directly through their distribution utility or through a private power supply contract with terms pegged to the PX price. Thus consumers who chose to enter into private contracts for power where the terms, conditions, and price were not public knowledge used the public information from the PX to gauge the attractiveness offers they received.

An Oversight Board of five members oversees this restructured electricity market. The governor makes three appointments to the Oversight Board and the legislature makes two appointments. The legislative appointees are non-voting members. The Oversight Board has established a governing board for the ISO and another for the PX. Both the ISO and PX are private, not-for-profit California corporations. They are not government agencies.

By June 2000 it was apparent restructuring was not working as intended. San Francisco experienced blackouts for the first time in the history of the region, and prices for power in San Diego more than tripled. San Diego became the first region in California to experience the full impact of the unregulated wholesale power market because SDG&E paid off its competitive transition charges earlier than the other utilities. The wholesale prices charged by power producers skyrocketed to unheard-of values, in some cases prices reached $1,500 per megawatt hour (MWh), or $1.50 per kilowatt hour (kWh). It was not uncommon for the PX to be paying $500/MWh to $750/MWh. The majority of ratepayers in the Pacific Gas and Electric and Southern California Edison service territories had their rates capped at $0.065/kWh, so they did not feel the direct impact of these large wholesale prices. However these utilities had to pay the full wholesale costs. They soon found themselves in serious financial straits and looked to the state for assistance. The two major utilities could not pay the PX for power already purchased, making it impossible for the exchange to pay the power generators. Finally the PX went out of business and the State of California assumed responsibility to purchase power for the investor-owned utilities at a cost of about $50 million per day.

Clearly California's experience with restructuring its power sector has been a failure from the perspective of supplying inexpensive power and from a regulatory and policy viewpoint. There is no single reason why it has failed. A constellation of events made it almost impossible to succeed. Some of these included:

- Lack of a competitive market for electricity at the wholesale level
- Greater-than-anticipated demand for electricity services
- Unfair and unreasonable wholesale prices, suggesting that power generators took advantage of a tight demand-supply situation
- A cumbersome and complex bidding process that appeared to force the ISO into paying the highest price available from power generators

Despite the failure of the California experience, it has become clear the price of energy services must reflect the true costs of these services to have a sustainable energy system. Determining the true cost of energy, including its environmental impacts, however, will always be difficult and contentious.

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III

The Interdependence of Water and Energy in the U.S.-Mexican Border Region

David A. Rohy

Abstract

Water and energy are two extremely important resources for the personal, economic, and environmental well-being of U.S.-Mexican border region residents. Neither resource is abundant nor independent of the other in this region. Continued economic growth requires both resources to be readily available and affordably priced with minimal environmental impact. Strong links exist between the two. For example, new technologies exist that greatly enhance potable water quality but require large inputs of electricity. In a similar manner, new highly efficient power plants can consume vast quantities of water in their cooling towers.

Wastewater is a disposal problem, a potential potable water resource, and an energy sink. New technologies to reclaim wastewater are based on electrotechnologies. This chapter focuses on the California-Mexico border region and includes recommendations for employment of new technologies throughout the border region.

La Interdependencia del Agua y de la Energía en la Región Fronteriza de México-Estados Unidos

David A. Rohy

El agua y la energía son dos recursos extremadamente críticos para el bienestar personal, económico y ambiental de los habitantes de la región fronteriza de México-Estados Unidos. Ninguno de estos recursos es abundante o independiente del otro en esta región. El crecimiento económico continuo requiere que ambos recursos sean de fácil disponibilidad y a precios accesibles con un impacto ambiental mínimo. Existen fuertes vínculos entre ambos recursos. Por ejemplo, existen nuevas tecnologías que aumentan considerablemente la calidad del agua potable, pero que requieren de una gran provisión de electricidad. De manera similar, las plantas nuevas de energía altamente eficientes pueden consumir vastas cantidades de agua en las torres de enfriamiento. Las aguas residuales presentan un problema de disposición, son una fuente potencial de agua potable y son un pozo de energía. Las nuevas tecnologías para sanear las aguas residuales están basadas en electrotecnologías. El autor se enfoca en la región de la frontera California-México e incluye recomendaciones para el empleo de las nuevas tecnologías a lo largo de la región fronteriza.

Critical Issues

Some 6% of all of the electricity used in California supplies potable water and processes wastewater (Anderson 1999). This is twice the United States' national average. Most of the border region would be uninhabitable desert without the energy-intensive and costly water systems put into place over the past century. And without modern technology the wastewater generated by the large populations in the border region would create an environmental disaster. Growth in population and economic activity requires additional water, wastewater, and energy facilities. The interdependence of these infrastructure needs cannot be ignored.

More stringent human water standards and more stringent environmental standards demand that both potable water and wastewater streams have higher purity and at the same time minimize or eliminate the use of chemical disinfectants and flocculants. Proper disposal of the greater quantity of impurities removed from the water is an additional problem. The technologies to achieve these goals are becoming available but require significantly more electrical energy than current practice. Similarly, high-efficiency power plants require large quantities of water to achieve maximum efficiency. The water is primarily used to condense spent steam used in the steam (Rankine) bottoming cycle. This water evaporates into the environment absorbing its latent heat of vaporization from the condenser and is lost to the cycle. Because of the strong links, some have anticipated the convergence of energy and water utility companies (Duque 1999). The public sector should also consider the convergence of the regulation and permitting activities of these two essential resources.

On top of it all, the population in the border region has seen high rates of growth, which are expected to continue throughout the border region.

Potable Water Use

In 1996, the San Diego-Tijuana region consumed 683,000 acre-feet (af) of water for residential, commercial, industrial, and agricultural uses (Ganster 2000). (An acre-foot is equal to 842 million cubic meters, or approximately 326,000 gallons. One acre-foot of water covers one acre of land in water one foot deep). Much of this water was imported into the region from the Colorado River and northern California. Tijuana and Rosarito Beach received additional water from the Guadalupe River. In 1996, 90% of the regional water was used in the San Diego area and 10% in the Tijuana area. In 2000 San Diego County consumed 695,000af of water. Experts project the use of 848,000af of water in the border region in the year 2010.

With more than 1 million new residents anticipated to arrive in the county, San Diego alone expects to use 813,000af of water in the year 2020. Few new sources have been identified to supply additional water.

Potable Water Supply for the Border Region

The Colorado River is the major source of water for the California-Mexico border region. Seven western states in the United States—including Arizona and New Mexico—and Mexico share that water under a 1922 agreement. Historically, California has been allowed to exceed its limit. But as the neighboring states grow and require more water, California's "take" of Colorado River water will be reduced to 4.4 million acre-feet (MAF) from 5.25MAF by 2015 (Conaughton 2001). This is a 16% reduction, some of which will be borne by the San Diego region. Possible new sources of water are the purchase of "excess" agricultural water from the Imperial Valley and the increased use of desalinated brackish groundwater, treated wastewater, and seawater desalinization. Incidentally, energy requirements increase as one moves from the treatment of brackish water to the treatment of wastewater to seawater desalination.

The San Diego County Water Authority has reached an agreement with the Imperial Irrigation District that will allow annual transfers of up to 100,000af of water conserved by agricultural users in the Imperial Valley for up to 75 years. The water authority has been investigating methods of transporting this water to the San Diego area.

Mexico is entitled to between 1.5MAF and 1.7MAF of Colorado River water per year. Mexican officials (San Diego County Water Authority web site 1999) have estimated that the need for water in the Tecate-Tijuana-Rosarito area will increase 70% between 1998 and 2020.

The existing Acueducto Río Colorado Tijuana is too small to deliver the water needed by the growing Tijuana and Rosarito areas. In October 1999 Mexican and American authorities at the International Boundary and Water Commission (IBWC) signed an agreement to collaborate on a $3 million feasibility study of potential binational aqueduct options that could bring Colorado River water to the Tijuana-Rosarito Beach and San Diego areas (San Diego County Water Authority press release 1999). The San Diego County Water Authority and the Comisión Nacional del Agua (CNA) are the lead agencies in the United States and Mexico, respectively. The study was completed in 2002. Each country would transport water it owns in the future aqueduct.

Should a new aqueduct be built, it will require several pumping stations, each requiring significant electrical service. The electrical load can be reduced with the use of recently developed high-efficiency motors. Variable speed electric motors are also being incorporated into water systems to lower the energy requirements when full flow is not required. The use of energy recovery generators on the downward sections of the water route will produce additional energy to use or sell.

There are many other critical issues surrounding potable water:

- The San Diego-Tijuana region is growing rapidly and will require 24% more water by 2010 than it used in 1996
- The sources of and delivery aqueducts for the new water have not been fully identified and existing supplies may be scaled back
- Pumping existing water requires considerable electrical energy, and that may require additional pumping and treatment facilities by 2010
- New electrical generating facilities may be needed for new pumping and treatment facilities
- Natural gas for generating facilities currently is limited
- Prices for natural gas are increasing
- Colorado River water is becoming increasingly saline, and it will require an energy-intensive desalination process to bring river water into compliance with United States' water standards in the future

Wastewater Issues in the Border Region

A large fraction of the used water in the region is disposed of in sewer and wastewater systems. These streams of wastewater must be pumped to treatment facilities; processed to remove solids, bacteria, and other substances; and then pumped again to the point of release or reuse. This water purification process—which involves aerating, stirring, processing for solids, and pumping—uses large amounts of energy, to the tune of 1,400 kilowatt hours (kWh) to 1,800kWh per million gallons. About 50% of that energy is used for aeration, 30% for solids processing, and 15% for pumping. Other processes consume the remaining 5%. New technologies such as ultraviolet (UV) radiation, ozone treatment, improved filtration, and low-pressure reverse osmosis will increase the energy use per gallon of wastewater treated.

Several new electrotechnologies are being developed and applied to treat water. Electrotechnologies are desirable because they lessen or eliminate the need to add chemicals like chlorine to the water. As these new technologies are applied, the environment will be healthier but the treatment of potable and wastewater will use more electrical energy. With the increases in the price of electricity in California and throughout the west, wastewater plant operators cannot ignore the cost of energy. In at least one wastewater facility in the border region, the electricity bill has more than doubled to $250,000 per month from the $110,000 per month it paid before California's energy crisis began.

Critical wastewater issues mirror those of potable water: The region is growing, flows of wastewater will increase with population and economic growth, considerable electrical energy is used to process the wastewater, new water treatment technologies require more electric energy, new power plants may need to be constructed to provide power to move and treat the waste, and bills for electricity at wastewater treatment facilities are escalating rapidly.

Economic Growth in the Region

The San Diego-Tijuana border region has seen high economic growth rates for the past decade. The confluence of trained human resources in this region and its presence in the Pacific Rim market area promise continued economic growth. But the two limiting factors for economic growth are water and power. There is no large-scale, indigenous fresh water resource in the border region. Except for a small amount of renewable energy, almost all energy products are imported. Economic growth cannot continue without adequate water and energy. Current limited supplies of both resources are close to stalling growth.

A healthy economy is associated with people who care about their environment. Reasonably affluent people have the resources to protect the environment and to restore that which has been abused. A limited or stagnant economy often leads to a lower quality of life with less attention paid to the environment.

Most engineering and financial organizations require only small amounts of water and power. Manufacturing activities associated with the engineering functions are more water- and energy-intensive. Certain high-tech industries consume large amounts of power for their computer systems, while others use water to cool manufacturing equipment. All these activities occur throughout the border region. In addition, each employee has a residence that consumes both water and power. These are all components of economic growth for the border region.

Air conditioning is an important aspect of economic growth. Due to earlier development along the ocean, most new construction is in hot, dry, inland areas. Occupants of these buildings demand air conditioning. There are two basic methods of providing this: evaporation of water or vapor-compression cycle machines. Evaporating water removes heat from an area and provides useful and economic cooling in the dry climate typical of the border. Since the water used in this cooling scheme must be relatively free of minerals, potable water is the best source for this purpose. Unfortunately, this technology, if widely deployed, would further strain the region's potable water supply. Electrically driven vapor compression cooling is the primary alternative to evaporative cooling. The vapor compression refrigeration device is driven by electricity but consumes no water. However, most electric power generating plants used to power the vapor compression machines do consume large quantities of water. Including the water used in generating electricity, vapor compression refrigeration uses less water than evaporative cooling.

Water Resources in the Region

The San Diego-Tijuana region has a highly diverse geography, numerous species of plants and animals, abundant sunshine, abundant seawater, but almost no indigenous sources of fresh water. The average rainfall at San Diego International Airport is less than 10 inches (25cm) per year. Mountainous regions to the east receive greater amounts of rain, while areas south, such as Tijuana, typically receive less rainfall.

The San Diego-Tijuana region has numerous water storage reservoirs. However, these man-made lakes are used for water system balancing, not to capture significant amounts of runoff from rains. Tijuana's water is stored in Rodríguez Reservoir. Water in that reservoir comes from the Colorado River and some winter flow from the Rio de Las Palmas. San Diego has numerous small reservoirs including Sweetwater, Barrett, Morena, Lake Murray, among others. To prepare for future water shortages caused by drought, earthquakes or other disasters, the San Diego County Water Authority is constructing the Olivenhain Emergency Storage Project. The dam is about 300 feet high and the reservoir will store more than 90,100af of water. The reservoir is scheduled to be complete in 2003 but it will take several years to fill to capacity. It is likely that other facilities of this type will be required to protect the growing population and business base of the border region.

Under California law, water districts like San Diego's can produce power for their own use or for sale to local governmental agencies and electricity can be produced by hydro facilities or by combustion turbines. Water agencies can produce electricity needed for water purification in their own facilities.

These facilities, if built in the proper terrain, can also be used as "pumped storage" for the electrical system. Pumped storage is a method of balancing the electrical system during a 24-hour period by "storing" electricity produced during the night and "replaying" it during the daytime. In this scheme, water is pumped from a lower reservoir to a higher reservoir during the night hours when electrical power is both plentiful and inexpensive. The water is released to the lower reservoir through generators during the high demand hours of the day, producing additional electricity for the region. No water is consumed in this process, no additional fuel is consumed for generation, no new electricity is produced, although some energy is lost due to inefficiencies in pumping and generating equipment. Pumped storage facilities have been built and are currently operating in other parts of the world. While pumped storage facilities have been proposed for the San Diego mountain region, none have proceeded into the licensing phase. This confluence of water storage and electrical energy balancing can be beneficial to a region. A drawback of such a system is the extensive use of land.

Orange County, California, currently relies on a local aquifer for part of its water balancing system. Maintaining the aquifer requires the addition of 300,000af per year. By 2020 the water authority will have to add an additional 150,000af per year into the aquifer both to meet demands for the water and to maintain a supply for drought years. To accomplish this mission, authorities have proposed an ambitious project—the Groundwater Replenishment System—that will produce a reliable supply of high-quality, low-salinity water (Mills 1999). By 2020 this system will reclaim 100,000af of wastewater per year. The reclaimed water will be pumped upstream to settling basins where it will re-enter the aquifer. The project will use the latest membrane processes, including microfiltration and reverse osmosis, and will be applied after conventional water treatment. Orange County estimates water produced by this process will require 1,470kWh/af. This is a marked reduction from the 3,200kWh required to import northern California water or the 2,200kWh required for Colorado River water. Other border municipalities could implement similar technology to increase their supplies of potable water.

Energy Resources in the Region

The border region has few traditional energy resources. While oil, natural gas, and coal have been developed within a reasonable distance, there is little commercial development in or near the region. Few electrical generating facilities were located in or near the region until recently. Recent changes in the western border region include the repowering of the Rosarito power station with modern gas-fired, combined-cycle equipment. This change alone will significantly improve the air quality in Northern Baja California, especially in Rosarito. Several other new power plants are being proposed including one in Otay Mesa (500 megawatts [MW]) near San Diego. Two plants are under construction in Mexicali (750MW and 300MW). A new natural gas transmission pipe to supply the fuel to these plants is being built.

Non-traditional or renewable resources are relatively abundant in the border region, although they are thinly deployed at this time. For example, the entire border region has abundant sunlight. Due to generally cloudless skies, photovoltaic and solar water heating systems have greater economic payback in this region than in almost any area of the United States. As well, geothermal resources are abundant in the California-Mexico border region. While the quality of the resource (temperature and mineral content) is not as high as some would like, it can be economically developed and managed. Additional geothermal generators with the combined capacity of several hundred megawatts can be added without imperiling the vitality of the resource. Wind generators, which produce electricity at a competitive price of between \$0.04 and \$0.05 per kilowatt-hour, can be installed in selected areas of the border. However, some people object to the noise and visual "pollution" of wind generators.

Manufacturing facilities and offices along the border generate significant quantities of waste paper and wood. While most is recycled into new paper and cardboard, some of the waste can be used as fuel in electrical generating plants. Combustible waste from border agriculture and industry, called biomass, can be burned to produce electricity, if properly sorted. Collection and preparation costs of the fuel result in relatively high-priced electricity.

Methane from wastewater treatment plants is burned as fuel in limited instances in the border region. Greater use of this relatively clean fuel should be encouraged. Used automotive tires, shipping pallets, and other waste is often used as fuel in small facilities today, but should be discouraged until new technologies are developed to reduce the extensive amounts of air pollutants generated.

Preserving Natural Resources in the Region

The border region has one of the more fragile ecosystems in the world. Abundant flora and fauna exist in a delicate balance with nature due to high summer temperatures, cold winter temperatures in some areas, and generally dry conditions. The low rainfall creates conditions in which the soil often lacks nutrients and materials needed to retain moisture. While plants and animals have adapted to these conditions, human intervention can quickly upset the balance. The impact of water development on the environment is well-documented. Energy development can have similar effects on the natural resources of the border region.

While every human action has an effect on the environment, some are more significant. Geothermal power production, with proper controls, can be beneficial. However if the brine is not re-injected into the ground and is instead spilled onto the ground, the ground and water resources are fouled. This results in catastrophic loss of plant and animal life. In a like manner, the development of coal bed methane can result in the loss of water supplies and the pollution of groundwater. Overall, the development of any water or energy resources must balance the needs of humans with those of the environment.

Electrotechnologies for Water Purification

The California Energy Commission (CEC) has estimated that total energy used to pump and treat water in California exceeds 15,000 gigawatt hours (GWh) per year, or at least 6.5% of the total electricity used in the state per year.

Potable Water Transportation and Treatment

Extensive canals and pumping facilities transport potable water to the California-Mexico border region. Pumping water from the Colorado River through pipes and canals is energy intensive. The Orange County Water District estimates 2,240kWh of electricity is required to move one acre-foot of water from the Colorado River to the Los Angeles Basin, and 3,240kWh is required to move the same quantity of water from northern California via the State Water Project (SWP) to Los Angeles.

The SWP delivers approximately 3MAF of water per year. Some 70% of this water is destined for cities and 30% for agricultural purposes. The SWP generates, buys, and sells electricity to balance its energy needs throughout the state. In 1996 the SWP paid $192 million for its net energy needs. It has a Capacity Exchange Agreement with Southern California Edison (SCE) under which the SWP supplies up to 412,500 megawatt hours (MWh) of energy to SCE during peak hours and Edison returns 110% of the energy received during mid- and off-peak hours.

Combining the energy load of the SWP (5.7 million MWh) with that of the California Department of Water Resources (4.6 million MWh) results in a total electricity load of 10.3 million MWh for delivering water (California Department of Water Resources 2001).

Approximately 1,100MW of installed electrical generating capacity is currently needed to move water from its source to California towns. For perspective, that is about the output of one large nuclear reactor. Pumping the additional water required in the San Diego-Tijuana border region by 2010 will require another 50MW of capacity. This additional requirement for power can be met with one medium-sized gas-turbine power generator burning natural gas. Unfortunately the region has extremely limited natural gas pipeline capacity and the price for natural gas has escalated recently.

Potable Water Technology

Potable water is treated with various processes, including flocculation and chlorine. These conventional processes consume about 30kWh/af. It is likely that the use of chlorine for water purification will be either limited or eliminated entirely in the future. To replace this method of purification, water scientists are developing the use of UV light radiation and ozone gas to eliminate harmful bacteria in water. Each of these two methods has had successful tests and is in the deployment stage. Each method is considerably more energy intensive than the use of chlorine. Other new processes are reverse osmosis and microfiltration. There are also two advanced filtration technologies: nanofiltration and ultrafiltration.

UV light is used to inactivate viruses and bacteria by causing a photochemical breakdown of the cellular nucleic acids within the target organism. This prevents the DNA within that organism from replicating. UV treatment is especially effective against *Giardia* and *Cryptosporidium*. This technology is used for the treatment of both potable and wastewater. Several facilities employing this technology are in routine operation. However, UV systems use an additional 5kWh/af of water treated. Considerable research is underway to apply UV light in the most complete and economical manner. Energy reduction and longer lamp life are two goals of that research.

