Woodrow Wilson International Center for Scholars

ENVIRONMENT, DEVELOPMENT AND GROWTH:

U.S.-Mexico Cooperation in Renewable Energies

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His research focuses on the reform of the Mexican energy sector, Latin American energy policy, Mexico's security challenges, and Canada-Mexico relations. He has published on Mexican energy, renewable energy, anti-narcotics policy, banking supervision, North American relations, Latin American oil policy and remittances.

In 2011 he will be lead researcher on two new projects. The first, with CSIS, will track political developments in Mexico as they impact on the race for the presidency in 2012. The second, with the Wilson Center, is a study of Mexican renewable energy resources at the U.S.-Mexico border.

His recent publications include:

- *Cooperative Mexican-U.S. Anti-Narcotics Efforts*, co-authored with Sidney Weintraub, Center for Strategic and International Studies, Washington, D.C., 2010.
- *Political Studies: An Introduction*, co-authored with George MacLean, (Toronto: Oxford University Press, 2010).
- *Energias Renovables en Mexico*, edited by Duncan Wood, Omar Romero and Sergio Romero (Mexico City: USAID/ITAM, 2010).
- *Environment, Development and Growth: Mexico-U.S. Cooperation in Renewable Energy*, Woodrow Wilson Center, 2010.
- *The Outlook for Energy Reform in Latin America*, Woodrow Wilson Center, Latin America Program, February 2010.
- "Canada-Mexico Relations: Decoupling or Concentrated Bilateralism?" in Peter McKenna, ed., *Canada Looks South: In Search of an Americas Policy,* University of Toronto Press, 2011.
- "The administration of decline: Mexico's looming oil crisis", *Law and Business Review of the Americas*, Winter 2011.

PROLOGUE

Since the writing of this report, U.S.-Mexico cooperation in the renewable energy sector has progressed significantly. During 2010, USAID has continued its activities in promoting renewable energy development in Mexico, with a series of activities aimed at increasing regulatory and technical competence in wind energy generation in particular. But of greater significance has been the commitment by both national governments to focus on one issue in particular, the export of wind energy from Baja California to California. The creation, by presidents Obama and Calderón in May 2010, of the bi-national Cross-Border Electricity Task Force initiated a formal dialogue between the two countries' energy agencies, involving stakeholders from private industry and state-level governments. This built on meetings, described in this paper, held in late 2009 and early 2010 on the subject.

In October of 2010, a meeting of 67 Mexican and U.S. stakeholders (representatives from the U.S. and Mexican federal and state governments, independent system operators, regional transmission organizations, private firms, original equipment manufacturers and project developers) was held in La Jolla, CA. Co-chaired by DOE Principal Deputy Assistant Secretary Jonathan Elkind, and SENER Undersecretary for Electricity Benjamin Contreras, the meeting was designed to identify challenges and action items to be addressed by the Task Force. These discussions have helped create an agenda that the Task Force will address in the coming months. A follow-on session, with purely public-sector representatives from the two countries, resulted in the creation of a cross-border electricity steering committee and six working groups, each to be co-chaired by one U.S. and Mexican federal government representative. The working groups will address:

- Land use and environmental planning;
- Market planning;
- Electricity planning;
- Financing and cost recovery;
- The creation of an information clearinghouse; and,
- Operational issues

The commitment by the two governments to the establishment of a more integrated cross-border electricity market for renewable energy is beginning to bear fruit, and offers one of the most positive stories in bilateral relations of recent and future years. This paper lays out the 20-year background to this story and offers suggestions for new policy directions.

Duncan Wood
Mexico City
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EXECUTIVE SUMMARY

The need for integration of North American renewable energy markets is real and immediate. Although the region has extensive renewable energy resources, their geographic distribution, and their nature (intermittent and of variable strength), mean that it makes sense to integrate both supply and distribution across national borders. This has long been the case with energy; electricity grids have seen extensive integration across the U.S. northern border, and pipelines have brought Canadian natural gas and oil to the United States for a long time. As U.S. demand for renewable energy increases, satisfying that demand will require importing energy from its neighbors, and Mexico offers a reliable and relatively low-cost supply from its wind energy farms in the north.