Ozone treatment of water improves disinfection, reduces or eliminates the formation of harmful byproducts of chlorine, enhances the coagulation process, and improves the color, taste, and odor of water. There are about 100 ozone treatment facilities in use in the United States and about 50 more are scheduled for construction. These facilities typically use 72kWh/af. Most of the electricity is used for the ozone generator. All ozone treatment devices include a subsystem to destroy excess ozone to prevent release into the air.

Reverse osmosis is a water purification technique that forces water through thin membranes. Until recently this process employed energy-intensive high pressure, but new membrane technology has reduced the pressure required. Nonetheless, energy costs are still high, ranging from $0.55 to $0.65 per 1,000 gallons. Some have estimated the cost to treat wastewater is as high as $3.75 per 1,000 gallons. Cost numbers vary greatly due to plant capital costs and use factors. This great variation in numbers is also indicative of a changing technology base.

In a 1995 test, the city of El Paso, Texas, demonstrated reverse osmosis that reduced the salinity of groundwater and Rio Grande water to less than 100 milligrams per liter (mg/l) from levels as high as 2,700mg/l. Reverse osmosis can be an effective method of reducing total dissolved solids common in high concentrations in aquifers in this region. The city of Harlingen, Texas, treats its wastewater for solids and then runs it through a reverse osmosis unit before selling the water to a cotton washing and dying facility. The facility has been expanded to a capacity of 4 million gallons of water per day.

Other membrane systems have been developed for desalinization. Torray Engineering Co. of Japan is working on a multiple-filter reverse osmosis arrangement for seawater desalinization (*Nikkei Weekly* 1997). The system uses pressures of up to 990 atmospheres to recover up to 60% of the original seawater as fresh water. The estimated cost is $6.50 per 1,000 gallons. However, one of the problems associated with seawater desalinization is the disposal of the concentrated brine that remains after the fresh water has been extracted. In many cases it is too concentrated to be returned safely to its source.

Wastewater Transportation and Treatment Technology

Wastewater treatment plants using modern technologies are producing relatively high-quality water that can be used for many purposes, including landscaping, industrial cooling, and power plant cooling. Wastewater facilities use many of the technologies discussed above. The international wastewater treatment plant at San Ysidro, California, is producing 26 million gallons of treated water per day. A Mexican plant in the border region treats 20 million gallons of wastewater per day. San Diego has built a modern wastewater reclamation facility that can handle 25 million gallons per day. However, according to a recent report, it was only selling 3% of the water it produced (Baliant 1999); 7% went to facility operations and landscaping and the remaining 90% was returned to the wastewater system to be retreated by another wastewater treatment plant before being dumped into the ocean. The cost to produce the reclaimed water in the San Diego facility is estimated to be between $310 and $990 per acre-foot depending on how grant and incentive monies are allocated. The cost of Colorado River water in 1999 was $434/af. Obviously, governments must find more buyers for high-quality reclaimed water.

Electric Generation Water Needs and Impacts by Generation Technology

Water is a constraining factor for energy development. The Electric Power Research Institute projects inadequate water supplies will limit energy development nationally by 2038. Specific areas could realize that limit sooner.

Gas Turbine Combined-Cycle Generators

Electricity generation can consume large quantities of water. Most new electricity generation plants use gas turbine, combined-cycle (GTCC) technology. This technology combines a modern gas turbine engine with a conventional steam generator. The exhaust heat from the gas turbine provides the thermal energy to create steam for the steam generator. In some applications, additional fuel is burned in the gas turbine exhaust stream to further increase the steam temperature, thereby increasing power output and efficiency. The gas turbine engine itself requires essentially no water to operate as all major components are air-cooled. Almost all the unused energy (waste heat) exits the engine in the exhaust stream. This unused energy flows through a tube bundle called a “heat recovery steam generator” (HRSG). The steam produced by the HRSG turns a steam turbine that in turn drives an electrical generator. Steam turbines require highly purified water to make steam. Therefore, the steam used in the expansion process must be recovered and reused. The steam is returned to the liquid state in another heat exchanger called a condenser. Most often the condenser is cooled with another stream of less purified water, called “cooling water,” with characteristics similar to ordinary tap water. As the cooling water condenses and cools the steam used in the turbine, it vaporizes and is released into the atmosphere. Almost all of the cooling water is lost. The small amount of water remaining contains a highly concentrated blend of the minerals that were in the original cooling water stream.

There are two major water/energy issues in this form of electricity production. First, the cooling water required by a modern GTCC is 1,000af of water per 100MW of power. More than 20,000MW of new power plants could be built in California to meet demand in the next 10 to 15 years. Perhaps as many as 5,000MW of new power could be generated in plants built in Baja California in the same period. If all this power were generated using GTCC technology with water-cooled condensers, California and Baja California would have to supply 200,000af and 50,000af of water, respectively, to these facilities. The new power plants alone would consume enough water to supply a city of 2 million people.

The second issue raised by new power plants is the disposal of the small amount of water that remains after the condensing process. The remaining water contains high concentrations of minerals found in normal tap water, but the concentrations are high enough to cause a disposal problem. SWP water contains magnesium at levels of 7 parts per million (ppm) to 15ppm. In most cases, power plant owners have applied for EPA permits to dispose of this brine in a dry well.

There is an option for the operator of a water-cooled GTCC to avoid disposing of the concentrated cooling brine. Technologies exist that could extract all the water from the brine. The result is water that can be reused in the cooling process and a “dry cake” of minerals that can safely be disposed of in approved landfills. But this option is expensive. To reduce the cost, operators can extract valuable minerals from the dry cake. For example, at the La Paloma power plant project the projected dry cake contained 5% magnesium by weight. The magnesium in the dry cake is a valuable resource and was valued at nearly $1.50 per pound in early 2001. The auto industry is planning to incorporate hundreds of pounds of magnesium into each vehicle in the near future to reduce vehicle weight and thereby increase fuel economy. Recovery of this metal might more than offset the cost of using the dry cake technology. To be cost effective, large metal recovery plants need to be built and several power plants in one region need to supply the dry cake to the one recovery plant. Several builders of new power plants would have to agree to use this process to make it economical.

Both of the aforementioned issues can be resolved by using forced air to cool the spent steam in the combined cycle plant. Air cooling is a proven technology. It requires no water and therefore has no wastewater with high mineral concentrations for disposal. Unfortunately there is a price to pay: Water is a very efficient coolant while air is not, thus air condensers must be considerably larger than water condensers. This is both an initial cost problem and a visual pollution problem. For a major power plant, the air condenser is comparable in size to a large aircraft hangar. In addition, air condensers require relatively large quantities of electricity to power the air blowers. Because of these factors, the air-cooled GTCC is 3% to 4% less efficient than a water-cooled GTCC. This is equivalent to a 6% to 8% drop in total plant efficiency. The combination of high initial cost and higher operating cost results in higher priced electricity.

The large water-cooled GTCC power plants use large amounts of water. In California, power plant operators are required to use processed wastewater where available. However, some citizens object to the use of wastewater in condensers because they fear the possibility of the spread of a virus or bacteria that could be released during evaporation. Most experts find this fear unfounded. While use of treated wastewater is highly desirable for power plant cooling, that water could find other uses displacing the use of potable water. At one power plant in the high desert region of Southern California, the applicant proposed using treated wastewater only to find that all such water had been committed to enhancing the wetlands of the area. Subsequently the applicant chose to buy potable water for condenser cooling, which added considerable operating cost to the project. However, in most areas there is excess treated wastewater suitable for industrial and landscaping uses.

The use of water in modern power generation plants creates many issues and possible solutions. Every potential site for a power plant has a different water infrastructure. Community planning should promote power plants being sited near sources of treated wastewater.

Nuclear Power Generation

While no new nuclear power generating facilities are currently being proposed, nuclear power is likely to gain increased popularity and there are several reasons why. First, the U.S. Department of Energy is likely to approve a high-level nuclear waste facility, an action that must be taken before any new nuclear facility can be built in the near future. Second, requirements to reduce atmospheric carbon dioxide (CO_2) are being raised. Fossil-fueled power plants are a major contributor to atmospheric CO_2. Nuclear power plants contribute to the CO_2 problem only during construction when large quantities of concrete are cured. Third, there is a need for greater fuel diversity. Fourth, while capital costs for nuclear plants are high, operating costs are below $0.02 per kilowatt-hour. This is a lower cost than the cost of electricity produced by coal.

If nuclear power plants are built in the border region, local water resources may be heavily taxed. Nuclear power generators have very large cooling requirements. While the GTCC technology is about 55% efficient, today's nuclear power plants are only 33% efficient. The higher the efficiency, the less waste heat is rejected in the condenser. Nuclear power plants reject 67% of the heat produced by the fission process. While it is technically feasible to use air cooling, California's nuclear power plants rely solely on ocean water cooling since most areas do not have sufficient fresh water for reactor cooling. Air cooling for nuclear reactors requires extremely massive structures with large parasitic power losses. Ocean water cooling heats the ocean in the immediate area of the cooling water return pipe, increasing turbidity and changing the local ecology. In addition, fish and mammals can be harmed by the water intake system if it is not properly engineered to prevent ingestion.

Hydroelectric Power Generation

Damming rivers to create reservoirs for hydroelectric generators can have both positive and negative social and ecological effects. Because of the lack of significant surface water resources along the U.S.-Mexican border, the possibility of dealing directly with such effects is rather remote. However, California receives about 23% of its electricity from large and small hydroelectric facilities located elsewhere. Any change in hydroelectric facilities in California could impact the electricity or water situations along the border. Some environmentalists advocate the removal of hydroelectric facilities to enable the restoration of salmon and other fish to their natural habitats. Removing these facilities could reduce the amount of electricity and potable water available for use elsewhere.

Increasing the use of wild-river hydroelectric power could also have deleterious effects on water and electric power. Over-dependence on hydroelectric power causes severe shortages of electricity when there is a dry weather cycle such as the severe spring 2001 drought in the Pacific Northwest and the northern Sierra. Power plant operators had to reduce electricity output to manage the available water for environmental protection and potable water. Power that would have been transmitted to California was not available. This puts additional stress on other power generation plants.

Renewable Energy

Renewable energy sources have varying needs for water. Solar photovoltaic and wind generators require no water to operate and have no impact on water availability or quality. Biomass power plants can have a significant effect on water availability and quality. Biomass power plants most often use the Rankine or steam cycle for power production. The water internal to the process is recycled. However water is needed for the steam condenser. In this way biomass power plants are similar to GTCC power plants. Both biomass and GTCC power plants have the same problems of water requirements and residual water disposal. Air-cooled condensers can be used on biomass power plants, but the cost of the fuel combined with the cost of the air-cooled condenser makes this combination prohibitively expensive.

Geothermal resources are abundant on both sides of the California-Mexico border. Power plants using geothermal energy employ the Rankine or steam cycle and require water-cooling of the condenser. Some of the cooling water can come from the spent geothermal steam. The major water quality issue with geothermal energy development is the disposal of the spent resource. In the border region the resource consists primarily of superheated brine, a hot liquid containing high concentrations of salts and minerals. In a geothermal power plant, the brine is “flashed,” producing the relatively pure steam used to drive turbines. In some cases, multiple flash steps are employed to maximize the energy recovered from the brine. Large quantities of brine remain after flashing. The best method of disposal is to return the spent brine to the underground areas where the brine originated, as is done in the California’s Imperial Valley. But it requires large amounts of energy to pump the brine back into the ground. If the brine is not returned to an underground reservoir, large amounts of salts from the brine accumulate on the surface. These deposits pose a possible risk to surface water supplies and surface soil quality. Recent advances in geothermal technology allow operators to “mine” the spent brine for economically valuable minerals. Zinc is being removed from the brine in the Imperial Valley at a cost competitive to a conventional zinc mine. Other valuable substances can also be removed from the brine to increase power plant revenue. Some of the increased revenue can be applied to proper disposal of the spent brine.

Fuel Diversity

Almost all power plants proposed in California and the western end of the U.S.-Mexican border region are fueled by natural gas. The increased use of natural gas in power plants throughout North America is causing major changes in the supply and price of this fuel. The Gas Technology Institute predicts the United States will import natural gas from outside North America by the year 2010. This gas will arrive at U.S. or Mexican ports as liquid natural gas (LNG). El Paso Natural Gas and others have announced their intention to locate LNG facilities in Baja California, possibly in Ensenada. Importing natural gas in this manner reduces energy security and can increase fuel costs. While LNG has been delivered safely to other countries for decades, many fear the possibility of a catastrophic explosion of a supply ship while in the harbor. These fears will drive considerable policy debate in both the United States and Mexico. Experts estimate that a sustained price of $3.50 (in 2000 dollars) or more per million British thermal unit (Btu) is required to import LNG.

Natural gas supplies will be a critical issue by 2010. Energy security and the safety issues associated with LNG are likely to drive the public debate toward a more balanced and diverse energy supply. It is likely many future power plants will use renewable or nuclear resources as fuel. At this point it is not clear that renewable energy resources alone can supply the quantity of power needed by 2010.

Non-traditional methods of securing natural gas supplies are now being used in the United States. About 6% of U.S. natural gas is being produced from underground coal beds where the gas is trapped in the coal formation by an overburden of water. Developers drill wells and draw down the water level to increase the flow of gas from the coal strata. There are several associated effects of this extraction method. First, the ground water level recedes, causing many wells in the area to go dry. The local aquifers may be permanently damaged, eliminating farming and ranching in those areas. Second, the water produced by this method is often laden with undesirable minerals. Usually that water is disposed of in nearby creeks and rivers, causing damage to local fish and wildlife populations. Until adequate research is undertaken to fully assess the impact of this form of energy development on water supplies and other parts of the environment, development of coal bed methane should be avoided in the water-short border region. Damage to any aquifer would have long-term effects on border residents' quality of life. Coal bed methane has been identified as a resource in the eastern end of the Texas-Mexican border region.

Effects of Natural Gas and Oil Shipment and Use on Water

Natural gas is supplied to the border area by long-distance pipelines. Except for small amounts of landfill gas, no natural gas is locally produced. The major impact of natural gas on water resources is the disruption of the surface environment when the pipes are installed.

Natural gas does contain measurable amounts of sulfur oxides. When natural gas is consumed in power plants, home heaters, industry, and the like, sulfuric acid can be produced in the atmosphere and subsequently dropped into fresh water rivers, reservoirs, and watersheds. This has not been a significant problem in the border region to date.

Due to increased demand for natural gas in the western region of North America, some companies are now proposing to build docking facilities for ships importing LNG. The docking facilities would include heat exchangers to gasify the liquid and pressurizing equipment for pipeline transportation. The gasification process absorbs large quantities of heat and thus could produce low-cost air conditioning or refrigeration. The equipment to pressurize the gas for pipeline transportation requires large quantities of energy. An alternate transportation system would have heavy trucks take the LNG to the user.

Petroleum is widely used in the border region for transportation. Almost all petroleum products are produced elsewhere and supplied to the area via ocean-going tankers, pipelines, or truck transport. The use of petroleum can lead to degradation of local aquifers, watersheds, and ocean habitats. Oil dripped on pavement by vehicles is the primary cause of seawater fouling from petroleum. Rain or irrigation water carries the oil from the streets into storm drains; from there the oil travels with the water into the ocean. Leaking petroleum storage tanks are another mechanism for fouling groundwater.

Oxygenating additives to gasoline, specifically MTBE, are particularly troublesome when they penetrate groundwater supplies. The human nose can detect extremely small quantities (parts per billion) of MTBE in drinking water. In addition, it is difficult to remove this chemical additive from groundwater supplies. If developers were to start to drill for oil and gas in the coastal waters off the border there would be a potential for water pollution from drilling mud and petroleum liquids. However, technology is now in place to control those fluids during seabed drilling. One company, Newpark Resources, accepts and processes about 10,000 barrels of such waste per day (Lyon 2000).

Overall, storage, transportation, development, and use of petroleum and natural gas can have detrimental effects on border water resources if not properly handled.

Potential Outcomes and Solutions

Potential Outcomes

Water and energy are two major requirements for a healthy environment and economy. If local and regional governments do not take aggressive action to improve the use of water and energy in the border region, economic development and growth will be halted and residents' quality of life will be impaired.

There is no question that large sums of time and money will be required to resolve the limitations on water and energy in the border region. New water purification technologies can be energy-intensive. Fortunately technology and clever engineering are being developed that, if intelligently employed, could provide solutions. For example, in the new Olivenhain water storage reservoir in northern San Diego County, static water head pressure provides all the energy necessary to operate new microfiltration devices. No electricity is used for this purpose.

Each community in the border region must be creative and adapt general solutions to the local water and energy problems. The requirements of time and money can be reduced when knowledge and experience are shared.

Potential Solutions

- GTCC power plants can use large quantities of water to cool the condenser, so as the need for power grows, power plant operators may have to find other sources for cooling than potable water
- Use treated wastewater wherever possible to cool condensers and other industrial equipment
- Reduce the condenser effluent to dry cake to recover and reuse as much water as possible
- Develop technology to recover cooling water from the exhaust stream of gas turbine generators
- Use dry cooling technologies if no other water source is available
- Implement renewable power sources such as photovoltaics and wind generators that require no water for operation

Water treatment technologies are becoming more energy-intensive. On balance, the use of these new technologies will provide higher quality potable water and will reclaim more wastewater for reuse. This beneficial use of electricity must be figured into future power demands.

Potable Water Solutions

- New water sources must be found to serve the growing needs of the border region. In the San Diego-Tijuana border region there are no obvious conventional sources of water that have not been developed. Conservation measures should be deployed first to reduce the need to pump potable water and wastewater. In that way, the region will also save electrical energy.
- A water resources conservation plan must be developed. A con-

servation program should focus on locating and stopping leaks and continuing to install low-flow water appliances. These elements alone can drastically reduce domestic water consumption. In some regions leaks in the water transmission and distribution systems and in users' facilities can account for 50% of all consumption. "Mexico City's leaks could supply a city the size of Rome" (Gleick 2001). Controlling leaks is not glamorous science, but it makes excellent economic sense.

- Agricultural activity varies greatly within the border region. Where agriculture and dairy industries are intense, the availability of good quality water is a major issue. Planting crops that require less water should be investigated in every farming area. Once these crops are selected, farmers should install modern drip or micro-sprayer irrigation systems. Technicians have demonstrated a 40% reduction in water use on tomato crops using drip irrigation (Gleick 2001). While most farmers use gravity-feed irrigation systems, farmers as a group spent $1.2 billion on various forms of energy in 1995 to pump water from its source to crops (U.S. Bureau of Census, Agriculture and Financial Statistics Division 1996).
- The people in the border region must find a means of using highly treated waste water to replace all uses of potable water that do not compromise human health. The remaining treated water should be used to recharge the local aquifers. A method to increase the quality of processed wastewater before returning it to aquifers has been developed for Orange County. Scientists estimate the returned water will remain in the ground for at least two years before being pumped out. Currently this water resource is being disposed of in the ocean.
- Communities should develop power plants and water process ing plants in close proximity. They should install technology to reclaim the water and heat energy in the exhaust of generating plants. When natural gas (methane) burns in those facilities the by-products in the exhaust are carbon dioxide and water. Over two pounds of water are produced for every pound of fuel. As the efficiency of the power plants increases, the exhaust temper ature decreases, making it easier to condense the water in the exhaust. While this may not be a large source of water, it may

be enough to supply the needs of the power plant itself. The unused heat in the exhaust of a power plant can be used to accelerate water evaporation in evaporative desalinization of brackish water or sea water. Alternately, the unused heat could be used in other water purification processes.

- "Distributed water-processing technology" should be developed for use in the border region. Potable water and wastewater services should be coordinated. Coordination of water and wastewater services through decentralized treatment and reclamation facilities can significantly reduce energy costs and can provide reclaimed water where needed for green areas and natural areas. The core of this concept is to reclaim the water at the site of its first use. Local processing not only reduces the total consumption of water, it also reduces the electricity needed to pump the water to a recycling center and back to end users.
- So-called "gray" water effluent—water that has been used in showers, basins, and washing machines—produced by residences should be recovered and re-used. In small villages or neighborhoods one could recover and upgrade this water to potable water standards in a community processing center. Very small users in remote areas could use solar-powered passive stills to reclaim brackish or gray water. Stills of this type are commercially available at a relatively low cost. With the appropriate technology, large office buildings or industrial facilities could have an onsite water processing facility. At least one building that housing 60 workers has such a facility (*Business Week* 2001) where approximately 900 gallons of wastewater per day are treated in a 2,800 square foot courtyard next to the office. The reclaimed water is used for outside landscaping and toilets in the building. The water is treated in a garden setting in which plants and organisms work together to break down noxious substances. Other plants consume any remaining nutrients before the water is reused. Using water several times before disposing of it can greatly reduce the need for new sources, allow economic expansion to continue in the border region, and consume less electricity overall. The displaced electricity can then be used for economic expansion.
- Wastewater processing plants produce off-gases that are pre-

dominately composed of methane. These combustible gases are used to produce electricity at many processing facilities. Distributed wastewater treatment facilities could provide some of their electricity needs by using this source of energy.

- Desalination technology has advanced significantly in the past decade. The amount of energy needed in desalination processes is no longer as high as it once was. The technologies employed now are low-pressure, reverse osmosis and micro-, ultra-, and nanofiltration. Capacitive deionization is a promising new technology. The salinity of Colorado River water delivered to the border region currently exceeds the standards for human consumption. To reduce salinity, the Metropolitan Water District in Los Angeles mixes Colorado River water with water from the State Water Project. In the foreseeable future the water districts may have to employ desalination technology to "fresh" water supplies to meet minimum standards. Low energy, desalination technologies also could be used to upgrade other sources of brackish water. Farmers often reuse water until the water leaches enough salts from the soil to be unusable for irrigation. That water could also be processed for additional uses in the fields.
- Public funding for water-related research and development should be increased. Research and development should emphasize reducing energy input to water purification processes. Other areas of emphasis should include methods to increase the use of reclaimed water, especially at decentralized water treatment facilities. Some thought should be given to the convergence of distributed energy systems with distributed water treatment.

Conclusions

Water and energy have a strong interdependence. Both resources are vital to the growth and well-being of the border region, and both are in limited supply. Communities must be proactive in the selection, design, and placement of capital assets used to provide these resources. New technologies must be carefully evaluated and selected on the potential benefits and negative effects in the affected community. No community should plan the expansion of facilities for one resource without first evaluating the effects on the provision of the other resource.

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IV

The Geography of Energy at the U.S.-Mexican Border

Martin J. Pasqualetti

Abstract

Ten state and two federal governments have been working for several years to set the stage to convert the U.S.-Mexican border into a 2,000 mile-long economic development zone, complete with new jobs, better living conditions, and more promise for the millions of people who live there. The most recent and most promising initiative focuses on the one commodity that can make everything else possible—energy. Much rides on the success of this large venture. What will result from these efforts? Is it possible to rescue the border from its present muddle by hitching it all to energy development's rising star? No one knows the answers to these questions but the experiment is about to begin, and after many years of preparation, energy projects are multiplying quickly in several forms, including power plant construction, new transmission lines, and new natural gas pipelines. Everyone, from border residents to energy-dependent maquiladoras and energy-desperate Californians, hopes it all works out favorably.

There is still much we must learn before the dreams of energy development, energy trade, and energy corridors can come true. The first step in that process is to concentrate not on considerations of price, technology, or politics, but on geography. It first needs to be

known, whether energy reserves are available, where they are located, where they are needed, and what routes can be used to get them from one place to another. Also strongly geographical are considerations of the environmental impact of acquiring, moving, and using the energy. All these questions exist within the fundamental geographical characteristics of the natural, cultural, and political landscapes tied to specific places. For any location, these elements comprise its geography of energy.

Both countries envision great rewards from closer energy ties in the form of more power, jobs, improved living standards, and better foreign exchange. Certainly, with the exception of the oil industry, the energy ties are fairly small at present. Small amounts of electricity are traded but a great increase is planned. More energy moves back and forth across the border in the form of natural gas, and this is also projected to increase substantially, but the volume of natural gas being moved between the countries now is small compared to the trade between the United States and Canada.

Several scenarios of cooperation are already being played out, including gas-fired plants that generate power for Mexico with fuel from the United States and gas-fired plants that generate electricity for both countries using U.S. fuel. A third is taking shape as a new plant being constructed by a U.S. company near Mexicali, which would be the first in Mexico to be entirely foreign-owned and -operated. Normally this is not permitted, but this plant is exempt from the ownership requirement because it will not serve Mexican consumers. Building power plants in Mexico for U.S. consumption is rapidly increasing in popularity because the necessary building permits can be acquired in six months, while it takes 12 to 18 months or longer in California. This pattern may repeat itself along the entire border.

Location is a key element in establishing closer ties between the two countries. Where will the power plants be positioned? Where will the pipelines and transmission towers be placed? Should energy corridors be encouraged, and should they be near the cities or isolated?

No one can answer these or many other questions because there is no coordinated or comprehensive energy development plan to follow. Both countries seem content to unshackle entrepreneurial zeal, aim it at the border, and hope for the best.

La Geografía de la Energía en la Frontera México-Estados Unidos

Martin J. Pasqualetti

Resumen

Los gobiernos de diez estados y dos gobiernos federales han venido trabajando por varios años para montar el escenario que convierta a la frontera México-Estados Unidos en una zona de 2,000 millas de desarrollo económico, con nuevos empleos, mejores condiciones de vida y más porvenir para los millones de personas que allí viven. La iniciativa más reciente y más prometedora se enfoca en el producto que puede hacer todo lo demás posible—la energía. Mucho depende del éxito de esta gran empresa. ¿Qué va a resultar de estos esfuerzos? ¿Es posible rescatar a la frontera de su actual desorden enganchándola toda a la estrella naciente del desarrollo de la energía? Nadie sabe la respuesta a esta pregunta pero el experimento está por empezar. Luego de muchos años de preparación, los proyectos de energía se están multiplicando rápidamente en varias formas, que incluyen la construcción de plantas de energía, nuevas líneas de transmisión y nuevos gasoductos de gas natural. Todos, desde los residentes de la frontera, hasta las maquiladoras dependientes de la energía, y los californianos desesperados por la energía, desean que todo resulte favorablemente.

Todavía hay mucho que se deb aprender antes que los sueños del desarrollo de la energía, comercio de la energía y los corredores de la energía puedan ser una realidad. El primer paso en dirección a ese proceso no es concentrarse en las consideraciones de precios, tecnologías, o políticas, sino en la geografía. Lo primero que se tiene que saber es si existen reservas de energía disponibles, en dónde están ubicadas, en dónde son necesitadas, y qué rutas se pueden usar para hacerlas llegar de un lado a otro. También son fuertemente geográficas las consideraciones del impacto ambiental para la adquisición, traslado y uso de la energía. Todas estas preguntas exis-

ten dentro de las características geográficas fundamentales de los contornos naturales, culturales y políticos que están atados a lugares específicos. Para cualquier lugar, estos elementos comprenden su "geografía de la energía."

Ambos países anticipan grandes recompensas a partir de los vínculos de energía más estrechos, en la forma de más energía, empleos, mejores estándares de vida y mejor comercio exterior. Ciertamente, con la excepción de la industria petrolera, los vínculos de energía son bastante reducidos actualmente. Pequeñas cantidades de electricidad son comercializadas, con un gran aumento planificado. Más energía se desplaza de un lado al otro de la frontera en la forma de gas natural, y esto también está proyectado en aumentar substantivamente, pero el volumen de gas natural que ahora se desplaza entre los países es actualmente bajo comparado con el comercio entre los Estados Unidos y Canadá.

Son varios los escenarios de cooperación que están en marcha, incluyendo plantas que generan energía gas para México con combustible de los Estados Unidos y plantas que generan electricidad a gas para ambos países usando combustible estadounidense. Un tercer escenario está cobrando forma con una nueva planta que está siendo construida cerca de Mexicali por una compañía estadounidense, la primera en México en ser totalmente propiedad de y operada por extranjeros. Normalmente esto no está permitido, pero esta planta está exenta de este requerimiento porque no va a servir a consumidores mexicanos. La construcción de plantas de energía en México para los consumidores estadounidenses es más rápida que en los Estados Unidos debido a que todos los permisos necesarios para la construcción pueden ser obtenidos en seis meses, mientras que esto toma de 12 a 18 meses o más en California. Este patrón bien puede repetirse a lo largo de toda la frontera.

La ubicación es un elemento clave en el establecimiento de vínculos más estrechos entre ambos países. ¿En dónde serán colocadas las plantas de energía? ¿En dónde serán colocados los gasoductos y las torres de transmisión? ¿Se debe fomentar los "corredores de energía"? ¿Debe estar estos cerca de las ciudades o en lugares aislados?

Nadie puede responder a estas preguntas o a muchas otras porque no hay un plan de desarrollo de energía que seguir que sea coordinado y comprensivo. Ambos países parecen satisfechos con desencadenar el entusiasmo empresarial, dirigirlo a la frontera y esperar lo mejor.

Introduction

With deliberate purpose and unaccustomed speed, ten states, two federal governments, and dozens of energy companies have been moving for several years to convert the U.S.-Mexican border into a 2,000 mile-long economic development zone, complete with new jobs, better living conditions, and more promise for the millions of people who live there. The most recent and promising initiative focuses on the one commodity that can make everything else possible—energy. The plan is to create a reliable, profitable, and integrated system for development and trade between two energy-rich and energy-reliant countries, and to inject this system with such buoyancy and momentum as to raise the border economy and reverse its downward trajectory. What will result from these efforts? Is it possible to rescue the border from its muddle by hitching it all to energy development's rising star?

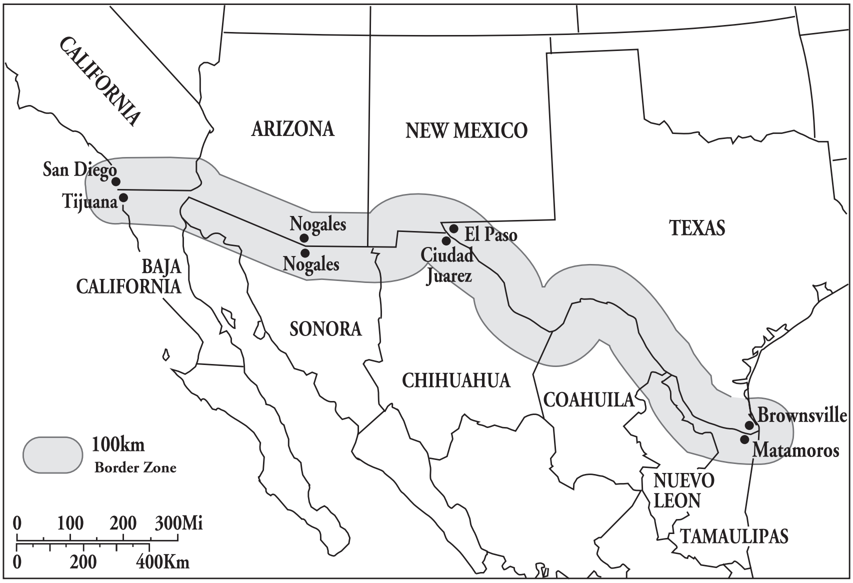
The answers to these questions may not be apparent for years, but the experiment is about to begin. There is such hope and promise for an energy boom along the border that leaders of both countries are speaking optimistically about the prospect. An article in *Borderlines* (2000) reported that: "In his February summit with Mexico's new president, Vicente Fox, [U.S. President George W.] Bush called for cross-border cooperation in the production and distribution of energy. That involves opening Mexico to private foreign investment to develop its oil, natural gas, and electric industries and smoothing the way for the transfer of energy resources to the United States. Fox has nodded his approval and spoke during the summit of a 'new vision' of cooperation in the development of a regional energy policy."

Everyone is rushing to board the borderland's energy train. In fact, officials of the Texas Railroad Commission and Mexico's Comisión Reguladora de Energía (Energy Regulatory Commission, in Spanish, CRE) met in September 2000 to discuss how they can best cooperate to promote the construction of a U.S.-Mexican gas infrastructure (Mexican Intelligence Report 2001). Mexico energy agencies have been restructured, international agreements have been approved and implemented, utility and construction companies are bidding new jobs, and even private citizens are seeking the gold ring of this anticipated energy bonanza. Present, but far in the background, others voice their concern about what all this will mean for the environment.

There is still much to do before the dreams of energy development, energy trade, and energy corridors can come true. The first step is to concentrate not on considerations of price, technology, or politics, but on geography. Leaders need to know whether energy reserves are available, where they are, where they are needed, and what routes can be used to get them from one place to another. Also strongly geographical, the environmental impact of acquiring, moving, and using the energy should be considered. All these questions exist within the fundamental geographical characteristics of the natural, cultural, and political landscapes tied to specific places. For any location, these elements comprise its “geography of energy.” This chapter addresses the matters of supply, transportation, and demand of energy that have bearing on the mainland border states.

The border between the United States and Mexico functions in three ways (Figure 1). First it is a 100 kilometer-wide area where millions of people live under the economic and social conditions characteristic of their home country, yet are uniquely influenced by proximity to the other country. Second, the border acts as a “moat,” constructed by history and maintained by governments, that must be crossed if international trade is to proceed at a meaningful scale. Third, the border is a line on a map to which the movements of water and air pay no attention.

Figure 1. U.S.-Mexican Border Region



Source: U.S.-Mexico Chamber of Commerce

Geographies of energy are inherently complex systems with elements of diverse origin brought together by the expectation of trading supply for profit. Such movement and trade is necessary because the quantity and variety of energy resources used in a place only uncommonly match what is available locally. Instead, spatial disequilibrium of supply and demand is the norm. For this reason, the first step to meeting energy demand is to find where the energy resources are located. Because they are only rarely nearby in sufficient abundance, the second step is to assemble a plan for securing a continued and affordable supply, a task that often requires a delicate diplomatic touch. The third step is to evaluate the environmental costs associated with securing and maintaining this supply and judging whether they are costs that we are willing and able to afford.

These three steps are usually taken simultaneously, inevitably within a mix of jurisdictions and influence. Along the U.S.-Mexican border, intrastate, interstate, national, and international jurisdictions must be considered, as well as the influence of powerful non-governmental organizations and corporate bodies. In addition, considerations must include conditions of topography, hydrogeology, regional weather patterns, local demographic dynamics, trade and economic incentives, energy policy, international agreements, legal restrictions, and the energy policies of countries half-way around the world.

Environmental concerns are not the focus here, and even disregarding their potential influence for a moment, there is ample room for caution on the basic premise that the rosy optimism that seems to be sweeping through the halls of power and the corporate boardrooms may be difficult to match with reality. Some energy analysts say that hoping Mexico can significantly help satisfy the "insatiable U.S. appetite for energy" in the near future is "unrealistic" given Mexico's own energy deficit (Treat 2001). Others worry that the environmental costs of making the effort will drag against any headway. Still others see the border areas as perfect for the promotion of effective large-scale developments of alternative energy resources.

Consideration of border energy issues has practical and theoretical saliency. The most fundamental question is: To what degree will energy interdependence develop between the two countries? The answer rests first on resource availability, but just as importantly, it also rests upon matters of political will, environmental impact, and economic feasibility. All these concerns are fundamentally geographical in nature: Where should power plants, electrical transmission equipment, and pipelines be located? How will decisions influence the environmental impacts that result? More significantly, how will anticipated impacts influence where things are placed?

Geographically, such questions cluster near the border while theoretical questions project the border's geography of energy around the world. Several are fundamental, such as:

- Whether closer interdependence on such public essentials as energy and environmental quality will contribute to a narrowing of the socio-economic gap between the two countries
- To what degree energy interdependence will help overcome socio-economic differences
- How much the cultural, social, and technical differences will influence international cooperation

The environmental ramifications of border energy issues will provide some insights into the role and effectiveness of environmental social movements and binational institutions, the political ecology of economic globalization, and the impacts of decentralization and democratization on environmental practices of local governments (Liverman et al. 1999).

Energy and the Border

Mexico's energy trade is largely with the United States, and land transport is the most obvious, simplest, and probably the cheapest way to accommodate anticipated increases. The most attractive feature of the border is how physically accommodating it is to movements across it. It is neither a mountain range, nor an ocean, nor a raging river. In short, it is not a significant physical barrier. That it is a cultural border, however, is of critical significance. Likely nowhere else in the world does an international frontier create such a disparate social, economic, and psychological divide. As important, and even more unusual, it is a stable border that is not in dispute or debate, and it does not pass through any significant energy reserves. Indeed, it is the presence of the border itself that stimulates discussion. It is the border's physical simplicity and the widely different economic conditions it bisects that make energy projects near it and energy trade across it so compelling, so important, and so ambitious.

Demographically, both sides of the border are growing at a startling speed, and the existence of the border is largely responsible for creating this condition. For example, people currently live and are attracted to living along the border because of the opportunities the border creates. Population growth, combined with the growth of border-related industries such as maquiladoras and border-hugging settlements called *colonias*, add additional strain on the system. Without the border, these problems would not exist.

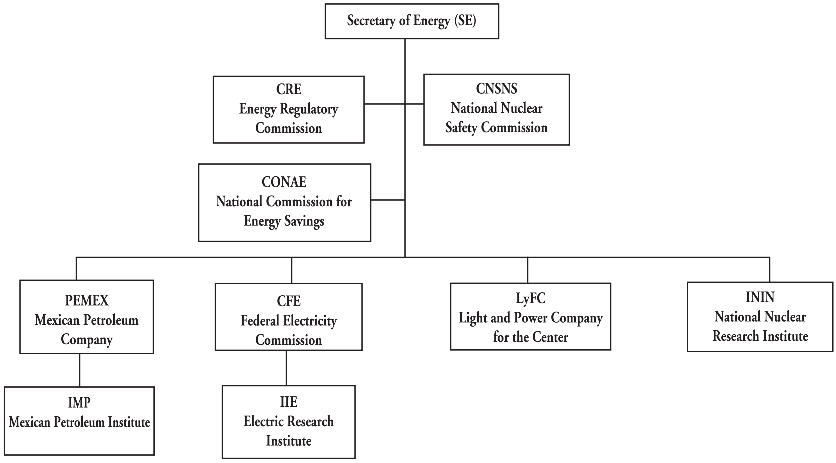
In a perfect example of why countries encourage and participate in international trade, both Mexico and the United States have something the other country wants. Both have weak energy resources and power plant development in the area, both are experiencing unprecedented growth and worsening conditions of environmental health, and both envision that some of these problems will be reduced by closer energy ties.

Agreements and Barriers to Trade

Any geography of energy relies not just on considerations of supply, demand, and cost, but on agreements and barriers to trade. When countries adjoin, these agreements are even more significant because overland trade is possible and comparatively simple. But this is only true in the absence of countervailing regulations; dissimilar and independent regulatory structures can impede cooperation and even stunt well-meaning plans for cooperation. As is often the case, different countries develop their own ways of organizing their energy industries, and the longer they are allowed to develop independently, the more work is needed to craft agreements and remove barriers.

Fortunately, Mexico has for years been developing its federal energy organization and structure in ways similar to those of the United States, with the exception of maintaining its state-run oil and gas monopoly, Petróleos Mexicanos (Pemex) (Figure 2). Both countries have governmental organizations headed by political appointees, and in both countries the organizations they direct are responsible for developing and implementing medium and long-term planning, conducting international energy affairs, tracking and reporting energy supply and demand statistics, as well as identifying trends and issuing forecasts. Mexico created the CRE in 1993 and it functions similarly to the U.S. Federal Energy Regulatory Commission (FERC) as an independent, autonomous agency responsible for regulating the siting, operation, and ownership of electrical generating facilities and oil distribution systems. Creation of the CRE afforded for the first time stable, non-discriminatory policies, rules, and procedures that could be used by the private sector to participate in the energy industry (U.S. Department of Energy [DOE] Office of Fossil Energy 1999). The CRE also monitors the activities of Pemex and the Comisión Federal de Electricidad (Federal Electricity Commission, in Spanish CFE). The CFE is solely responsible for permitting the generation, transmission, and distribution of electricity and is wholly under the authority of Mexico's Secretary of Energy. The CFE will play an important role in planning electrical transmission between the two countries.

Figure 2. Mexico's Energy Regulatory Structure



Source: U.S. Department of Energy

The CFE has enjoyed a monopoly in the electric power sector for 60 years and owns most of Mexico's 36 gigawatts (or 36,000MW) of installed electricity generating capacity (Mexican Intelligence Report 2001). However, this is beginning to change because the CFE lacks the funds needed to meet Mexico's rapid growth in the demand for electric power. Reforms begun in 1992 allow independent power producers (IPPs) and cogenerators to generate power for their own use, although they must sell excess capacity to the CFE. While the CFE is still the only supplier of electric power for the public, domestic and foreign investors may now invest in IPPs. The Mexican government anticipates that much of the future growth in electricity production will come from IPPs, especially those close to the border. The degree of trade that occurs will also be related to the proposed privatization of the electricity sector.

Another policy change has affected natural gas. While upstream exploration and production are the sole domains of Pemex, the downstream gas market has been open to private investors since the passage of the 1995 Natural Gas Law. This legislation modified the constitution to allow private companies to become involved in gas transportation, storage, distribution, and power generation in

Mexico, although it prohibits a company from ownership in more than one function within the industry. In addition, a regulatory framework was established to foster productive investment and an efficient energy market to benefit the end-user. The legislation also liberalized exports and imports and established the regulatory framework for building and expanding transmission and distribution pipelines.

In addition to Mexico's recent bureaucratic accommodations, the North American Free Trade Agreement (NAFTA) simplified international energy trade, although such trade is not a surely-successful venture. Indeed, the agreement is unique in subjecting the economy of a less-developed country to the rigors of competition with two fully industrialized countries (Watkins 1993). Provisions to place foreign investors in Mexico on the same footing as domestic investors represent a significant departure from traditional Mexican doctrines and portend more foreign investment in Mexico's energy sector. In energy terms its aim is to provide a long-term framework for energy trade among the three countries of North America, while not erasing the borders (Watkins 1993).