The history of cooperation between Mexico and the United States in renewable energy is surprisingly long and multi-faceted and it has been a vital, albeit unheralded, dimension to bilateral relations and a significant boost to rural and later national development for over 18 years. Cooperation in some areas goes back even further than that, with geothermal energy collaboration extending back to the 1970s. Although it is now seen as crucial in the context of efforts to mitigate climate change, renewable energy in Mexico is and always has been seen as a development tool, helping to bring energy and employment to marginalized areas that are not connected to the national electricity grid.

Beginning in the 1990s, USAID has invested in long term programs seeking to increase opportunities for renewable energy in Mexico, focusing mainly on small projects in rural areas but also increasingly on projects that are having a far-reaching impact on Mexico's energy profile. The investments made by the U.S. government in mapping Mexico's wind energy resources in Oaxaca and other parts of the country have helped to develop a new source of energy for the national grid and for private consumption, and a new source of employment, investment, technical expertise, and economic growth.

Although public entities have also benefited from the development of the wind energy sector, it is predominantly private companies that have been responsible for the sector's impressive growth in recent years. The generation of wind energy for self-supply by private firms has been one of the great successes of the Oaxacan wind projects, and it is likely that this will be repeated in the north of the country.

But it is not just wind energy that has benefited from bilateral cooperation. In almost every sector connected with renewable energy, the complementarities between the two nations, particularly at the border, have generated opportunities for working together—to both develop the industry within Mexico and to satisfy U.S. demand for renewable energy. In the geothermal sector, electricity produced in Baja California has been exported to California since the 1970s. With regards to solar energy, cooperation has produced valuable programs that have been adopted by Mexican government ministries to apply solar technologies to remote areas to assist in agricultural production.

The obvious and glaring exception has been the biofuels sector, in which only disparate interest from the private sector, but no meaningful agency-to-agency cooperation has been seen. It remains a sector ripe for development, particularly given Mexico's climate and the potential for plants such as jatropha, succulents high in sugar, and of course sugarcane itself.

This report argues that U.S. involvement in the Mexican renewable energy sector has paid substantial dividends in terms of improving access to energy for poorer communities and in terms of building up the wind energy sector. In the future, it is likely that both Mexico and the United States will benefit from imports of Mexican wind energy into California, and from the expansion of renewable energy opportunities south of the border.

Further, this report argues that one of the factors that currently prevent the realization of the potential for integration of renewable energy markets is the absence of a comprehensive bilateral agenda for developing renewable energy on the border. Although the Border Governors Conference and the North American Development Bank have made efforts in this direction, it will require executive leadership on this issue to make meaningful progress. The emphasis by the U.S. Department of State on a "New Border Vision," announced in March 2010, provides an opportunity to do just that.

In addition to the report's numerous recommendations specifically focusing on geothermal, wind, solar and biofuels, two general recommendations stand out. First, it is vital that financing opportunities are increased for renewable energy projects. This can be achieved through bilateral mechanisms at the border, through international mechanisms such as the Global Environment Facility (GEF) and through the Mexican government's renewable energy fund, announced in November 2008.

The second general policy recommendation is to enhance current programs designed to build human capital in renewable energy. Through the Mexico Renewable Energy Program, the work of USAID, and through the U.S.-Mexico TIES program, investments in human capital are bringing long-term benefits to Mexico's renewable energy sector, and more should be done in this regard, both through facilitating more and closer collaboration between university-level programs and through support for Mexico-based training programs in the issue area.

Renewable energy stands out as one of the most positive items on the bilateral agenda between Mexico and the United States today. Whereas the media coverage of Mexico is dominated by drugs, migration, and violence, the potential for Mexican renewable energy to contribute to development, employment, and growth there, as well as helping to satisfy growing demand for clean energy in the United States, should be seen as a truly positive example of what can be achieved through sustained and well-thought-out bilateral cooperation. With continued attention from agencies and firms on both sides of the border, the Mexican renewable energy sector holds enormous potential to contribute even more in the future.

ENVIRONMENT, DEVELOPMENT AND GROWTH: U.S.-MEXICO COOPERATION IN RENEWABLE ENERGIES

INTRODUCTION

As the world debates the future of climate change in international forums, most countries are implementing their own mitigation strategies at the national and local levels while at the same time looking to their neighbors for opportunities to establish regional plans for climate-change response and energy security. In Europe, region-wide policy and carbon emissions reduction strategies have been in place for a number of years. Ideas for regional carbon markets in North America have been discussed for a long time, but little has been achieved.

In April of 2009, however, presidents Obama and Calderon, of the United States and Mexico respectively, signed the "U.S.-Mexico Bilateral Framework on Clean Energy and Climate Change." The two leaders agreed on the importance of promoting clean energy, combating climate change and the value of collaborating to reach these goals. Some observers in the United States may have been surprised by this development because the energy issue of which most foreign observers immediately think with regards to Mexico is, of course, oil. The continuing problems of PEMEX and declining production from its mature fields have been one of the most important issues coming out of the country in recent years.

However, although it is most often seen as a classic hydrocarbon nation, Mexico has in recent years emerged as a leading country in the region, and more broadly in the developing world, in the areas of clean energy and emissions controls. As President Felipe Calderon has attempted to present himself to the world as a leader in climate change initiatives (most recently in Cancun in December 2010) with the idea for a *Fondo Verde* (Green Fund), many Mexicans expressed surprise that their country could be seen as a leader given the overwhelming national political and economic importance given to oil. But Calderon was building on a reputation established in successive international meetings, most notably in Bali in 2007 when Mexico was ranked fourth out of all nations for its commitment to mitigating climate change, by the policy group Germanwatch, in their Climate Change Performance Index (CCPI).[1] This reputation had been won by a variety of initiatives from the local to the national level, from both the public and the private sectors. Though Mexico has since slipped down the rankings to eleventh place, it still maintains a favorable image in terms of its commitment to mitigating climate change, and ranks third out of all newly industrializing countries.

In order to meet the expectations that President Calderon has worked so hard to build up concerning climate change mitigation strategies, Mexico now has to invest heavily in both energy efficiency projects and in the development of a renewable energy sector that takes advantage of Mexico's considerable resources. Large-scale investment by the state, by the private sector (both national and foreign), reforms to the legal framework surrounding renewable energy, and a change in the mentality of Mexican political and economic elites are needed in order to make this happen, but there is good reason to be optimistic. The potential is certainly there in Mexico, and there is considerable interest from foreign investors and governments.

This study examines one of the most important and potentially lucrative dimensions of the growth of the renewable energy sector in Mexico, namely bilateral cooperation between Mexico and the United States. The 2009 bilateral framework should be seen in the context of an emerging trend in Mexico toward renewable energy, and as recognition of the need for the United States to take advantage of this if it is to meet its own carbon emissions reduction goals. The long border shared by the two countries, so often seen as a point of conflict due to the thorny issues of migration, drugs, and security, holds the potential to benefit both states through the trade in renewable energy from wind, geothermal, biomass, and solar sources. But the promise of collaboration in the sector goes far beyond the border. The United States has been engaged with Mexico in RE issues for over 15 years now on multiple levels, and this has brought tangible results that have had a significant impact on both Mexico and on bilateral relations.

U.S. engagement with Mexico in the area of renewable energy has been driven by three main concerns. First, the U.S. government has focused much of its efforts over the past 15 years on using renewable energy applications to improve living standards and business opportunities for Mexicans living in rural areas. Second, the contribution of RE to climate change mitigation strategies has become a central pillar of U.S. work in the area. Mexico's impressive potential for RE offers great hope for the reduction of current dependence on fossil fuels. Third, the possibility of satisfying growing U.S. demand for RE from Mexican sources has not been lost on decision-makers in both countries, and collaborative work has progressed toward this goal.

Although the second and third of these concerns have been dominant in recent discussions of renewable energy, the first should not be overlooked. In fact it has played a much more important role in the history of cooperation in renewable energy and has had a profound impact on the lives of Mexicans. Renewable energy technologies can give access to electricity to rural communities that lack connections to the national grid. Such access is fundamental in many ways to granting a basic standard of living, but it is particularly important in enhancing the prospects for small- and medium-size enterprises (SMEs). Providing electricity to a small farmer can give him the capacity to better irrigate his fields, to work later into the evening once he has electric light, to refrigerate perishable goods such as fruits, fish, and meat so that he does not have to take his goods to market each and every day, and allows the farmer to think beyond the mere harvest of produce to products that have a higher degree of value added.