The export and import of power are both addressed in NAFTA. For example, NAFTA does allow for the export of power from privately-owned generation facilities in Mexico, although they must not affect local consumption. The regulations also permit the import of power into Mexico exclusively for use by the importer (DeGrandis and Owen 1995). The imported power must, however, cost less than the cost of power available through the CFE. Also, the parties must comply with all other agreements required under Mexican law and international treaties.

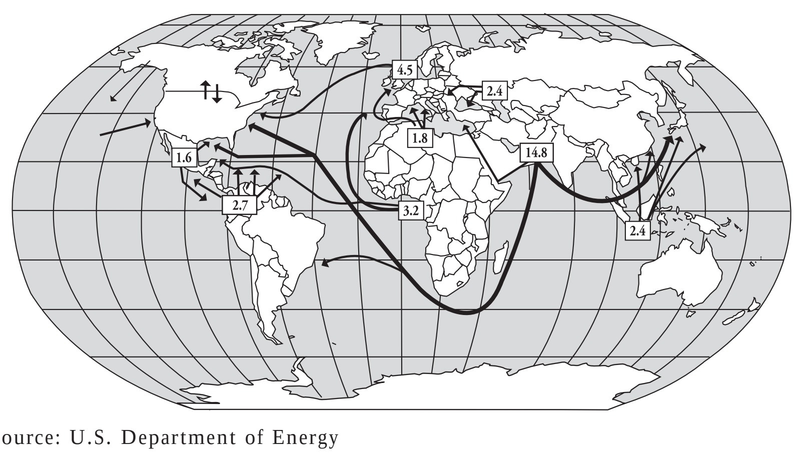
Energy Resources and Present Trade

Every country has an energy profile and just about everything is linked to it. Mexico honors this rule and perhaps is its best example. The first step in discussing the geography of energy at the U.S.-Mexican border is to identify the key elements of such a national energy profile, including available resources, reserves, and locations; degree of production; patterns of distribution; and final demand and use. Laying out such an overview must precede any discussion of energy trade.

The Dominance of Oil

Both the United States and Mexico are rich in energy resources. The United States has substantial deposits of all the fossil fuels, as well as uranium, geothermal, solar, and wind. Mexico's primary energy wealth is in the form of oil, and its importance represents a resurgence from conditions present more than 75 years ago. Mexican oil production peaked in 1921 at 193 million barrels, which was then 25% of the world total and second only to the United States in petroleum output. Mexico led the world in oil exports (Library of Congress 1996). By the early 1930s it had fallen to just 20% of its 1921 level as a result of the Great Depression. As with many other countries such as Norway and the United Kingdom, Mexico's oil reserves increased appreciably in the 1970s. Current estimates put Mexico's reserves at about 40 billion barrels, placing them second in the western hemisphere only to Venezuela, which has reserves of 41.5 billion barrels (U.S. Energy Information Administration [EIA] 2001). In 1998, Mexico ranked fifth in the world in oil production (Mexican Intelligence Report 2001). By 2000, oil production was 3.5 million barrels per day of which 3 million barrels per day was crude. Mexico remains a major player in world oil trade (Figure 3).

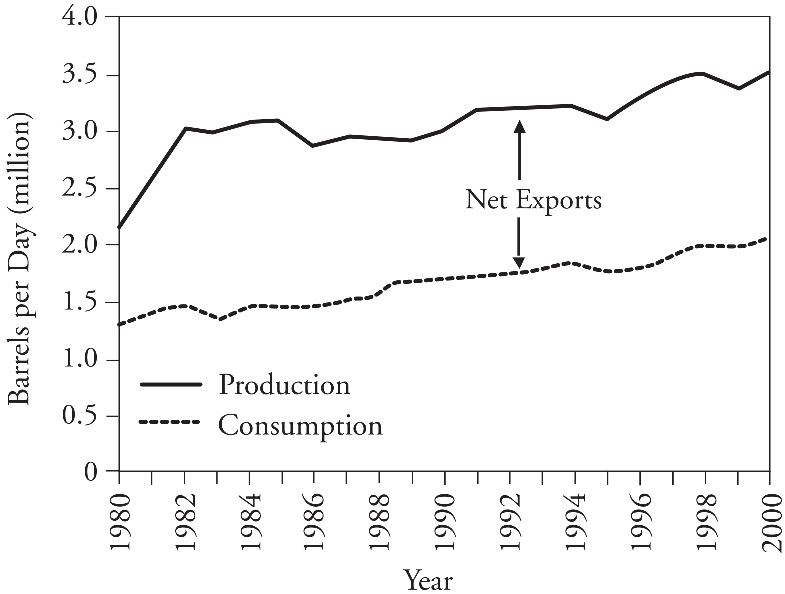
Figure 3. World Crude Oil Flows 1997



Source: U.S. Department of Energy

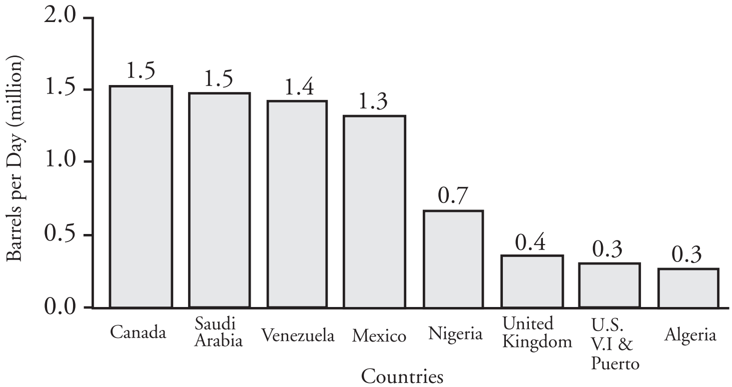
Tankers move more than 1 million barrels of oil to the United States daily, bringing Mexico its greatest source of outside revenues and making the United States the most important market (Figure 4) for Mexico's oil. In 1999, the amount of oil being imported into the United States from Mexico was only slightly lower than the amount imported from Saudi Arabia (Figure 5). Although little if any oil passes across the land border with the United States, its sale to the United States has substantial indirect links to border energy trade by providing the capital reserves to allow economic flexibility for other projects, and by producing "associated" natural gas that many believe will become the most important cross-border energy commodity.

Figure 4. Mexican Oil Production and Consumption



*Data for 2000 are estimated
Source: U.S. Department of Energy

Figure 5. Petroleum Imports to the United States



Source: U.S. Department of Energy

The Growth of Natural Gas

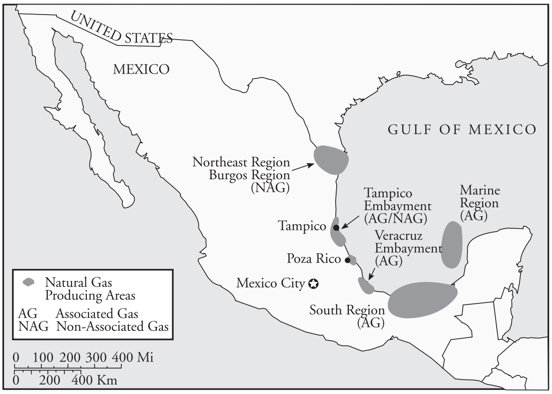
Recent Mexican energy policy has been stressing the expansion of their natural gas markets while reducing their reliance on oil sales. Reforms published in November 1995 allow the private sector to build, operate, and own facilities for the distribution, storage, and transportation of natural gas. Mexico intends to use natural gas as its principal source of fuel in the future, and its federal energy secretary has initiated an Integral Fuel Policy that seeks to significantly reduce the use of fuel oil within 10 years. The policy has four main components:

- Construction of new natural gas-fired combined-cycle power plants
- Conversion of several power plants from fuel oil to natural gas operation
- Expansion of the industrial use of natural gas resulting from new environmental standards implemented in 1998
- Promotion of industrial and domestic use of natural gas (Office of Fossil Energy 2001)

Today, the natural gas industry is more liberalized than any other Mexican energy sector and this is tied to both an anticipated rise in demand and the relative size of the reserves. Mexico has proven natural gas reserves of 29.5 trillion ft^3 (EIA 2002). In 1999, natural gas production was 1.29 trillion ft^3 and consumption was 1.26 trillion ft^3. Domestic demand has been expected to grow faster than production, at an average annual rate of 12%, reaching 2.5 trillion ft^3 feet by 2006. The sector with the highest growth was the electricity sector, with an annual growth rate of 20.1%. This was expected to be the most important energy sector beginning in 2006. Pemex wants 7.5 billion ft^3 to 8 billion ft^3 by 2008 (Oil & Gas Journal Online 2001b).

There are several identified and active natural gas fields off Mexico's east coast, with two being particularly important (Figure 6). One is the Cantarell field in the southeastern part of the country, consisting mostly of "wet" gas associated with oil development. In the same neighborhood is about 84% of Mexico's gas processing and sweetening capacity (Mexican Intelligence Report 2000). The second major field is in the Burgos basin in the northeastern part of the country near the east end of the international border. This reserve is overwhelmingly "dry" or not associated with oil. Production in the Burgos field reached 4.8 billion ft^3 per day by 1999, and the total reserves may amount to 21 trillion ft^3 to 75 trillion ft^3, or roughly three- to 10-times the current proven reserves, according to the Gas Technology Institute of Arlington, Virginia (Oil & Gas Journal Online 2001a).

Figure 6. Map of Natural Gas Fields



Source: CRE

The great increase in the demand for natural gas will come from the anticipated tripling of demand for electricity generation (excluding cogenerators) between 1999 and 2020. This will increase the forecast share of electricity generated using natural gas from 16% in 1999 to 36% in 2020 (Figure 7). This includes both new plant construction and conversions (EIA 2001). The Mexican Secretaría de Energía (Ministry of Energy, in Spanish, SE) predicted that the demand for natural gas between 1998 and 2007 would grow the fastest in the electricity sector—about 20% per year, which amounts to a 400% increase in the demand for gas for electricity generation and a 129% increase in overall demand (Bauer 2000).

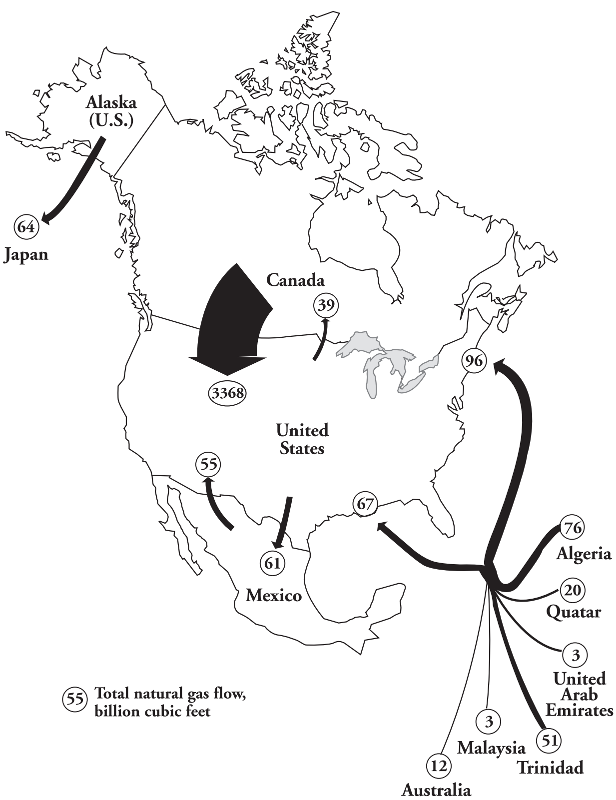
Natural gas' low emission rates favor its use as a fuel to meet the increased demand for electricity, especially in the north where demand is growing faster than anywhere else and where environmental quality is already severely compromised. Recognizing this growing demand, Pemex has begun an ambitious plan to increase production to a peak of 1.4 billion ft^3 per day in 2001 (Mexican Intelligence Report 2001). Pemex planned to spend \$2 billion through 2000 (and \$5.5 billion over 15 years) on efforts to increase the production natural gas in northern Mexico.

Already new gas-fired power plants are coming online in the northern states. The Samalayuca power plant, for example, receives natural gas through the 45-mile Samalayuca Pipeline Project. This project required construction of 22 miles of pipeline in the United States and 23 miles of pipeline in Mexico. The \$35 million project, with a capacity of 212 million BTUs per day, supplies the Samalayuca I and II power plants with fuel from El Paso Natural Gas Company's Hueco Compressor Station, located across the border. The \$600 million 700-megawatt (MW) project has three 233MW units. This project is being developed by a consortium of General Electric Capital Corporation, Bechtel Enterprises, Inc., Coastal Pan American Company, El Paso Natural Gas Company, and Empresas ICA, Sociedad Controladora, which is Mexico's largest construction company. All of the power generated by the plant will be used by CFE for the state of Chihuahua and will be delivered through the CFE power grid. The 24-inch pipeline, which crosses the Rio Grande River east of El Paso, was the first pipeline in Mexico owned in part by El Paso Energy (DeGrandis and Owen

1995), illustrating the increasingly closer ties to develop energy.

Until recently, the limited network and lack of investment for pipeline infrastructure held back the use of natural gas in the north, because the development and use of Mexico's natural gas reserves were not priorities. Again, the regulatory atmosphere is changing. CRE is in the process of issuing 20 natural gas distribution zone permits to domestic and foreign companies through tender offers (International Trade Association 2000), having awarded only 11 distribution zone permits as of 1998. The permits allow companies to construct, operate, and own natural gas distribution and storage systems for 30 years. When the 30 years expire, companies have the option to renew the permits for an additional 25 years.

Figure 7. Canada and Mexico Natural Gas Trade



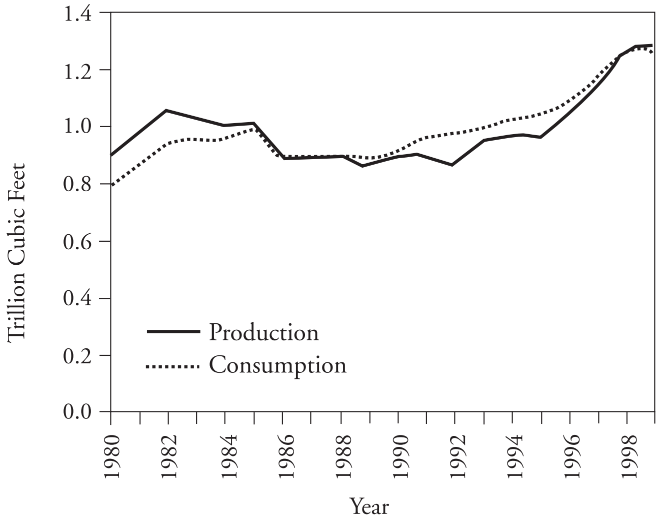
Source: Natural Resources Canada

Despite the exploding energy demand along the border, the persistent energy shortages in the interior of both countries, and the accommodating nature conditions for the overland movement of energy commodities, relatively little energy actually moves between the two countries. Even trade in the most important fuel in this regard—natural gas—is small when compared to the volumes coming from Canada (Figure 7). This is more surprising, given the long history of trade in natural gas.

The United States and Mexico have traded in natural gas since 1949; however, most of the volumes exchanged have been typically minor in nature. Since 1949, the United States has exported small volumes of gas to serve markets along the international border isolated from indigenous supplies due to the lack of pipeline infrastructure. Initially the United States exported between 10 billion ft^3 per year and 15 billion ft^3 per year, but that trade declined in the 1970s and 1980s to roughly 2 billion ft^3 per year. For much of the same period, the United States imported an average of about 40 billion ft^3 per year from Mexico between 1957 and 1971. Volumes of imports from Mexico doubled between 1980 and 1984 to 86 billion ft^3 per year, reflecting a gas purchase contract between Border Gas, Inc. (a consortium consisting of six interstate pipeline companies) and Pemex to supply up to 300 million ft^3 per day, or 110 billion ft^3 of gas per year.

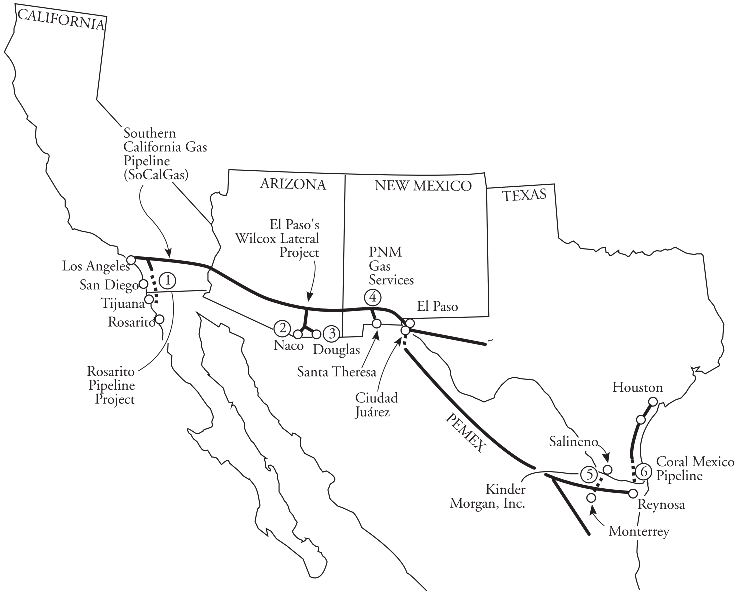
Mexico currently consumes most of what it produces (Figure 8), and is indeed importing from the United States, principally at four places. Mexico is, nevertheless, looking northward with the hope of exporting into the substantial distribution network in the United States once the infrastructure is improved south of the border and the Burgos field is more fully developed (Figure 9, Table 1). Thus, Mexico has two large markets in mind, one near the border, and another through all of North America.

Figure 8. Mexican Natural Gas Production and Consumption



Source: Pemex

Figure 9. Planned Natural Gas Pipeline Projects



Source: U.S. Federal Energy Regulatory Commission

Table 1. Proposed and Recently Completed Export Pipelines

Delivery Point	Pipeline Sponsor	Established Capacity (million ft^3/day)	Pipeline Diameter	Planned Markets
Otay Mesa, CA	Sempra Energy	300	30	Industrial and commercial users in Baja California (primarily the Rosarito Power Station, south of Tijuana)
Cochise Co., AZ West Br-Monument 90 Meter Station)	El Paso Natural Gas Co.	80	16	Existing and planned power plants near the city of Hermosillo, Sonora (170 miles southwest of Naco, AZ)
Cochise Co., AZ East Br-El Fresnal	El Paso Natural Gas Co.	50	16	Planned El Fresnal power plant located near city of Agua Prieta, Sonora (7 miles south of Douglas, AZ)
Santa Theresa, NM	PNM Gas Services	35	8	P lans to serve Santa Theresa Industrial Park in Chihuahua, Mexico
Salineño, TX	Kinder Morgan, Inc.	275	24	Monterrey, MX (LDLs, industrial users, power plants)
Hidalgo Co., TX* King Ranch Meter Station	Coral Mexico Pipeline LLC	300	24	U.S. and Mexico

*intended to be bi-directional

Source: Office of Fossil Energy

Coal, LNG, and Alternative Resources

As rich as Mexico is in oil, it is poor in coal. But, even its small reserves will have a bearing on border energy supplies and the environmental impact of electrical generation. Recoverable coal reserves at the beginning of 1997 were 1.3 billion short tons, while coal production in 1999 was 11 million short tons, yielding a production ratio of about 100 (Watkins 1993). With coal consumption in 1999 at 13.1 million short tons, Mexico is a net importer of 2.1 million short tons, from the United States, Canada, and Colombia. Illustrating Mexico's relatively small coal reserves, U.S. coal production is about 1.1 billion tons per year, just a bit under the total estimated recoverable coal reserves of all of Mexico.

Mexico's coal reserves are important to border issues because they are concentrated in the Sabinas Basin of the northern Mexico state of Coahuila, about 100km north of Monterrey. These reserves are largely bituminous and sub-bituminous in rank and have high ash content. Absent sufficient and expensive power plant emission controls, combustion of such coal will release most of its pollution into the dominant southerly winds that will potentially carry it across the border and into the United States. This prospect is the basis of worries about the construction and operation of coal-burning power plants on the Mexican side of the border. Whereas the limited reserves of coal might restrict how many coal-burning power plants might be reasonably proposed for construction in Mexico, there are other supplies of coal north of the border that could be transported south from the United States.

The other energy resources available in Mexico fall mostly into the "alternative" category and provide about 3% of the nation's electricity. The most fully developed of these—geothermal—produces more than 500MW, mostly at Cerro Prieto, which is located close to the border in northern Baja California near Mexicali. Other little-developed renewables include wind and solar, the latter having the greatest presumed capacity to provide electricity, either from thermal plants similar to those in the Mojave Desert of California or photovoltaic cells, which convert sunlight into direct-current electricity. Despite the poor record of solar energy development in Mexico so far, the EIA anticipates a substantial rise in the reliance on alternative energy in Mexico by the year 2015. This might bode well for some interesting possibilities for the northern states.