The argument of this paper is that, though many of the opportunities created by bilateral cooperation in the past have gone unexploited by U.S. actors, the long-term impact of this cooperation has been highly beneficial, for Mexico as a country, producing jobs, new sources of alternative energy, and economic opportunities. For the United States, the development of the RE sector in Mexico offers hope to states such California as they seek to satisfy growing demand for renewable energy. Continued cooperation in the areas of geothermal wind, solar, and biofuels are therefore vital if Mexico's true potential is to be fully realized.

RENEWABLE ENERGY AND THE GLOBAL CHALLENGE

It is by now common knowledge that the world is facing a climate change crisis caused by the effects of fossil fuel-driven industrialization. A significant rise in global temperatures, combined with more severe weather conditions, and more frequent floods and droughts, are bringing a paradigm shift to the way we think about our relationship with the planet. For the first time in over 150 years, policymakers are thinking seriously about decreasing dependency on fossil fuels and looking for alternatives that may be more expensive in the short and medium terms, but ultimately more sustainable.

All of this has happened at the same time as two other, related phenomena. The first is that the global population is reaching new highs and by 2040-2050 will total over 9 billion people. Experts predict that 85 percent of the world's population will be located in the developing world, which will mean a rapidly growing demand for goods and for energy. Both of these factors will result in a need to increase energy efficiency, as well as to find new sources of energy. What's more, this massive jump in population will coincide not only with climate change but also with increasingly difficult conditions for hydrocarbons exploration and production. As most of the world's "easy" oil has already been discovered, oil companies and nation states are turning to alternatives such a non-conventional oil reserves (tar sands, complex fields) and reserves that in the past would have been considered unrecoverable, such as in very deep ocean waters. Furthermore, political conditions in many of the world's oil rich regions are uncertain, unstable and often unfriendly to private oil companies and to the countries of the West.

CLIMATE CHANGE AND NATURAL DISASTERS

The urgency of finding alternatives to fossil fuels has been confirmed in recent years by mounting scientific evidence that we are undergoing a noticeable anthropogenic shift in the world's weather and temperature. Not only is a range of indicators showing that the planet is warming, but the retreat of the polar icecaps, the melting of glaciers, and, most importantly in the short term, extreme weather conditions and increased incidence of natural disasters have highlighted the consequences of maintaining the status quo in our patterns of energy consumption and industrial development.

It is estimated that we have experienced a 1-degree Celsius rise in global temperatures over the past 100 years and that by the end of the current century global temperatures may have risen by as much 7 or 8 degrees. Even with the reduction in greenhouse gas emissions that is contemplated by the most ambitious mitigation strategies, global temperatures may rise by as much as 6 percent. This would have a dramatic and disastrous impact on both developed and developing nations and will threaten the existence of both humans and animal and plant species.

Though the connection between man-made greenhouse gases and global warming was denied for many years by industry and governments alike, it has now been accepted that something must be done to reduce the amount of greenhouse gases released into the atmosphere. Given that 86 percent of all global energy comes from fossil fuels, and that these fossil fuels produce 27,000,000,000 tons of CO^2 emissions annually, finding alternative sources of energy is a crucial component of climate change mitigation strategies.

THE RISE IN GLOBAL POPULATION

With global population expected to exceed the 9-billion mark by 2040, and with estimates of global carrying capacity (that is the total number of people that the planet can support under given technological and social conditions) set at around 10 billion, demographics have once again become a central element in world politics.

Population matters for both energy supplies and climate change. As the global population rises, there is a greater demand for both energy and for consumer goods, which in turn means higher levels of energy consumption. More importantly, as the global population gets wealthier on average, demand will jump again. At the income level of around US$6,000 per capita, individuals and families consider the purchase of an automobile and this drives up demand for hydrocarbons and, in particular, gasoline.

From this, the impact on climate change should become clear. Rising populations also impact on climate in other ways, with increased demand for agricultural land, for example, which means the clearing of forests. Large-scale agriculture to produce sufficient food also means the unleashing of massive amounts of greenhouse gases from rice paddies and cow and pig farming. Indeed the methane that is released from these sources has a greater impact per ton than CO^2.