Electricity

Of the fossil fuels, coal is used entirely to produce industrial heat, much of it in electrical generating stations. Oil, although useable for making electricity, is regularly converted to a wide variety of other uses—from fertilizer to fingernail polish—but primarily for the transportation sector. This means that other than oil, all the other energy resources are being developed to generate electricity.

The demand for electricity in Mexico is rising rapidly, although it still is a long way from that of U.S. demand. Despite having about one-third the population of the United States, Mexico's demand for electricity is only about one-twentieth of its northern neighbor. In 1999 Mexico's generating capacity amounted to 38,502MW (1.2% of the world), compared to 775,884MW for the United States (24.4%). To put the disparity with the United States into perspective at the individual level, in 1993 Mexico's demand for electricity was 1.2 megawatt-hours per person per year. They expect this to rise to 2.5 megawatt-hours per person in 2015. In the same time period, they expect the demand in the United States to rise from 11.1 to 12.6 (EIA 1993, 1994, 1996).

The demand for electricity is expected to rise quickly. In 1996, the CFE predicted a 38% increase over the installed capacity of 34,791MW, based on an average annual growth rate of 5.4% in gross domestic product and 5.5% in electricity demand (Bauer 2000). The CFE estimates annual national demand for electrical energy will grow at an average rate of 6% for the period of 1998 to 2007.

At one time isolated from the population concentrations in central Mexico, the northern states are now major consumers of power. The rate of growth in the several areas will be much faster, especially the industrialized regions of Baja California, at 7.7% yearly and the northeast at 6.6%. Electricity demand in much of Mexico's north averaged between a 6% and 8% growth rate for much of 2000 (International Trade Association 2000). In some areas, such as the city of Monterrey, the rate has been 10% and 12% (International Trade Association 2000). This growth is due to a rapid rise in manufacturing in the region, including the maquiladoras that hug the border, and the increased commercial and residential consumption. In energy terms, these facilities have tended to concentrate the demand far from the resource supply.

These and other factors have placed Mexico's electricity sector at a crossroads. Although generation has increased rapidly over the past decade, they do not expect supply to meet growth over the next two decades. Given current grid capacity constraints, shortages could result, and regular shortfalls are predicted to result in potential nationwide blackouts (DeGrandis and Owen 1995). Failure to make substantial investments in generation capacity and infrastructure could adversely affect the international competitiveness of key northern industrial regions.

To meet the increasing demand, the CFE has predicted a need for an additional 15,000MW in generation capacity by 2007, at an estimated cost of $15 billion (Energy Online Daily News 1998). They expect the annual electricity growth in Northern Mexico to reach 10% to 14%, compared to 2% to 3% growth in the United States). Between 2001 and 2007, they will need $25 billion to increase the supply of electricity and modernize and expand the transmission systems (infoCRE 1999). An addition of 15,000MW capacity during this period will be more than one third of today's available capacity, built over more than a century.

> "The investment requirements of the electricity sector during the coming years will place an unprecedented burden on the budget and the financing capacity of the public sector. Meeting these investment needs solely from state funds would impinge upon social spending. In fact, the resources required are so large that the government would have difficulty providing them even by diverting resources away from other social priorities ... [T]he participation of the private sector in the electricity industry will reinforce the ability of the government to attain high priority objectives for social welfare" (infoCRE 1999).

Mexico needs to construct a minimum of 2,000MW per year of new electric power (Yergin and Scott 2000), and perhaps as much as 3,000MW of additional capacity per year between 2005 and 2007 (CountryWatch.com 2000). Where should new generating plants be located? Many of them will be built in the northern part of the country to supply the growing needs there, and such a location also suggests opportunities for cross-border transmission in both directions. They expect international companies (especially from the United States) to play a major role in bringing online the new generating capacity that they will need. Currently, however, relatively little electricity moves internationally (Tables 2 and 3).

Table 2. Imports to U.S. Electric Utilities by North American Electric Reliability Council Region and Hawaii, 1995–1999 (thousand kilowatt hours)

North American Electric Reliability Council Region and Hawaii	1995	1996	1997
Electric Reliability Council of Texas	n/a	5,566	526,185
Western Systems Coordinating Council	4,017,709	9,764,193	10,061,509
Contiguous U.S.	42,852,428	43,495,343	43,029,601
U.S. Total	42,853,530	43,496,528	43,031,230
From Canada	40,596,119	42,233,376	43,008,501
From Mexico	2,257,411	1,263,152	22,729

Source: Office of Fuels Programs

Table 3. Exports from U.S. Electric Utilities by North American Electric Reliability Council Region and Hawaii, 1995–1999 (thousand kilowatt hours)

North American Electric Reliability Council Region and Hawaii	1995	1996	1997	1998
ERCOT	925,370	1,029,628	1,103,530	1,026,672
WSCC (U.S.)	1,877,904	949,907	3,970,568	4,539,167
Contiguous U.S.	3,622,665	3,301,986	8,974,039	12,729,923
U.S. Total	3,622,665	3,301,986	8,974,039	12,729,923
To Canada	2,468,244	1,986,361	7,470,332	11,683,276
To Mexico	1,154,421	1,315,625	1,503,707	1,046,647

Source: Office of Fuels Programs

Export of electricity from the United States requires a Presidential Permit and Export Authorization. Several exist and applications for many more have been filed. As of November 2000, the connecting points between the United States and Mexico included those outlined in Table 4.

Table 4. Locations of Electricity Export

Location	Size of Plant
Arizona	
San Luis	2 at 34.5 each
Douglas	34.5
Nogales	13 ; 2.3
Lochiel	13.8
Sasabe	2.3
California	
Calexico	34.5kV
San Diego County	230kV
Imperial Valley	2 at 230kV each
Texas	
El Paso	115 kV
Brownsville	69kV and 138kV
Presidio	12.5kV in 3 phrases
Redford	7.2kV
Amistad Dam	12kV
Comstock	7.2kV
Eagle Pass	138kV
Laredo	138kV
Baja California	
Tijuana	69kV and 12kV
Tecate	12kV

Source: Mintz

Although little electricity moves in either direction, this condition is unlikely to continue for long. Because of the rising demand in both countries, growth of maquiladoras, relaxation of legal barriers—including those swept aside or changed by NAFTA—political will, and perceived good sense of such moves, substantial talk has focused on increasing future energy trade. It is not yet clear, however, how it will all work out or which county is going to supply which.

Nevertheless, one thing is clear: Mexico does not currently have the funds to build the power generation, transmission, and distribution infrastructure it needs to meet its growing electricity demand and avert possible widespread blackouts in its northern states, where the infrastructure is lightest. The administration of President Vicente Fox has proposed legal and regulatory changes that would allow for greater private sector investment in an electricity generation and transmission infrastructure. Such cooperation also presupposes the elimination of technical barriers such as dissimilar electrical specifications.

AN ENERGY BOOM

The prospect of closer energy cooperation at the U.S.-Mexican border could not be drawing more attention. Presidents of both countries are promoting it, applications for Presidential Permits for the export of electricity are up, individual companies are planning new pipelines, new transmission lines have been proposed, new power plants are under construction and some are operating, and a variety of alternative energy scenarios have been suggested. There are high hopes on both sides of the border that mutual accommodation and benefit can be achieved. The essence of this vision is that an increased energy interdependence will provide each side what it needs in the form of jobs, revenues, electricity, natural gas, and opportunities for other improvements.

Like in the United States, natural gas in Mexico is expected to play the largest role in this burgeoning energy market, through its use as a fuel for new power plants and as a conversion fuel for old plants needing to comply with the stricter air quality regulations. The Mexican Secretaría de Energia (SE) recently estimated that between 1998 and 2007 there would be a 20% annual rise in the demand for natural gas use for electricity in the maquiladora sector alone (Office of Fossil Energy 1999).

In the Lower Rio Grande Valley, the Mexican system is experiencing significant growth in demand for electricity, and merchant power producers have announced plans to build new generating plants in Texas. This area may be a logical place to create energy corridors to flow either north or south to meet the needs of customers on both sides of the border. Jess Totten, Director of the Office of Policy Development for the Public Utility Commission of Texas, voiced his enthusiasm for this possibility: “The prospect of helping establish corridors for trade with Mexico is ... exciting. Access for Texas producers to competitively priced power would contribute to economic growth in Mexico and make the Texas market more desirable for new competitors.”

Many projects would support such enthusiasm. For example, since the opening of the electricity generation and natural gas distribution sectors to private participation, $8.65 billion of investments in the energy sector have been announced (Mexican Intelligence Report 2000). The border states of Baja California, Sonora, Chihuahua, Coahuila, Nuevo León, and Tamaulipas, received $3.56 billion for projects or 41% of the total investment in the energy sector in the last six years. Among the major investors participating in the energy sector are: Iberdola, Gas Natural de México, Gaz de France, Sempra Energy, InterGen, Electricite de France, Pegi, Enertek, and Tractebel (Mexican Intelligence Report 2000). As of February 2001, 12 IPP permits have been issued for a total investment of $3 billion. They expect the projects to add more than 6,000MW of capacity by 2004. Of the 12 IPP projects, 10 were in northern Mexico, five of them totally dependent on natural gas imports from the United States, while the other five are partially dependent on U.S. imports (EIA 2001).

Many types of projects are possible, including those that focus on movements of coal and the development of alternative energy. Sandia, with funding from both the DOE and the U.S. Agency for International Development (USAID), has been working with a variety of governmental and non-governmental entities to facilitate successful deployment of photovoltaics in Mexico. The Mexico Renewable Energy Program unites the goals of promoting the use of renewable energy systems as well as enhancing economic and social development, creating new business opportunities, and offsetting greenhouse gas emissions. The program is focused on rural, off-grid, productive-use applications of renewable energy, particularly photovoltaics and small wind, with some interest in small hydropower and solar thermal systems. As a result of the program, more than 400 photovoltaic, wind, and hybrid systems have been installed in rural areas of 14 states in Mexico, including Baja California, Sonora, Chihuahua, and Tamaulipas.

But the three types of projects that dominate discussions are natural gas pipelines, electrical transmission lines, and power plant construction. New natural gas pipelines often attract the earliest attention because they are commonly the quickest commercialized.

Some projects are more contentious. Carbón II, a 1,400MW coal- and oil-fired power plant in Piedras Negras, Coahuila, was criticized because emissions from the coal burning would enter U.S. airspace, violating U.S. environmental standards.

In 1996, a consortium formed by U.S. firms Enova and Pacific Enterprises and Mexico's Proxima, a private Mexican company that develops and invests in infrastructure projects, was granted the first concession to deliver natural gas in the Mexicali area. Since then, several additional projects have been proposed. The CRE announced on August 24, 2000 that an IPP permit was granted to Energía Azteca X, a subsidiary of InterGen, which will invest $262 million. InterGen was established in 1995 and is property of Shell Generating Limited and Bechtel Enterprises Inc. Their Rosarito 10 and 11 stations will be located in Mexicali and will have an 895MW gross generating capacity. Although the IPP permit authorizes the generation of up to 497MW that will be sold to the CFE, InterGen plans on exporting the remaining capacity, for which it has also requested an export permit from the CRE. It will produce 7,200 gigawatts (GW) annually with the CFE purchasing approximately 4,800GW per year (CRE 2001). A subsidiary of the utility holding company Sempra Energy Inc. is building a $350 million 600MW natural gas-fired power plant in Mexico, nine miles west of Mexicali and three miles from the U.S.-Mexican border. It is connected to California through a 230kV interconnect. Named Termoeléctrica de Mexicali, it is to be commercial by 2003. Natural gas will be supplied through a $230 million pipeline being developed by Sempra Energy International, PG&E Corporation, and Proxima Gas S. A. de C.V. The project will begin at an interconnection with El Paso Natural Gas Co. near Ehrenberg, Arizona. PG&E National Energy group is slated to build the 77-mile U.S. leg of the pipeline, which will traverse southeastern California and northern Baja California, Mexico, and terminate at an interconnection with an existing pipeline system (Mexican Intelligence Report 2001). The CRE issued a natural gas transportation permit required for the construction of the 135-mile Mexican segment of the North Baja Pipeline Project, part of the 215-mile Arizona-to-Mexico pipeline (Mexican Intelligence Report 2000). Sempra, in partnership with Proxima, will build the 135-mile Mexican part of the pipeline. The route will intersect the company's existing pipeline from San Diego to the power plant it built and operates in Rosarito. The 400 million ft^3 of gas daily will come from different sources, such as Canada or the Gulf of Mexico, depending on price and availability.

The new Sempra plant near Mexicali is a watershed project because it is believed to be the first in Mexico to be entirely foreign-owned and -operated. It will also be the first time all of the electricity will be marketed in the United States. Normally, all electrical plants in Mexico are owned and operated by the CFE. The Sempra plant is exempt from this because it will not serve Mexican consumers. Building in Mexico should also allow the project a shorter planning phase because in Mexico all the building permits can be acquired in six months while it takes 12 months to 18 months or longer in California to obtain the necessary permits (Mexican Intelligence Report 2000).

Several more projects have been announced to improve the northern states' infrastructure. For example, in March 2001 Canadian-based Transalta Energy Corporation announced its success in obtaining permission to build, operate, and manage the Chihuahua III electricity plant. The new facility is expected be operational by May 2003 at an investment of $192 million and with a capacity to generate 259MW of power (Mexican Intelligence Report 2001). In addition, several improvements to the Mexican infrastructure have been announced, including the following:

- A 300-mile line proposed by Public Service Company of New Mexico to link the switching yard at the Palo Verde Nuclear Generating Station 50 miles west of Phoenix to CFE's system in Sonora, Mexico.
- A transmission line into southern Arizona constructed by

Tucson Electric Power Co. (TEP) to boost reliability of electric service in that region. The company also has filed for approval from the DOE to extend the line into Mexico. A primary subsidiary of UniSource Energy Corp., TEP plans to build a $70 million, 345,000-volt transmission line 50 miles south to Nogales, Arizona, and then connect to an existing electric sub station in the Mexican state of Sonora (Mexican Intelligence Report 2000).

- Transmission facilities proposed by Wilson-7 Energy Systems Inc. in Texas, would allow export of power to Mexico. The project would consist of transmission lines capable of carrying direct current and related substations and other equipment. The facilities would be located in Hudspeth County, Texas, just southeast of El Paso. The lines would cross the Rio Grande from Fort Hancock to Guadalupe-Bravos. The power would come from three yet-to-be-built 2,000MW power plants in Hudspeth. The power would be sold into Mexico and unnamed Central American countries (Energy Online Daily News 1998).
- In July 2000, a cable from Eagle Pass, Texas, to Piedras, Mexico, connected the transmission systems of the U.S. utility AEP and CFE. This is a new kind of electric connection, using asynchronous (high-voltage, direct-current) technology to combat the problem of differing power currents between countries (EIA 2001)
- Coral Mexico Pipeline, L.L.C., has proposed facilities consisting of 1,375 feet of 24-inch pipeline that will connect with existing and new natural gas pipelines operated in Mexico by Pemex. Coral would build a 97-mile, 300,000 million ft^3 per day pipeline between Kleburg County and Hidalgo County, Texas, to the border, which will serve Pemex downstream at Arguelles, Mexico. The 1,375-foot pipeline would be for a border crossing, whereas the new 97-mile pipeline would be operated wholly within two Texas counties that connect upstream with Tejas Energy pipeline facilities (Office of Fossil Energy 1999).
- The El Paso Natural Gas Company Willcox Lateral pipeline project consists of a 20-inch pipeline to be constructed 56 miles down stream from its California mainline, where it would

separate into two branch lines that will end about 15 miles apart at the U.S.-Mexican border. The two 16-inch branch lines would have a daily pipeline capacity of 80 million ft^3 for the West Branch and 50 million ft^3 for the East Branch. The gas is intended for existing and proposed gas-fired electric power plants located in Sonora that serve utilities near Hermosillo and Agua Prieta. Construction began in July 2000 and service commenced on January 1, 2001 (Office of Fossil Energy 1999).

- KN Energy, Inc., of Lakewood, Colorado plans to build a new cross-border natural gas pipeline near Salineño, Starr County, Texas, and Ciudad Miguel Alemán, Tamaulipas. The facilities would consist of an 800-foot, 24-inch diameter pipeline and meter. The proposed new cross-border facility would connect with 15-miles of new pipeline to be built upstream in Texas by KN Energy's MidCon Texas Intrastate Pipeline, and new pipeline facilities to be built in Mexico by KN Energy's Mexican affiliate, MidCon Gas Natural de México, S.A. de C.V. (MidCon México). MidCon México would take delivery of the natural gas near Ciudad Miguel Alemán, and transport the gas 100 miles to Monterrey, Mexico. Mid-2000 Daily Pipeline Capacity will be 275 million ft^3 (Office of Fossil Energy 1999).
- Public Service Company of New Mexico plans to construct and operate a new pipeline facility at the U.S.-Mexican border near Santa Theresa, New Mexico. The pipeline would connect with a Pemex pipeline and would supply an industrial park just across the border in Chihuahua (Office of Fossil Energy 1999).

The Borderland Energy Network and its Challenges

Amid the enthusiasm to develop the U.S.-Mexican Border into something of an energy zone are nagging questions about whether it will work at all, and if it does, how it will work and how to measure its success. The air along the border is crackling with the excitement of a coming energy boom and its promise of a better future. The two countries are starting to sew together with a network of pipelines and transmission wires, although it is not clear which direction the energy is most likely to flow or whether, without a coordinating plan for all this effort, any of this is wise.

There is a great deal to see at the border for the observant. Those in the United States look south and see nearby energy reserves. Those in Mexico look north and see a voracious energy appetite and a willingness to pay to feed it. Both views are, of course, clear and accurate. Everyone knows that the United States has more money available to pay the price of meeting its demand. And most people believe Mexico covets the foreign exchange to help its own programs of economic development. People on both sides of border question whether meeting local domestic energy demand is sensible and whether exchanging energy for currency is a good long-term strategy. Both countries see energy shortages deep in their countries as well as right at the border, and both recognize the tremendous opportunity for economic development if sufficient energy can be brought in to meet local needs.

As both the United States and Mexico look to the other for help in establishing greater energy security, each dedicates little attention to whether future energy interdependence will help resolve problems or worsen them. Neither country knows which of several possible scenarios will play out, and neither seems to have much of a plan to follow. Both seem content mostly to unshackle entrepreneurial zeal, aim it at the border, and hope for the best.

From the perspective of energy, the border presents both promise and risk. The promise is for economic improvement, even prosperity, from closer energy ties. The risk is environmental. The promise comes, in part, from the successful example of U.S.-Canada energy relations. As is the future case with Mexico, Canadian energy exports are mostly natural gas and electricity. Canada, however, encompasses a greater land area than the United States, just 10% of the people, and huge energy reserves. It can afford to share. Mexico has only a fraction of the land area of Canada, more than four times the population, and smaller energy reserves. Despite Mexico's preference to keep its energy for home use, it cannot afford <u>not</u> to share it with others. The hope is that by sharing its energy with the United States, Mexico will not only put money in its coffers, but it will improve the conditions of its people, particularly those near the border. The question is whether this is a reasonable expectation.

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V

Characterization and Dynamics of Air Pollutants in the Lower Rio Grande Valley

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Abstract

The Lower Rio Grande Valley (LRGV) has become a region of increasing interest because of its rapid economic development, increased international border crossing traffic, and extensive agricultural activities. Over the past few years, air pollution problems in the region have substantially increased. However, very few air quality studies have been performed in the area. This paper provides a characterization of air pollutant dynamics and a model in the LRGV, which include the comprehensive interactions of criteria pollutants, VOC's/SVOC's (volatile organic compounds/semi-volatile organic compounds) and fine particulate matter (PM_{fine}). The analysis involved researchers on both sides of the U.S.-Mexican border. A highly mobile monitoring station equipped with a broad array of physical and chemical samplers and sensors was used in December 1995 and March 1998. PM_{10}/ $PM_{2.5}$ and oxides of nitrogen (NO_X) (the latter only in the March 1998 study) concentrations were measured in Reynosa, Río Bravo, and Matamoros, Tamaulipas; Hidalgo, Coahuila; Brownsville, Texas; and along the freeway between Brownsville and McAllen, Texas. The photochemical model predicted peak ozone concentrations that reached, and on some days exceeded, air quality standards. The concurrent $PM_{10}/PM_{2.5}$ study involved both physical (size distributed counting) and time-resolved (two-hour) organic chemical (VOC/SVOC-type PM_{fine} adsorbates) characterization methods. Recently completed multivariate data analysis results from a December 1995 study at one of the sites (Hidalgo International Bridge) are presented to illustrate the capabilities of the time-resolved PM_{fine} characterization approach. The results of this work show that the LRGV region does not yet appear to have grave air pollution problems, with the possible exception of transient episodes of extremely high PM concentrations. However, with the increase in cross-border traffic over the next few years, air quality is likely to deteriorate.