THE ENERGY SQUEEZE

At the same time as climate change has become an issue at the top of the international agenda, declining oil reserves around the world and rising demand for oil and gas (in particular in Asia) have produced enormous volatility in energy markets in recent years, offering up an insight into the long-term challenge that is the stable provision of energy to the global economy. As "easy oil" is used up, oil companies have to look deeper, further, and in non-conventional sources to discover new reserves. What's more, much of the world's remaining oil reserves are located in unstable, hostile, or unpredictable political environments. Although coal and uranium remain in plentiful supply, their environmental impact is such that most nations are trying to turn away from their use.

When we think that the economic development of the past 200 years has been driven by the increasingly intense use of energy, first from coal then from oil, the consequences of facing constrictions in energy supplies should become obvious. Slower economic growth, a degraded standard of living in the developed world, increased international and local conflict for resources, and the need for rapid and drastic technological change will be unavoidable.

Renewable sources, on the other hand, offer an alternative that is almost without limit. Although at the present time they represent a tiny fraction of the world's energy use, their potential is sufficient that in the long term they can completely replace non-renewable sources. What is interesting and particularly appealing about renewable energy is that the technology needed to exploit it already exists, in either a developmental state or fully matured. This means that, with adequate levels of investment, effective government policies and the necessary cultural and attitudinal shifts in society, renewable energy stands to advance rapidly and significantly in the next few years.

SUSTAINABLE AND CLEAN DEVELOPMENT

The joining of these three phenomena—climate change caused by human activity, rising populations and the energy squeeze—serves to put further importance on the concept of sustainable development. A term coined in the late 1980s in the Brundtland report, titled *Our Common Future* "sustainable development" focuses on the notion that today's development must not compromise the ability of future generations to meet their own development goals. This means less emphasis on non-renewable resources and on development policies that destroy or irrevocably damage the environment. "Sustainable development" has become a central theme and has been mainstreamed into government and international organization policy across the world in the two decades since the Brundtland report.

This new understanding of the limitations of development has meant that the search for alternative sources of energy has become more and more important in recent years. All areas of renewable energy generation have seen impressive growth, albeit from a very small initial position, across the globe. Of course some of these forms of energy generation have been around for more than a hundred years, but the application of new designs and technologies has seen a dramatic improvement in their efficiency as well as the realization of new potential.

Hydroelectric power, for example, has a long history going back to the 19th century, with the earliest power plants completed in the 1860s. In the mid-20th century hydroelectric power flourished, with massive investments in mega projects in both the industrialized states and, through funding from organizations such as the World Bank, in the developing world. With huge investments in China in recent years, hydroelectric power currently makes up 20 percent of electricity generation capacity in the world. Paraguay is 100-percent dependent on hydroelectric generation and exports hydroelectric power to its neighbors, and other countries, such as Brazil, Canada, and

Norway, depend overwhelmingly on dams for their electricity generation.

Wind power too has a long history, going back to the use of windmills for grinding grains and pumping water in early modern times. The generation of electricity from wind dates to the late 19th century, although its use remained limited throughout the 20th century until the application of new materials and designs in the late 1970s in Denmark, which then spread around the world. In recent years, rapid innovation in design and new lighter materials have made huge turbines possible, with a subsequent rise in power generation capacity, enhanced by greatly improved system control. The rise in global wind power capacity in recent years has been remarkable: in 2008, installed capacity rose by 28 percent, with another 31-percent rise in 2009. According to the Global Wind Energy Council:

> *The world's wind power capacity grew by 31% in 2009, adding 37.5 GW to bring total installations up to 157.9 GW. A third of these additions were made in China, which experienced yet another year of over 100% growth.*[2]

The power of the sun has been harnessed for thousands of years by human communities for drying, heating and lighting, and there were solar powered distillation projects in Chile in the 1870s to produce drinking water, but the use of solar power to generate electricity is relatively recent. Electricity can be generated from the sun's power in two main ways: from photovoltaic cells, which generate electricity from the interaction between the sun's radiation and chemicals contained in photovoltaic cells; and secondly from solar thermal plants, where the heat of the sun is harnessed to generate steam which then drives turbines to produce electricity.