Dinámica y Caracterización de Contaminantes del Aire en el Valle Bajo del Río Grande

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Resumen

El Valle Bajo del Río Grande (VBRG) se ha convertido en una región de interés creciente debido a su rápido desarrollo económico, el incremento del cruce fronterizo internacional, y sus actividades agriculturales extensivas. En el transcurso de los últimos años, los problemas de contaminación del aire se han incrementado substancialmente en la región. Sin embargo, muy pocos estudios de calidad del aire han sido realizados en el área. Este capítulo proporciona una caracterización de la dinámica de contaminantes del aire y un modelo en el VBRG, el cuál incluye interacciones comprensibles de contaminantes criterio, COV/COSV (compuestos orgánicos volátiles/compuestos orgánicos semi-volátiles) y partículas finas de materia (PM_{fina}). En el análisis participaron investigadores de ambos lados de la frontera E.U.-México. Una estación de monitoreo de alta movilidad equipada con una amplia gama de muestreadores físicos y químicos y sensores fue usada en diciembre de 1995 y marzo de 1998. Concentraciones de PM_{10}/$PM_{2.5}$ y óxidos de nitrógeno (NO_x) (el último solo para el estudio de 1998) fueron medidas en Reynosa, Río Bravo, y Matamoros, Tamaulipas; Hidalgo, Coahuila; Brownsville, Texas; y a lo largo de la autopista entre Brownsville y McAllen, Texas. El modelo fotoquímico predijo concentraciones máximas de ozono que alcanzaron, y en algunos días excedieron, estándares de calidad del aire. El estudio simultáneo de PM_{10}/$PM_{2.5}$ involucró ambos tipos de caracterización, el físico (conteo por distribución de tamaño) y químico orgánico de solución por tiempo (dos-horas) (PM_{fina} absorbida de tipo COV/COSV). Los análisis multivariados de los datos completados recientemente de un estudio para diciembre de 1995 en uno de los sitios (Puente Internacional Hidalgo), son presentados para ilustrar las capacidades de la solución en tiempo para el enfoque PM_{fina}. Los resultados de este trabajo muestran que la región VBRG aún no parece tener problemas graves de contaminación del aire, con la excepción posible de episodios transitorios con concentraciones de PM sumamente altas. Sin embargo, con el aumento en el tránsito fronterizo durante los próximos años, la calidad del aire probablemente vaya a deteriorarse.

Introduction

Air quality throughout the Lower Rio Grande Valley (LRGV) is being threatened by rapid urbanization, extensive industrial and agricultural development, and significant increases in vehicular cross-border traffic (Gilbreath 1992). Yet, until recently, relatively few air quality studies of the LRGV area have been published, and emission inventory data for the LRGV area are far from complete. In 1997, results of the multi-media Lower Rio Grande Valley

Environmental Scoping Study (LRGVESS) (Mukerjee 1997) began providing systematic data on air pollution sources, transboundary transport mechanisms, and exposure risks. Also, preliminary emission inventory data reported by Mejia and Rodriguez (1997) enabled the Instituto Tecnológico y de Estudios de Superiores de Monterrey (ITESM) team to perform a first assessment of photochemical pollution mechanisms (Mejia and Meuzelaar 1997).

In 1995, the University of Utah and ITESM started a collaborative effort, sponsored by the Southwest Center for Environmental Research and Policy (SCERP), aimed at physical, chemical, and biological characterization of fine particulate matter (PM_{fine} also known as $PM_{2.5}$) in the LRGV (Mejia and Meuzelaar 1997). In December 1995, 48- to 72-hour-long scoping studies were carried out at four selected sites (Hidalgo International Bridge, Santa Ana Wildlife Refuge, Brownsville International Bridge, and Matamoros Industrial Park). Typically, PM_{fine} levels and size distributions were measured around-the-clock and microgram-sized samples were collected on quartz fiber filters at two-hour intervals for subsequent laboratory analysis by means of specialized GC/MS techniques. Simultaneously, PM_{fine} samples were taken for microbiological analysis, meteorological parameters were recorded, and a limited number of VOC samples were collected and analyzed on site using the University of Utah's mobile analytical laboratory with field-portable GC/MS equipment.

Although detailed multivariate analysis of the extensive data sets obtained continued into 1998, preliminary evaluation of the voluminous data revealed modest overall PM_{fine}- and VOC-type air pollutant levels when compared with earlier field tests in Nogales, Arizona (Dworzanski et al. 1993), with the exception of one severe nocturnal PM_{fine} episode at the Hidalgo site and unexpectedly high levels of airborne fecal bacteria at the Brownsville site. The application of a diagnostic meteorological model for the LRGV at the Hidalgo site provided plausible explanations for the observed severe PM_{fine} episode, which apparently followed the passage of a cold front accompanied by low inversion layer and urban dust trapped above Reynosa slow drifting into the Hidalgo International Bridge area. The specific origin of the high levels of airborne fecal bacteria at the Brownsville International Bridge is still unknown, but they probably originate from the Rio Grande.

Based on the preliminary VOC and PM_{fine} findings of the scoping studies, a follow-up field study was performed that focused on detailed physical (including size distribution) and organic chemical characterization of PM_{fine} at selected receptor sites on both sides of the border. In addition, an attempt was made to model simultaneously and monitor criteria pollutants such as NO_X, ozone (O_3), and sulfur dioxide (SO_2) in order to understand the origin and dynamics of both primary and secondary PM_{fine} in the LRGV section of the U.S.-Mexican border. Consequently, in March 1998, a second five-day field study was undertaken on both sides of the U.S.-Mexican border between the twin cities of Brownsville-Matamoros and McAllen-Reynosa. During this study, PM_{10}, $PM_{2.5}$, and NO_X concentrations were measured in Reynosa, Río Bravo, and Matamoros, Tamaulipas; Hidalgo, Coahuila; Brownsville, Texas; and along the freeway between Brownsville and McAllen, Texas. A diagnostic meteorological model was applied to the region to simulate wind patterns during the sampling period.

This work consisted of two parts: (1) development of a comprehensive criteria pollutant model for selected LRGV areas involving the integrated use of emission, dispersion, and photochemical submodels that attempted validation by field monitoring data obtained in March 1998, and (2) development of a novel time-resolved $PM_{10}/PM_{2.5}$ characterization approach. This approach combined fast, sensitive physical and chemical receptor monitoring techniques. The work used principal component analysis techniques to detect and identify the dominant emission sources for the selected sites and time windows. It focused on the Hidalgo International Bridge data obtained in December 1995.

Methodology

Data Collection

On-site monitoring and sample collection were performed with the University of Utah's mobile laboratory, which is equipped with a Medium Vol (50 l/s) PM_{10} sampling tower with a QFF (quartz fiber filter) sample collector, a 400 Ah battery bank with 2000 W battery charger/inverter, a four kW propane-driven generator, a Peltier-cooled refrigerator for sample storage, and a broad range of air pollutant measurement and sampling devices as described below.

Physical measurements included particle size distribution determinations obtained from a six-channel CLIMET aerosol counter, and meteorological measurements (temperature, pressure, humidity, wind speed, and direction) using a Davis model III weather station. Planned on-site chemical analyses involved NO_X and O_3 measurements, as well as VOC/SVOC speciation using a novel GC/MS technique with miniaturized, fast GC and Curie-point desorption modules. Off-site chemical analyses of QFFs obtained at two-hour intervals were performed at the University of Utah Center for Micro Analysis with a standard HP GC/MSD equipped with a special Curie-point desorption/pyrolysis inlet. Detailed descriptions of these techniques have been given elsewhere (Mejia and Meuzelaar 1997; Dworzanski et al. 1993). Multivariate analysis of physical and chemical measurement data involved the use of principal component analysis (PCA) techniques in combination with graphical rotation methods (Dworzanski et al. 1993).

Several problems were encountered during the 72-hour measurement period (March 11–14, 1998), namely: (1) frequent rain showers that reduced pollutant levels and necessitated longer collection periods while turning monitoring sites into mud pools; (2) electrical failure of the ozone analyzer; and (3) intermittent leaks in the VOC/SVOC desorption inlet. As a result, the number of monitoring sites, originally anticipated to be as high as 20, had to be reduced to six.

Modeling of Photochemical Pollutants

Modeling techniques used by the ITESM group included the application of a diagnostic meteorological model, the use of GIS to generate an emission database, and the application of a photochemical model. The meteorological model was used to reconstruct wind fields in the LRGV during the periods studied. Data from United States and Mexican monitoring stations and airports in the region were used as input to the model. The GIS was used to create a database of meteorological, emission, and predicted concentration. The database made it easier to create input data files for the photochemical model and to display wind, emission, and concentration data in a map of the LRGV for better understanding of the results.

The CIT Photochemical Model (McRae, et al. 1982) was applied to study the dynamics of pollutants in the region. Input data files included emissions, wind fields, incoming solar and UV radiation, and land use. Outputs of the model are maps of pollutant concentrations in the region and time series for different pollutants. In this paper, the predicted SO_2 and O_3 concentrations when a cold front passed through the region on December 6, 1995, are discussed. Predicted NOx concentrations are compared with data collected during the monitoring study in March 1998.

Emissions in Mexico were estimated using the Mobile5 Juárez model developed for Ciudad Juárez by the United States Environmental Protection Agency (U.S. EPA) (Tejeda and Mejia 1998; Kishan et al. 1996). Other emissions in the area were estimated in a previous study based on fuel consumption and emission factors (Mejia and Rodriguez 1997). Stationary source emissions in Texas were obtained from the Texas Commission on Environmental Quality (TCEQ). Mobile source emissions were not available but were estimated using a regression analysis of population and emissions of other counties in Texas made in a previous study of the border area (Mendoza 1996). Wind fields were reconstructed with a diagnostic meteorology model developed to interact with the CIT model. Data obtained with the monitoring station and from the airports were used for this purpose. Land use data of the LRGV were obtained from Instituto Nacional de Estadística, Geográfica, e Informática (INEGI) and from the United States Geological Survey in digitized form. Solar radiation measurements were not available and, therefore, data were estimated from the geographical coordinates and calculated incoming solar radiation (Seinfeld 1986).

Results

Wind Patterns in the LRGV

Transport of air pollutants in the LRGV is dominated by air flowing in from the Gulf of Mexico (from east to west), although at night, quiet periods are common and sometimes the wind blows from the land to the sea ("land breeze"). In winter, cold fronts coming from the north transport pollutants from west to east at ground level, while the warm air from the Gulf of Mexico flows in the opposite direction in the upper part of the atmosphere. This effect may cause periods with high concentrations of particles and other air pollutants in some areas of the LRGV, especially when occurring in combination with low mixing heights.

Meteorology data from the Matamoros and Reynosa airports and United States monitoring stations in the LRGV were used in the meteorology model to estimate wind field vectors in the region for December 1995 and March 1998. The data analyzed showed dominant winds coming from the Gulf of Mexico, the east, and the southeast for the two periods. In particular, on December 6, 1995, a cold front coming from the northwest collided with the warm air coming from the southeast. The leading edge of the cold front slid below the warm front but over the lowest elevations, trapping urban dust (mostly from unpaved roads) under a low inversion ceiling and also causing precipitation of air pollutants emitted upwind in the warm air. This explained the high levels of PM_{10} measured in Hidalgo at the same time and day during the 1998 monitoring trip, as discussed in the following sections.

PM_{10} Physical Size Distribution

Table 1 shows the average particle size distribution for the different sites and monitoring periods covered during the field trip in March 1998. The data from five of the six channels of the CLIMET are shown in the first column, and covered the range from 0.3 microns to 10 microns. Three of these ranges covered $PM_{2.5}$. The sixth channel covered the number of particles larger than 10 microns, but it is not shown in this table. The average number of particles per every $2ft^3$ sampled are shown in the second column, N(dp). The flow rate of the CLIMET was $1ft^3$/min. The volume of particles in each range (Vi) was calculated assuming that particles were spherical (Seinfeld 1986). The total volume (Vt) is the sum of the Vi, hence, Vi/Vt represents the volume fraction of each range of particles.

Table 1. Average Particle Size Distribution at the Monitoring Sites in the Lower Rio Grande Valley

Hidalgo, Texas. March 11, 1998. Sampling period: 10:30 to 18:30 hrs.				
dp (microns)	N (dp)	Vi (thousand of microns^2)	Vi/Vt	∑Vi/Vt
0.3-0.5	801026	26.84	0.0482	0.0482
0.5-1.0	124480	27.5	0.0494	0.1550
1.0-2.5	20935	58.75	0.1056	0.2033
2.5-5.0	7061	194.95	0.3504	0.5536
5.0-10.0	1124	248.35	0.4464	1.0000
Total	954626	556.39	1.0000	
Matamoros, Tamps. March 12, 1998. Sampling period: 0:00 to 4:30 hrs.				
dp (microns)	N (dp)	Vi (thousand of microns^2)	Vi/Vt	∑Vi/Vt
0.3-0.5	889181	29.8	0.0374	0.0374
0.5-1.0	130958	28.93	0.0363	0.0738
1.0-2.5	28517	80.02	0.1005	0.1743
2.5-5.0	13737	379.31	0.4766	0.6509
5.0-10.0	1258	277.88	0.3491	1.0000
Total	1063652	795.94	1.0000	
Reynosa, Tamps. March 13, 1998. Sampling period: 0:00 to 2:00 hrs.				
dp (microns)	N (dp)	Vi (thousand of microns^2)	Vi/Vt	∑Vi/Vt
0.3-0.5	1377389	46.16	0.0233	0.0233
0.5-1.0	469544	103.72	0.0523	0.0756
1.0-2.5	62086	174.22	0.0879	0.1635
2.5-5.0	36804	1016.22	0.5126	0.6761
5.0-10.0	2908	642.25	0.3239	1.0000
Total	1948730	1982.57	1.0000	
Reynosa, Tamps. March 13, 1998. Sampling period: 6:00 to 12:00 hrs.				
dp (microns)	N (dp)	Vi (thousand of microns^2)	Vi/Vt	∑Vi/Vt
0.3-0.5	653962	21.91	0.3075	0.3075
0.5-1.0	47599	10.51	0.1475	0.4550
1.0-2.5	2420	6.79	0.0953	0.5503
2.5-5.0	520	14.35	0.2013	0.7516
5.0-10.0	80	17.7	0.2484	1.0000
Total	704580	71.27	1.0000	
Río Bravo, Tamps. March 13, 1998. Sampling period: 16:00 to 18:30 hrs.				
dp (microns)	N (dp)	Vi (thousand of microns^2)	Vi/Vt	∑Vi/Vt
0.3-0.5	1538943	51.57	0.0722	0.0722
0.5-1.0	629158	138.98	0.1946	0.2668
1.0-2.5	37294	104.65	0.1465	0.4133
2.5-5.0	5736	158.38	0.2217	0.635
5.0-10.0	1180	260.71	0.365	1.0000
Total	2212311	714.29	1.0000	
Brownsville, Texas. March 14, 1998. Sampling period: 9:00 to 13:00 hrs.				
dp (microns)	N (dp)	Vi (thousand of microns^2)	Vi/Vt	∑Vi/Vt
0.3-0.5	1026347	34.39	0.0175	0.0175
0.5-1.0	225479	49.81	0.0253	0.0428
1.0-2.5	81753	229.41	0.1165	0.1593
2.5-5.0	30711	847.97	0.4306	0.5899
5.0-10.0	3655	807.47	0.4101	1.0000
Total	1367945	1969.05	1.0000	
Hidalgo, Texas. March 14, 1998. Sampling period: 15:00 to 17:00 hrs.				
dp (microns)	N (dp)	Vi (thousand of microns^2)	Vi/Vt	∑Vi/Vt
0.3-0.5	1236071	41.42	0.0229	0.0229
0.5-1.0	229274	50.65	0.0281	0.0510
1.0-2.5	72259	202.77	0.1123	0.1634
2.5-5.0	32180	888.55	0.4923	0.6557
5.0-10.0	2813	621.47	0.3443	1.0000
Total	1572598	1804.87	1.0000	

In general, Table 1 shows that although small particles are large in number, big particles are more important in volume and, consequently, in mass. On the other hand, $PM_{2.5}$ represents the fraction of PM_{10} most hazardous to health. During the monitoring trip, $PM_{2.5}$ were found to represent approximately 16% to 20% of PM_{10} in Hidalgo and Brownsville. Similar values were found in Matamoros. In the case of Reynosa and Río Bravo, $PM_{2.5}$ was found to account for 55% and 41.3% of PM_{10}, respectively. These values were found during monitoring periods that corresponded to high traffic at the sites—0600–1200 in Reynosa and 1600–1830 hours in Río Bravo. These two cities are located downwind, have many unpaved streets, and receive most of the pollutants emitted from the highway between Matamoros and Reynosa. In Reynosa, during a monitoring period from 0000 to 0200 it was found that $PM_{2.5}$ accounted for 16.3% of PM_{10}. This value was obtained at night after a rainy period and at a monitoring site with very low traffic. From these results, $PM_{2.5}$ was observed to be an important fraction of PM_{10} in locations downwind of the LRGV. However, to obtain more reliable results and conclusions, more data collected during different seasons of the year are necessary, as are measurements of mass concentration of PM_{10} to obtain concentrations of $PM_{2.5}$, which can then be used to evaluate the population's health exposure to particles.

Multivariate Data Analysis and Integration

Preliminary findings from the 1998 field tests showed:

- PM_{10}/ $PM_{2.5}$ and VOC levels well below the maximum levels allowed by all applicable United States and Mexican air quality standards at all monitoring sites
- Repeated NO_X levels in excess of 100ppb at the Hidalgo International Bridge and along the freeway near the city of Harlingen, Texas

Organic PM_{fine} characterization data are still being integrated and processed. However, multivariate analysis of the 1995 scoping study data for the Brownsville and Hidalgo International Bridge sites has been completed and some results for the latter site, also included in our 1998 field study, are discussed.

Table 2 shows the variables included in the final principal component analysis of the Hidalgo PM_{fine} scoping study involving 24 samples obtained at two-hour intervals. Note that this includes organic chemical compounds and meteorological parameters, as well as PM_{10} and $PM_{2.5}$ density estimates. After varimax rotation, only five principal components were needed to explain nearly 80% of the total variance in the data set. The loadings for these five (varimax-rotated) factors are listed in Table 2 and reveal a relatively well-behaved clustering of the variables along the different principal component axes. Fortunately, a reasonable chemical and physical interpretation of the first four factors appears to be relatively straightforward and is in agreement with the dominant trends observed by Mukerjee et al. in their varimax-rotated principal component analysis of inorganic PM_{Fine} characterization data for the LRGV region (1999).

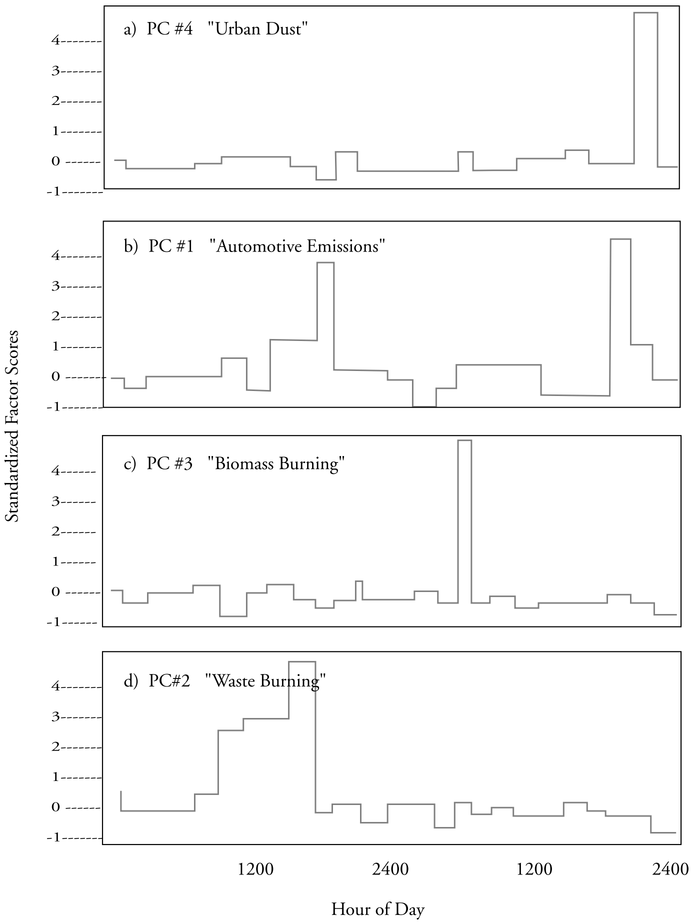
Figure 1 shows the power of the time-resolved PM_{fine} analysis approach in that it provides the opportunity to help tie observed receptor sample patterns to possible emission sources on the basis of known circadian human activity cycles and events (e.g. traffic peaks, waste burning) or observed meteorological patterns and events. (Note characteristic morning and afternoon rush hour peaks “in automotive emissions” component and major “urban dust” event in the late evening of the second day.)