In recent years, biofuels have received a lot of media, policy and academic attention as industries, governments and societies have sought to reduce their dependence on hydrocarbon-based liquid fuels. Ethanol is perhaps the best known of these, and it is important to recognize that in the 19th century it was regularly used as a heating source. In the early 20th century ethanol briefly challenged gasoline as a fuel source for automobiles, although the low cost of petroleum rapidly overcame this potential. Massive production of ethanol in Brazil, the United States, and the European Union in recent years has brought back the prospect of a central role for ethanol in transportation, although relative cost remains a challenge, as does the question of grain production for ethanol use impacting food prices, directly or indirectly.

But ethanol is only part of the biofuels picture. Biodiesel, derived from a variety of sources, is emerging as an important complement to regular diesel, and offers potentially huge benefits to poorer countries. Biogas (methane) projects abound at the present time, as governments attempt to harness harmful emissions from agricultural, industrial, and municipal sources to be used to generate electricity, although financing limitations suggest that most of these projects will not advance past the planning stage in the near future. The potential for this in Mexico is great, however, particularly with a view to exporting the electricity generated from agricultural and municipal waste in border communities.

THE NORTH AMERICAN CONTEXT

The North American economic region is experiencing an impact from all of the issues mentioned above. Climate change, population growth, tightening energy markets, and the need for sustainable development pose a series of challenges for policymakers at both the national and regional levels. A number of studies, some dating from the early years of the 2000s, have called for the creation of North American renewable energy markets, with adequate integration of electricity transmission systems, funding programs and intergovernmental cooperation.[3]

The demand for integration of RE markets is urgent. As nations, states, and municipalities struggle to meet carbon emissions targets, they are looking to their neighbors to satisfy demand for RE and to benefit from synergies across sectors. Unfortunately, we are still a long way away from such integration. There is still a lack of knowledge about the full extent of renewable energy resources across the region and differences in regulatory regimes, both within and between countries remains an obstacle. A comprehensive study and database of renewable energy resources is a vital component for developing RE in the region that was attempted in 2003 by the North American Commission on Environmental Cooperation (CEC),[4] but which sadly came to nothing. However, it is encouraging that significant progress has been made in recent years on both the technological and the regulatory fronts, and there is significant interest from the private sector in exploiting renewable energy across borders in the region.

THE INDUSTRY IN MEXICO

Mexico enjoys one of the world's most privileged positions in terms of its potential to generate renewable energy. Possessing tropical, temperate, and arid climates, very long coastlines, areas of high wind velocity and stability, geothermal activity, and high levels of solar irradiation, Mexico is naturally extremely well-endowed. However there has been very little development of the renewable sector in Mexico until very recently (with the exception of hydroelectric and geothermal electricity generation). This lack of development can be explained by:

- The dominance of energy thinking by issues related to oil and, to a lesser extent, gas
- The absence of any consideration of energy security issues due to the abundance of hydrocarbons
- A lack of awareness on the part of the executive branch and legislators of the potential for renewable energy generation
- A low level of environmental consciousness on the part of government, society, and the private sector
- The absence of economic and financial incentives for public or private sector development of renewable resources

This is not to say that there have not been actors in Mexico who have pushed for the construction and consolidation of a national renewable energy sector. Within civil society and higher education, a wide range of groups have been very active for years in the development and application of renewable energy technologies. Furthermore, there are a small number of private businesses that have been active in a variety of renewable energy technologies since the mid-to-late 1990s.[5]

However, unlike countries such as Brazil, the renewable energy sector remained relatively under-developed in Mexico until quite recently. A major impulse to building up capacity has come from the growing concern over climate change. The Mexican Ministry of Energy (Secretaria de Energía or SENER) has identified two major axes in the national climate change mitigation strategy. The first concerns energy efficiency and savings, the second increasing the use of renewable energy sources. Both of these axes are well-developed in terms of concrete policy initiatives although funding for meaningful programs is still scarce. Also important have been the prospect of lucrative carbon credits for renewable energy projects, as well as President Felipe Calderon's reforms to renewable energy regulation and the creation of financing mechanisms. At the present time, there is growing interest in the sector and, for the first time, important incentives in the form of financing and market opportunities. A national fund was created in the 2008 energy reforms, putting aside 3 billion pesos a year to help the renewable sector. The *Ley para el Aprovechamiento de Energías Renovables y el Financiamiento de la Transición Energética* (LAERFTE), which came out of 2008's energy reforms, set up a fund of almost US$250 million a year for the promotion of renewable energy.

At the federal level, Mexico has taken the lead in Latin America in the struggle to improve energy efficiency, with multiple projects across the country aimed at improving the ratio of energy per unit of GDP. For a number of years, the Federal government agency, formerly known as CONAE (*Consejo Nacional del Ahorro Energetico*), and now known as the CONUEE (*Consejo Nacional para el Uso Eficiente de la Energia*) has promoted energy savings and energy efficiency in both domestic and industrial and commercial contexts. Successful programs such as that promoting the use of low-energy light bulbs have appealed to Mexican citizens for the money, as well as for the energy-saving aspects involved.

In addition to policy innovation, Mexico has emerged as a leader in the region in wind energy. Best known is the La Ventosa wind park in the southern state of Oaxaca, but wind projects are underway in a number of states. Of particular interest for this report is the development of the La Rumorosa wind field in Baja California, which shows enormous potential for exports of wind energy to the United States. What's more, Baja California is not the only state with such potential for export, and work is underway identifying the scope and extent of wind corridors near the northern border.

Mexico also shows great potential as a producer of solar energy too, with highly favorable geography and insolation levels in many parts of the country, but particularly in the northern states. Both photovoltaic and solar thermal energy show great promise, both for domestic consumption and for export. Public and private sector from the United States has helped to explore and develop this potential, and will continue to be important in driving the business forward. Biofuel production too, though low at the time of writing, is an area that should develop rapidly in the coming years. The recent announcement of permits for

Table 1. Mexico's Renewable Energy Capacity, 2008

Technology	Capacity (MW)	% Total	Annual (GWh)	% Total
Wind power CFE	85.250	0.15%	231.505	0.09%
Wind power Private Producers	0.000	0.00%	0.000	0.00%
Small hydro CFE	270.128	0.46%	1309.525	0.53%
Small hydro LFC	23.330	0.04%	52.988	0.02%
Small hydro private producers	83.492	0.14%	228.053	0.09%
Geothermal CFE	964.500	1.66%	7057.768	2.86%
Biomass & biogas	498.116	0.86%	819.345	0.33%

Table created by author using data from the Comision Federal de Electricidad, CFE, March 2009.

ethanol and biodiesel purchases by PEMEX marks a first important step towards the scaling up of biofuel production and utilization in Mexico, even though civil society organizations and small private ventures have been producing ethanol and biodiesel for a number of years.

The scale of Mexico's advance in renewable energy can be seen by a simple data comparison. In 2006, of total electricity generating capacity, 22 percent came from renewable sources, but hydroelectric power dominated this segment, and was responsible for 19 percent of the total. It is notable that of the other renewable energy sources, wind only made up 0.004 percent of total generating capacity and geothermal only 2 percent. By 2008 this renewable quotient (not counting large-scale hydro) had risen to 3 percent, and its growth is predicted to continue to around 8 percent by the end of 2012. Of this amount, wind will grow most rapidly in percentage terms, to 0.09 percent in 2008 and to almost 3 percent by 2012, including both CFE facilities and private producers. In total the capacity of the renewable energy sector in Mexico (not counting large-scale hydroelectric) will grow from less than 2 gigawatts (GW) in 2008 to almost 5 GW in 2012, according to SENER figures. This rapid growth is being fueled by both demand for cleaner electricity and an interest in investment coming from private and public sources.

EARLY COOPERATIVE MECHANISMS

Programa de Cooperación en Energía Renovable (PROCER)

In November 1991, Sandia Laboratories of the United States, a multi-program laboratory operated by Sandia Corporation, a subsidiary of Lockheed-Martin, began work on a program to engage Mexican public and private entities in the area of renewable energy. Sponsored in part by the U.S.