Table 2. Factor Loadings After Varimax Rotation in Hidalgo, 1995 Study

Parameters	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
4-hour daytime intercal	-0.376	-0.055	0.217	-0.320	0.216
Ambient temperature	-0.099	**-0.942**	0.045	0.100	-0.136
Ambient pressure	0.209	0.205	-0.071	0.218	-0.121
Wind speed	0.371	0.030	-0.131	0.107	**-0.710**
N/S wind vector	-0.362	-0.177	-0.083	-0.066	0.050
E/W wind vector	-0.081	-0.193	-0.081	0.168	**-0.910**
PM10 concentration	-0.299	0.102	0.125	**-0.949**	0.087
PM2.5 concentration	-0.210	0.121	0.118	**-0.955**	0.061
D PM (PM10-PM2.5)	-0.397	-0.130	0.178	-0.672	0.361
m/z 83-85 alkanes/alkenes (f)	-0.500	-0.011	-0.017	**-0.846**	-0.009
m/z 99 tributylphosphate (f)	-0.196	**-0.910**	0.088	-0.039	0.084
m/z 129 quinoline	-0.165	0.073	-0.348	0.065	**0.731**
m/z 149 DEP (f)	0.163	0.092	**-0.945**	0.092	0.121
m/z 149 DBP (f)	0.027	**-0.920**	-0.071	0.161	-0.194
m/z 149 DPP (f)	-0.075	**-0.964**	0.124	0.108	0.007
m/z 149 DOP (f)	0.013	-0.145	0.058	0.069	-0.087
m/z 151 4-acetyl-2-methoxyphenol (f)	-0.099	**-0.930**	0.124	0.088	0.009
m/z 153 4-acetyl-2,5-dimethoxyphenol (f)	0.338	0.205	-0.542	0.332	-0.179
m/z 165 4-vinyl-2,6-dimethoxyphenol (f)	0.145	0.088	**-0.922**	0.188	-0.204
m/z 191 17a(H),21b(H)-hopanes (f)	**-0.917**	-0.136	0.085	-0.243	-0.009
m/z 191a hopane [C29H50] (f)	**-0.916**	-0.037	0.073	-0.335	-0.005
m/z 191b hopane [C30H52] (f)	**-0.892**	-0.216	0.092	-0.159	-0.013
m/z 202 PNAHs [C16H10]	**-0.930**	-0.053	0.150	-0.210	0.114
m/z 202a fluoranthene	**0.830**	-0.018	0.046	-0.456	0.145
m/z 202b pyrene	**-0.931**	-0.076	0.218	0.001	0.080
m/z 219 retene (f)	0.131	0.060	**-0.957**	0.083	0.079
m/z 239 methyl dehydroabietate (f)	-0.092	0.139	0.112	**-0.972**	0.036
m/z 306 tetraphenylene	-0.128	0.136	0.088	**-0.975**	-0.012

(f) fragment ion, DEP = diethyl phthalate, DBP = dibutyl phthalate, DPP = dipentyl phthalate, DOP = dioetyl phthalate. Bolded figures are those above 0.6, underlined figures are above 0.8.

Figure 1. Standardized Principal Component Scores (varimax-rotated) Corresponding to the Loadings of Ambient Temperature, Pressure, Wind Speed and Direction over Two Days



The factor scores in the abscissa of Figure 1 are standardized, thereby permitting a rough estimate of the statistical significance of the various events. Assuming multivariate normal distributions, both the (inferred) "urban dust" event in Figure 1a, which followed the arrival of the cold front on day two, and the "biomass burning" (primarily hardwood-markers dominated) event in Figure 1c can be classified as being well in the four-sigma range. The high amplitude of both events may create the mistaken impression that the corresponding chemical markers were only detected during these events. In fact, even when leaving out these extreme episodes, the nature of the underlying parameter associations does not change much at all. In addition, the first principal component ("automotive emissions," Figure 1b) shows regular, traffic-peak-related fluctuations dominated by the afternoon rush hours when most of the traffic was passing on the same (downwind) side of the bridge on which the mobile lab was stationed. The proposed "urban dust" factor is speculative at this point since the peaks at m/z 239 (abietic acid, aprominent filler in car tires) and at m/z 306 (tetraphenylene, perhaps an oily-road tire stabilizer) have not yet been positively identified in local source profiles and the "waste burning" events are inferred from the prominent contributions of alkylphthalate-type plasticizers. However, the "automotive emissions" and "biomass burning" events are firmly rooted in the pioneering GC/MS studies of well defined source samples described by Rogge et al. (1991). Also, the inferred, broad "waste burning" event in Figure 1d was primarily characterized by the presence of several different types of plasticizers, plus a fire retardant. Finally, the very similar "urban dust," "automotive emissions," "biomass burning," and "waste burning" factor loading and score behavior was observed in the Brownsville International Bridge site data obtained during the same 1995 scoping study, as well as in two earlier December time window studies at the U.S.-Mexican border (Nogales, Arizona in 1991 and Mexicali, California in 1993). This suggests a marked degree of similarity in major PM_{Fine} sources along the border and further supporting the chemical and physical significance of the numerically extracted principal component patterns.

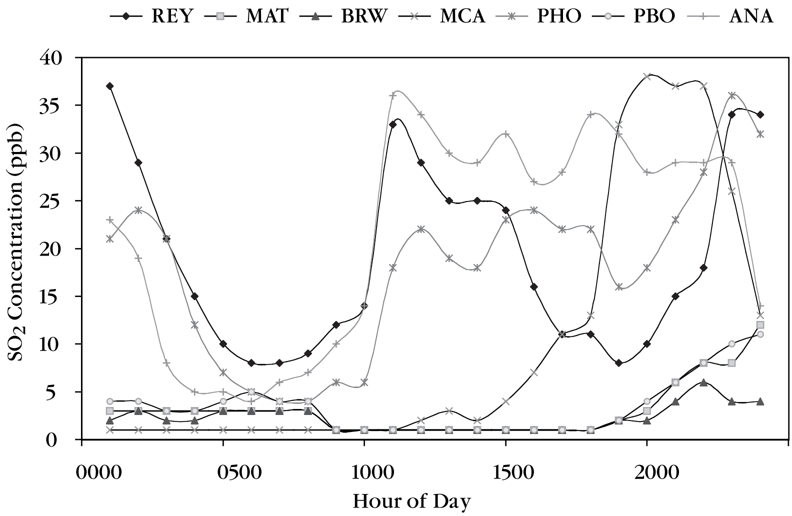
Sulfur Dioxide and Ozone Dynamics

Emission sources in the LRGV include mobile sources in Mexico and the United States, small stationary sources in Cameron and Hidalgo counties in the United States, a Pemex refinery in Reynosa, and a power plant in Río Bravo. Several uncertainties exist in the estimated emissions used to create the data files for the CIT photochemical model. These uncertainties include aspects such as a lack of data to estimate mobile source emissions from both the United States and Mexico. Furthermore, an official emission inventory of stationary sources in Mexico is not yet available; biogenic emissions from vegetation are not known and were estimated from land use; distribution of mobile emissions in highways is not well known; emissions from diesel trucks were estimated; and diurnal variations in emissions of mobile sources were not considered. These uncertainties represent research areas from which results are needed to improve the data necessary to obtain more reliable results. Nevertheless, the results represent general trends of transport of air pollutants and potential areas affected by high levels of pollution.

The region of study, the domain, and computational mesh covered with the photochemical model covered a surface of 180km X 180km, with cells of 5km X 5km (i.e., 1,296 cells). Five layers were defined in the vertical dimension, which makes a total of 6,480 cells. A GIS database was loaded with the necessary emission and land use data files to create the input files to run the CIT Photochemical Model. The files were created using a procedure developed within the GIS for automatic transfer data to each cell. This procedure was generated with a computer, minimizing processing time and numerical errors when data were assigned to each cell.

The results of the model give average hourly concentration data for the different pollutants in each cell in the three spatial dimensions. Understanding results given as lists of numbers is very difficult and usually visualization techniques are used to facilitate this procedure. In this paper, the predicted SO_2 and O_3 concentrations in the different monitoring sites during December 6, 1995, are analyzed. Figure 2 shows plots of SO_2 concentrations for seven sites in the domain: Reynosa (REY), McAllen (MCA), Hidalgo Bridge (PHO), Santa Ana Park (ANA), Matamoros (MAT), Brownsville (BRW), and Brownsville Bridge (PBO).

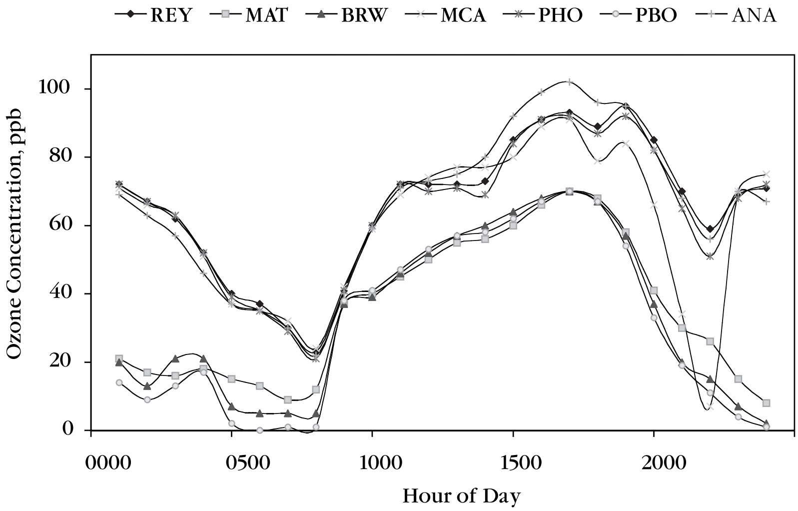
Figure 2. SO_2 Concentrations Predicted by the Photochemical Model on December 6, 1995, for Seven Sites in the Domain



The data displayed in this figure show higher concentrations of SO_2 in the area of Reynosa-McAllen. This is expected since air is blowing from the sea and SO_2 emissions of the Emilio Portes-Gil power plant and the Pemex refinery in Reynosa are transported west of the source. The figure also shows the effect of dispersion predicting different concentrations in REY, MCA, PHO, and ANA, which are located downwind. It is important to note that the higher concentrations predicted by the model are close to 40ppb, which is well below the Mexican air quality standard for SO_2 of 130ppb. The effect of the cold front passing that day is reflected in Figure 2. The model also predicts low concentrations of SO_2 in the area of Matamoros-Brownsville. This, too, is expected since air is blowing from east to west and emission sources are located west of these cities. When the cold front arrived in the region, the wind changed direction and the air blew from west to east, bring SO_2 emissions to the area of Matamoros-Brownsville and thus decreasing SO_2 concentrations in the area of Reynosa-McAllen. As mentioned above, if sulfur content in fuel is lower than the values assumed, lower SO_2 concentrations are expected in the area. Fluctuations in SO_2 concentrations are most often caused by changes in atmospheric stability during the day and the night. During the day, dispersion increases in the atmosphere and SO_2 concentration increases at ground level in McAllen, Reynosa, and Río Bravo. At night the atmosphere becomes stable and, in the same locations, the ground level concentrations decrease.

Emissions of mobile and industry sources have a significant direct impact on carbon monoxide (CO), hydrocarbon (HC), and NO_X concentrations, which indirectly react to produce O_3. Concentrations of this pollutant for the same seven sites are shown in Figure 3.

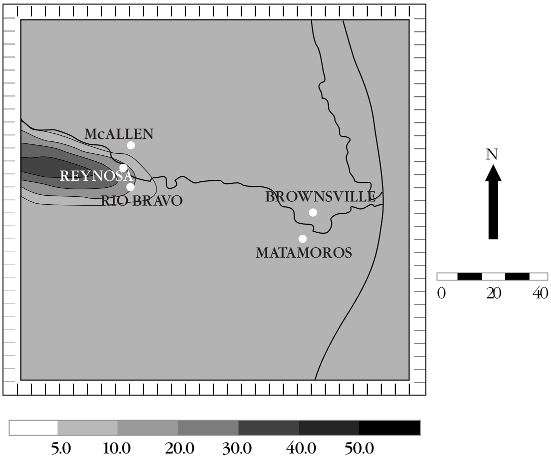
Figure 3. Ozone Concentrations Predicted by the Photochemical Model on December 6, 1995, for Seven Sites in the Domain



This figure shows the same levels of predicted ozone concentrations in nearby sites. This is due to mobile source pollutants emitted mainly in the cities and highways along the domain. Higher concentrations of O_3 in sites located downwind in McAllen-Reynosa, as is the case for SO_2 concentrations, were found. As expected, the figure shows the cycle in ozone formation during the day. Ozone is formed by photolysis of nitrogen dioxide (NO_2) and, consequently, its concentration increases during the morning, peaks early in the afternoon, and decreases at night. High levels of ozone may be encountered at night if it is not dispersed in the atmosphere or if it is not consumed by nitric oxide (NO) when the concentration or emission of this pollutant are low at night. The model predicts peak ozone concentration of approximately 90ppb to 100ppb, which is close to the Mexican and United States air quality standards for ozone of 110ppb and 120ppb respectively.

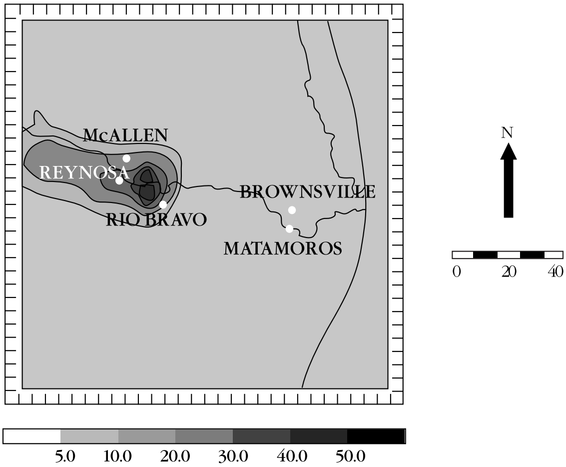
One of the pollutants of higher concern in the LRGV is SO_2. With the application of the photochemical model, it is possible to study the daily variations and impacted areas of the different pollutants. Maps of predicted concentrations of SO_2 are shown in Figures 4 through 7 for the study of December 6, 1995. These figures show the daily variations in concentrations and expected areas impacted by emissions of this pollutant. Figure 4 shows a map of SO_2 concentrations at 0300.

Figure 4. Map of SO_2 Concentrations in the LRGV at 0300, December 6, 1995



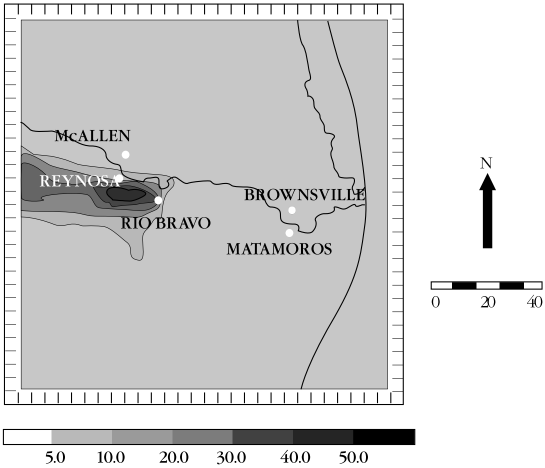
Although several sources of this pollutant exist in the area (Mejia and Rodriguez 1997) and were considered in the application of the model, this figure shows that the impact on air quality results mostly from the power plant located in Río Bravo. This plant's emissions were calculated assuming that fuel oil with 3.5% of sulfur and natural gas with 0.5% of sulfur were consumed. Today, this plant has been using fuel oil and natural gas with lower sulfur content. Therefore, SO_2 emissions are expected to be lower than those used in the model. Nevertheless, even with high SO_2 emissions, values of concentrations of this pollutant are below 40ppb west of the urban areas of Reynosa and McAllen, and this value is well below the Mexican air quality standard of 130ppb for 24-hour average. At 0900 hours, the conditions of the atmosphere become unstable, and the mixing is favored by buoyancy forces. At this hour, Figure 5 shows that concentrations close to Reynosa increase to values between 50ppb and 60ppb, which are still below the air quality standard.

Figure 5. Map of SO_2 Concentrations in the LRGV at 0900, Hours, December 6, 1995



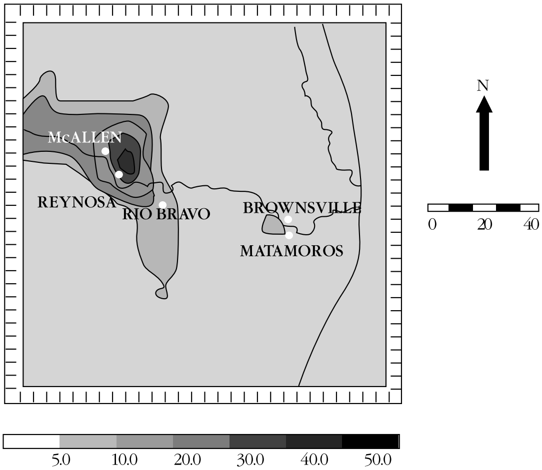
With higher temperatures, the land reaches its peak temperature during the day, and, for example, at 1500 hours the atmosphere becomes unstable and the higher values of SO_2 concentration are located between Río Bravo and Reynosa. However, the values are only in the range of 40ppb to 60ppb as shown in Figure 6.

Figure 6. Map of SO_2 Concentrations in the LRGV at 1500 Hours, December 6, 1995



In the evening, the atmosphere becomes stable and the dispersion of pollutants decreases. In this case, Figure 7 shows the higher concentrations of SO_2 at 2100 hours are now found downwind in the urban areas of Reynosa and McAllen.

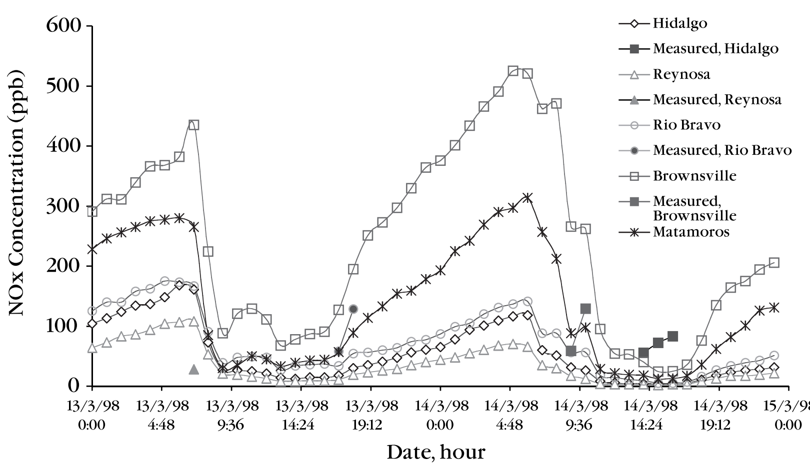
Figure 7. Map of SO_2 Concentrations in the LRGV at 2100, December 6, 1995



As before, the predicted higher values are around 50ppb and occur in McAllen. Figures 4 to 7 also show that, because of transport and dispersion of gases and particles in the atmosphere, higher concentrations of pollutants may be found in rural areas rather than in urban areas. An important limitation is that these results obtained with the model were not validated since actual air pollutant concentration data did not exist for the December 1995 study.

In the study of March 1998, NO_X concentrations were measured at the different sites. The results of the predicted values with the photochemical model and the actual concentrations measured are shown in Figure 8.

Figure 8. NO_X Concentrations Predicted with the Photochemical Model and Actual Measurements in the LRGV in March 1998



In this figure, the model predicts concentrations of NO_X in Brownsville and Matamoros that exceed the one-hour air quality standard of 210ppb, while measured concentrations of NO_X and values predicted for other cities are below this standard. Reasonable correspondence was observed between predicted and measured NO_X concentration profiles or trends at some sites. The discrepancies between measured and modeled NO_X values at other sites are thought to be due to the highly unusual weather conditions, the lack of sufficient data points to fully calibrate the models, and the lack of complete emission inventories (particularly the fact that United States emission data are summed per county and not specified by highway).

CONCLUSIONS

The results of this study show that the LRGV has, in general, relatively low levels of PM_{10}. Depending on meteorological conditions, these levels may increase to high concentrations during some periods of the day. Size distribution results show that $PM_{2.5}$ seems to be an important component of PM_{10}. It is important to obtain data for longer periods and different seasons in the year to achieve more reliable results for the size composition of PM_{10}. To obtain better calculated values of ozone, SO_2, and other pollutants it is necessary to have better emission estimates of stationary and mobile sources as well as their diurnal and spatial variation.

The predicted concentrations of SO_2 do not exceed the air quality standard in the LRGV, including the impact of the power plant located in Río Bravo. Moreover, this plant's emissions were estimated consuming fuel oil and natural gas with high sulfur content and, since today it is using combined cycles with natural gas that has a lower sulfur content, it is expected that its impact will be below the predicted values of SO_2 concentrations.

It is necessary to obtain actual concentrations of air pollutants to validate their predicted concentrations with the photochemical model. Usually air quality data are collected in urban areas. However, transport of pollutants to rural areas may cause higher concentrations there. Technical and logistic achievements were trouble-free crossing (twice) of the U.S.-Mexican border with a fully equipped mobile laboratory and successful (nearly around-the-clock) operation of a mobile laboratory on both sides of the U.S.-Mexican border with a binational team of investigators while covering six sites over a 200-mile distance within a 72-hour period.

Acknowledgments

The research reported here was supported by the Southwest Center for Environmental Research and Policy (SCERP). The research team thanks the personnel of Secretaría de Desarrollo Social de Tamaulipas for their valuable support during the monitoring trip. The information supplied by the Texas Commission on Environmental Quality, Subsecretaría de Ecología de Nuevo León and Secretaría de Comunicaciones y Transportes is gratefully acknowledged.

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VI

Energy Efficiency in the Northern Border States: Cooling Device Replacement

Odón de Buen Rodríguez and José A. González Martínez

Abstract

Northern Mexico is a predominantly hot and dry region, making cool air a basic necessity. Cool air is generally provided by devices that require electricity. In northern Mexico the acquisition and use of oversized, second-hand appliances imported from the United States at very low prices is widespread. This results in the northern border's residential sector consuming the highest levels of electricity in Mexico. High electricity use has a significant impact on the economy and the population's income. In addition, because power is generated primarily by fossil fuel plants, electricity use in northern Mexico has a great impact on air quality and water consumption in the region. An appliance replacement program, in particular for air conditioners and refrigerators, in the northern states would yield important environmental and economic benefits for the region. This chapter analyzes the problem of low energy efficiency in residential air conditioning in Mexico's northern states, identifies the opportunities for existing regulations and institutions to help solve the problem, and outlines a recommended mechanism for the development of a large-scale program to replace inefficient refrigerators and air conditioners currently used in the region.

Eficiencia Energética en los Estados del Norte del México: Reemplazo de Refrigeradores y Aires Acondicionados

Odón de Buen Rodríguez y José A. González Martínez

Resumen

El norte de México es una región predominantemente árida y calurosa, causando que el uso de aire frío se convierte en una necesidad básica. El enfriamiento de aire se obtiene principalmente de equipos que consumen energía eléctrica. En el norte de México es común la práctica de adquirir y utilizar equipos baratos, de segunda mano, ineficientes y de capacidad mayor a la requerida, provenientes de los Estados Unidos. Esto provoca que en la zona se presenten los más altos índices de consumo eléctrico en el sector residencial de todo México. Esta mayor intensidad de consumo eléctrico tiene fuertes impactos económicos y en el ingreso de la población. Además, como la electricidad es principalmente generada por plantas que consumen combustibles fósiles, el consumo de energía eléctrica en el norte de México tiene importantes impactos en la calidad del aire y en el consumo de agua en la región. Por lo anterior, un programa para reemplazar los equipos ineficientes en el norte del país, en particular refrigeradores y aires acondicionados, representaría importantes beneficios económicos y ambientales. Este trabajo analiza el problema de los bajos niveles de eficiencia en el uso residencial de aires acondicionados en los estados del norte de México e identifica las oportunidades que las instituciones y regulación existentes ofrecen para resolver el problema, y describe un programa a gran escala para reemplazar refrigeradores y equipos de aire acondicionado actualmente usados en la región.

Introduction

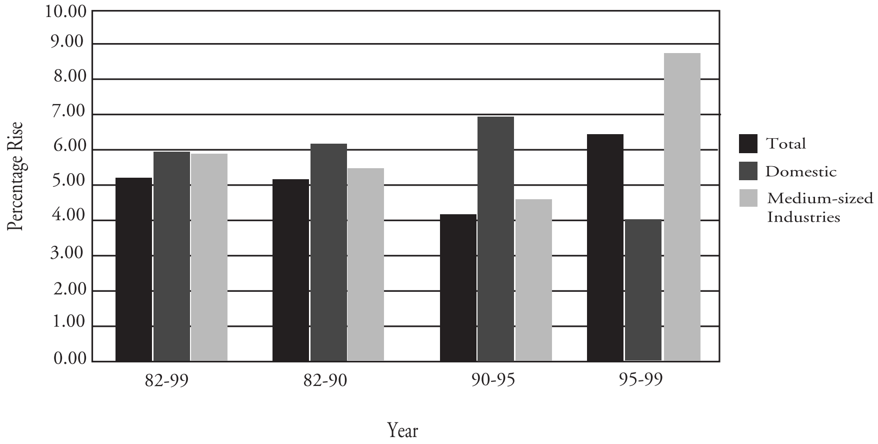
There are significant opportunities to increase energy efficiency in Mexico's Northern Border States (NBS). Higher energy efficiency improves levels of comfort, reduces electricity bills, increases disposable income, and reduces negative environmental impacts that result from the generation of electricity. The chapter discusses why, in spite of the successful application of programs that reduced electricity consumption in the country from 1995 to 1999, consumption in the NBS is still increasing quickly. This chapter also discusses the circumstances and patterns of use of cooling devices in the NBS and their estimated environmental costs. Finally, it describes a program that may further improve the quality of life of citizens at the U.S.-Mexican border.

Mexico's Northern Border States

The Mexican side of the border with the United States comprises six states: Baja California, Sonora, Coahuila, Chihuahua, Nuevo León, and Tamaulipas. These states have a total population of 16.6 million, equivalent to 17% of the national total (Instituto Nacional de Estadística Geografía e Informática [INEGI] 2000). About 68% of this population lives in urbanized counties with more than 500,000 inhabitants (INEGI 2000).

Electricity consumption growth rates in the NBS have been higher than in the rest of the country (Figure 1). From 1982 to 2001, the share of total electricity consumption in the six northern border states has risen from 27% to 32% of the national total. Consequently, meeting electricity demand has become a challenge for the Mexican electricity sector, one that requires important investments to secure adequate electricity supply as well as consideration of the environment.

Figure 1. National Electricity Sector Annual Growth Rates



Demand growth is due, first and foremost, to the industrial development of the region. This is chiefly reflected in the growth of medium-sized export-oriented manufacturing industries. These industries represent one-third of the region's electricity consumption—44% in the case of Chihuahua—and are responsible for creating a demand growth rate that is double the country's rate.

Electricity consumption in the residential sector also explains the demand growth in the region. The total number of residential electricity users in the region exceeds 3.9 million (Comisión Federal de Electricidad [CFE] 2001), accounting for 89% of the total users in those states. Although in 1999 the NBS accounted for 17% of the national population and held one-fifth of the total residential users in the country, its national share of residential electricity consumption was 32.3% (CFE 2001). Furthermore, there are 3.25 million residential electricity users under hot-weather rates and residential electricity use in the region represents 55.6% and 82.6% of the nation's electricity consumption under the two highest hot-weather electricity rates.[1] The hot and dry climate conditions of the region cause electricity consumption to be significantly higher in the summer.[2] Peak load occurs on summer afternoons from June to September because of air conditioning use (Figures 2 and 3).

Figure 2. CFE Northeast Division Sales

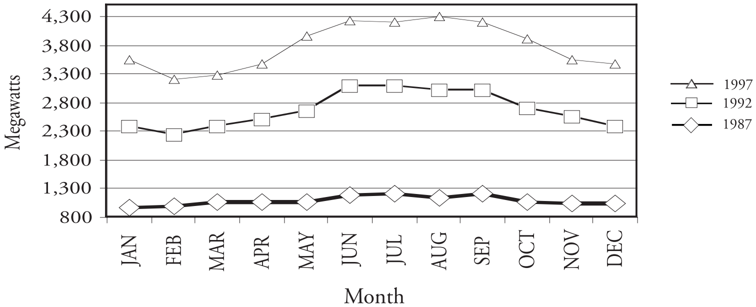
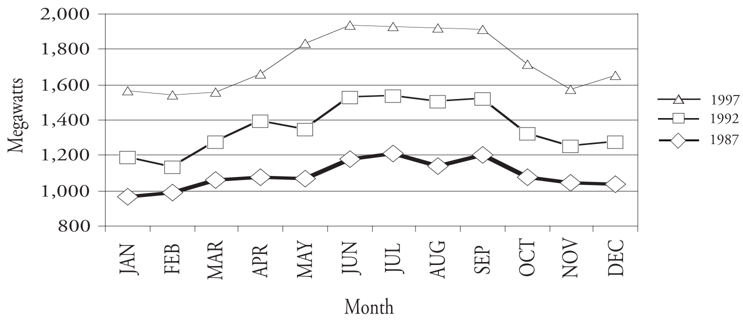
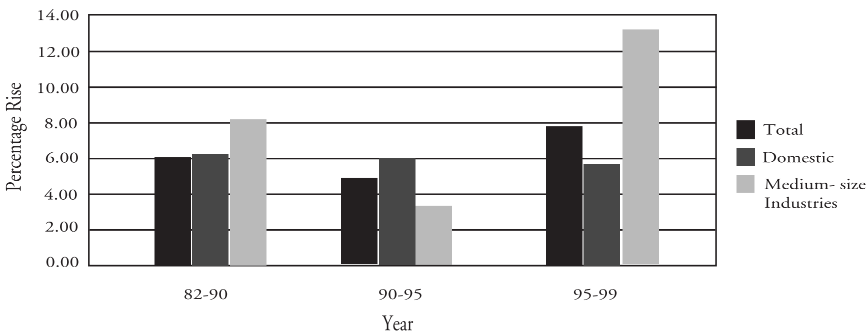


Figure 3. CFE North Division Sales



In addition to the region's climate and the importance of cooling devices, northern Mexico is an important market for low-priced second-hand appliances from the United States. These normally use more energy than new appliances. The acquisition and use of oversized, second-hand air conditioning units is common in the border region. Lack of energy efficiency measures integrated into construction standards further promotes use of inefficient appliances. A clear sign of this problem is the difference in growth rates of electricity consumption in the residential sector in the region compared to the growth rates in the residential sector at a national level. Nationally, as a result of energy efficiency programs, residential consumption was notably lower than that of all other electricity users from 1995 through 1999 (Figure 4). In the NBS however, the rate of growth in the residential sector was not reduced in the same period. As noted previously, this is explained by the extensive use of second-hand appliances from the United States.

Figure 4. Northern Border States Annual Growth Rates



The City of Mexicali as a Case Study

In Mexico and in the NBS, the city with the highest level of residential energy consumption is Mexicali, located south of California's Imperial Valley. With nearly 800,000 inhabitants, Mexicali is the third largest city along the U.S.-Mexican border. It has a relatively important agricultural and industrial base. Although there has been no research on potential electricity savings in the NBS region, studies for the state of Baja California, and particularly Mexicali, can be used to estimate possible impacts of a large-scale program.

A 1990 study showed electricity used for air conditioning in Mexicali is influenced by the characteristics of the dwelling and the system used to provide cool air. Houses in Mexicali have characteristics that necessitate large cooling loads (De Buen 1992). The same study found an estimated two-thirds of residential customers have evaporative coolers and one-third have compressor-based units. The study also suggested a large fraction of compressor-based air conditioning units installed in Mexicali are "bought used through a well-established market that brings discarded equipment from the U.S. ... and the only test performed on the equipment is to demonstrate its ability to provide cool air." According to observers, truckloads of appliances are bought in Calexico, California, and sold in Mexicali for less than one-third the price of new appliances of the same size (de Buen 1993).

In Mexicali, according to the study, "The cheapest first-cost option for residential air cooling is the most energy-inefficient ... A used compressor-based unit is up to five times cheaper than a new one and also cheaper than an evaporative cooler." Another important conclusion of the study was that "this is also the option with the highest operating cost per unit of heat removed: the cost per year of operating a used air conditioner can be more than twice the price paid for the device." Consequently there exists a large potential for energy conservation and possibly increased comfort by replacing the low-efficiency air conditioning units currently installed.

According to the study, replacing old air conditioners with new units would increase the average EER[3] from 6 to 12[4] and reduce approximately 60% of the electricity consumption, assuming levels of comfort remain constant.[5] This would reduce demand an estimated 1.5 kilowatts (kW), or 82.5 megawatts (MW) (assuming all air conditioning units are on at the same time) per customer, and would avoid annual generation of 210.4 gigawatts (GWh), considering 15.31% of transmission and distribution losses are from gross electricity generation (Secretaría de Energía [SE] 1998). If Mexicali represents 5% of the NBS population, with 50% less consumption per household throughout the region, possible avoided generation for those states could reach 2,000GWh per year. This has a value, in real costs, of about $200 million.

Economic and Environmental Aspects

The principal environmental effects of electricity consumption in the northern states result from a high percentage of fossil-fuel-based generation. There are six important fossil-fuel powered generating plants with 4,738MW in capacity, equivalent to 14.33% of the country's total (SE 1999), located in the border region.

Fossil fuel power plants not only cause air pollution, but they also consume significant water quantities. According to Pace University estimates, each gigawatt generated in a fossil fuel plant releases 800 tons of carbon dioxide (CO_2), 11 tons of sulfur dioxide (SO_2), and 1.7 tons of nitric oxide (NO_x) into the atmosphere. In a system that cools by evaporation, 500 cubic meters of water are required for every gigawatt produced.

The United States has designed policies to address the pollution problem. California, a state with some of the highest levels of air pollution in the country, enacted the Clean Air Act in 1988 to establish procedures to attain higher air quality. In 1990 the California Energy Commission (CEC) directed that "all costs and emission impacts of compliance with air quality regulations be accounted for in the analysis of the cost effectiveness of power generation." CEC also specified externality values for five categories of emissions, based on the estimates of the marginal cost of the best available control technology (Energy Information Agency 1995).

Pace University estimates of emissions per gigawatt and the costs of the best available control technology as specified by the CEC[6] show that for every gigawatt generated there is an environmental cost of more than $60,000 (U.S. Energy Information Agency 1995).[7]

The monetary environmental value for the 210.4GWh of avoided annual generation for the NBS, mentioned in the previous section, would be $133 million. This environmental value is equivalent to the price of 16,613 new air conditioning units. The same 16,613 air conditioning units are equivalent to 30% of the compressor-based air conditioning stock currently installed in Mexicali.

Substantial investment is needed to install new power plant capacity to meet the demand created by the growing number cooling-device users. The cost of each new megawatt installed can be in the range of $650 to $1,000. The estimate for the avoided demand detailed above is 82.5MW.

Institutional Capacities and Energy Efficiency Program Experience in Mexico

Since 1995 several actions and programs have notably reduced the rate of growth of residential electricity consumption. Three of these, in order of importance, are:

- Comisión Nacional para el Ahorro de Energía (the National Energy Conservation Commission, in Spanish CONAE) has invoked in the last six years a wide array of mandatory ener gy efficiency standards for equipment and systems commercialized in Mexico, such as refrigerators, air conditioners, clothes washers, and water pumps.

- Daylight Savings Time, first introduced in 1996, reduces electricity demand and consumption in peak hours when electricity is more expensive to generate.
- CFE and the Fideicomiso para el Ahorro de Energía Eléctrica (Electricity Savings Trust, in Spanish FIDE) have developed programs such as CFE's roof-insulation and compact fluorescent lamp programs and FIDE's incentive program.

More specifically, CFE has been working since 1980 to improve the efficiency of its electricity customers. Through its programs, it has become an outstanding marketer of efficient appliances and materials for energy efficiency. CFE has set up several trust funds, such as FIDE and Fideicomiso para el Aislamiento Térmico (FIPATERM), to operate its programs.

FIDE is a private trust created in July 1990 to "support actions that induce and promote electricity savings." Its funds flow from CFE, its contractors, and its own union. In 1996 FIDE began a market transformation program to reduce electricity demand by providing monetary incentives for purchase and installation of high-efficiency equipment by industrial, commercial, and residential electricity users. In 1999 FIDE's incentive programs fostered savings of 554GWh of electricity consumption and 152MW of avoided capacity (CONAE 2001).

FIPATERM is a program managed by CFE. Its main objective is to foster the massive installation of thermal insulating material in households with high electricity consumption in northwestern Mexico. Its thermal insulation program has allowed the insulation of 59,426 households, creating an annual savings of 31.6GWh and 22MW of avoided capacity (CONAE 2001). Last year FIPATERM also began providing financial support for door and window insulation and compact fluorescent lamps (CFLs).

Actions undertaken by FIDE and FIPATERM have resulted in annual savings of more than 140GWh. In particular, FIDE has helped replace 3.2 million light bulbs with CFLs in 134 cities of 22 states (CONAE 2001), all paid through CFE bills. CFE has the institutional and technical infrastructure and the experience to develop and implement large-scale programs for the NBS.

CONAE

CONAE is the wing of the Ministry of Energy that focuses on the development of energy efficiency programs and the promotion of renewable energies. In addition to its involvement in the development of energy efficiency standards, one of its main functions is to link actors to promote energy efficiency. Recently CONAE held a meeting with the main stakeholders to discuss developing an energy efficiency program in the NBS. Participants included appliance manufacturers, CFE, FIDE, consultants, and development banks.

A Program to Replace Air Cooling Devices in the Border Region

The first step should be to conduct a well-designed survey to provide relevant socio-economic information, including average income per household, average electricity consumption, electricity consumption costs per household, average type and patterns of use of existing cooling devices, and consumer willingness to participate in a program.

The information collected would be used to develop a draft blueprint with objectives, strategies, and actions; a scope and time frame; an evaluation mechanism; and tasks to be performed by stakeholders. The information collected would determine which locality should start a program, the feasibility of a program, and what financial arrangements are required to develop a program. The information would also be useful to estimate the direct and indirect benefits of a program.

Two actions are crucial for a program's success: Finding both national and international mechanisms to preclude introduction and use of discarded air conditioners[8] and procuring participation of relevant experienced institutions and achieving consensus and cooperation of stakeholders and international institutions.

The main actors—CONAE; CFE; FIDE; local governments; federal agencies such as the treasury, energy, environment, and commerce ministries; manufacturers; wholesalers; national and international development banks; international agencies; and consulting firms—should achieve consensus. Relevant organizations should discuss the draft blueprint and participate in the program's design, operation, and evaluation.

Conclusions

There are great opportunities to increase the quality of life in Mexico's northern border states by promoting energy-efficient cooling devices like air conditioners. The program presented here aims to improve economic conditions, increase levels of comfort, and reduce the negative environmental impacts of electricity generation.

The program proposed here requires the consensus of many actors, including the government, manufacturers, development banks, consultants, the national utility, FIDE, and CONAE. The program should be initiated by conducting a well-designed survey and involving all relevant institutions. It is also important to put into effect both national and international mechanisms to preclude introduction and use of discarded appliances from the United States.

Endnotes

[1] Electricity in Mexico is sold under 20 different rates, six of which apply to residential customers depending on climate. The first is Rate 1, which is applied for temperate climates; the other five are for hot climates (1-A, 1-B, 1-C, 1-D, and 1-E). Rates for hot-climate users apply only from May to September; all residential customers are under Rate 1 for the remainder of the year.

[2] The average residential unit consumption in the region (233 kilowatt hours [kWh] per year) is 66% greater than the national average. Average unit consumption under the 1-D rate is 62.7% higher than the national average for that rate, and 46.1% higher than the national total under the 1-E rate.

[3] The EER is equal to the heat extraction capacity of the compressor-based air conditioning unit in British thermal units per hour (Btu/h) divided by the power of the motor of the compressor (in watts).

[4] The assumption made to calculate savings potential is based on the electricity consumption of a Mexicali's average air conditioning unit (1.5 Ton, EER=6, unit) and it is used by 30% (55,000) of the households.

[5] According to the survey used for the study, a used 2.4 kW, 1-ton EER=5 unit would consume 5,184kWh per year while a new 1kW, one-ton EER=12 consumes 2,160kWh per year. Estimations are made considering 12 hours of use per day and 180 days of use per year.

[6] These numbers were first used in California in its 1993 planning process. For simplicity this chapter will not take into consideration inflationary adjustments or improvements in cost and technology.

[7] California requires utilities to consider quantitative estimates of externalities. The 1992 values of San Diego Gas and Electric, which provides electricity to the San Diego border region, are as follows: $31,448 per ton of NO_x; $9 per ton of CO_2 . As California does not specify enternality's monetary values of SO_2, New York's value ($2,500 per GWh) was used.

[8] Air conditioners in Mexico have an import tariff (ad valorem) of 20% per unit, except for imports coming from the United States, Canada, Bolivia, Costa Rica, and Chile, for which there is no tariff, thanks to free trade agreements. Countries such as Colombia and Venezuela can export air conditioners to Mexico with a preferential tariff of 7.2% to 5.7%. Hotels, restaurants, and other service businesses located in the border region and registered at the Ministry of Economic Affairs can import air conditioners with a preferential tariff.

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