Department of Energy (DOE) and the U.S. Committee on Renewable Energy, Commerce, and Trade (CORECT), the PROCER focused on developing awareness of renewable energy applications, particularly among institutions, technical training and building local capabilities and networks to encourage sustainability. The program was highly successful in reaching diverse groups across Mexico and also played a role in monitoring renewable energy applications put in place by state and federal governments. One example is that of Xcalak, a small fishing village in Quintana Roo that had never been connected to the national grid and had had a number of abortive experiments to establish reliable electricity supply with diesel generators. Through Mexican state and federal government funding, and with technical assistance from PROCER, a hybrid PV-wind project was initiated and was then monitored by PROCER partners. Not only did the monitoring help to guide the development of this project, but the data gathered was instrumental in designing HOMER, an NREL-designed "a computer model that simplifies the task of evaluating design options for both off-grid and grid-connected power systems for remote, stand-alone, and distributed generation (DG) applications."[6]

The Mexico Renewable Energy Program (MREP)

In 1994, USAID began to take an interest in the PROCER experience and negotiated a cooperative agreement with the Department of Energy and Sandia Laboratories. Thus began a program to promote renewable energy in Mexico for the purposes of development. Focusing on rural communities without access to the national electricity grid, USAID worked with a number of U.S. and Mexican partners to promote the appropriate and sustainable use of renewable energy technologies in Mexico with the goals of:

- Increasing the quality and reducing the costs of renewable energy technologies
- Increasing the use of clean-energy sources to combat global climate change
- Increasing economic, social, and health standards in rural off-grid households and communities by utilizing renewable energy systems for productive applications

In addition to these three goals, USAID aimed to promote the U.S. renewable energy industry in Mexico and to develop partnerships between U.S. and Mexican firms in the sector. The MREP incorporated a number of major actors in the implementation of its projects, including:

- The U.S. Department of Energy (DOE)
- Sandia National Laboratories (Sandia)
- Southwest Technological Development Institute (SWTDI)
- National Renewable Energy Laboratory (NREL)
- Winrock International, a nonprofit organization focusing on resource sustainability and development

- Ecoturismo y Nuevas Tecnologías (EyNT), a business set up in 1994 to promote the use of renewable energy applications
- Valdez Engineering, a Mexican engineering firm
- Centro de Investigación en Energía (CIE), a research center within the UNAM
- Asociación Nacional de Energía Solar (ANES), a Mexican NGO promoting solar energy

In addition, institutionalized cooperation between the MREP and federal government ministries in Mexico, such as the energy ministry (SENER), the agricultural ministry (SAGARPA), the education ministry (SEP), the environmental ministry (SEMARNAT) and the national indigenous institute (INI) ensured widespread acceptance and replication of MREP projects at the national level.

The sustainability of the program's goals was to be ensured through long-term partnerships with in-country organizations, the implementation of pilot projects to institutionalize renewable energy use, the building of technical capacity, and the provision of technical assistance to assure quality. Originally intended to last for five years, the program was extended twice, first in 1999 and then in 2004, and has focused on four main sectors in which to apply renewable energy technologies: agriculture (working with SAGARPA and FIRCO), protected environmental areas (with SEMARNAT and CONANP), distance education (working with SEP and DGTVE) and finally rural electrification (working with SENER and INI).

The major focus for the MREP throughout its existence has been solar energy, with an emphasis on photovoltaic (PV) technologies, but from 2004-2009 small-scale wind applications were also promoted. In the agricultural sector, PV applications have been used to power water-pumping systems and cooling and refrigeration. The importance of both of these is obvious. A farmer who can irrigate his fields more efficiently and reliably has more chance of guaranteeing harvests, and a dairy farmer, for example, who can cool and refrigerate his or her milk, will lose less of his product through spoilage before it gets to market.[7]

The importance of RE applications for remote rural locations that are not connected to the grid, and whose connection is not likely in the near future, is made clear by this quote from Sandia's final report of the MREP:

> *Bringing electricity to remote communities makes it possible to illuminate homes, refrigerate food, and establish home businesses for a more productive and better quality of life. Solar lighting enables rural families to engage in productive activities at home during evening hours. Modest amounts of solar electricity can be used to power village micro-enterprises such as electric sewing machines, refrigerators, and battery chargers.*[8]

The direct and far-reaching link between energy and development can be seen here; bringing electricity to remote communities can be revolutionary for both domestic and productive life. Fishing communities were now able to use PV technologies to refrigerate their fish. Thanks to a PV-powered icemaker employed by the MREP, they could now keep fish fresh and not need to go to market every day, saving valuable time that could be better employed in productive activities.

In 1998, Sandia noted the success of the MREP by highlighting the experience of cattle farmers in the north of the country who had benefited from the program by installing solar power water pumps for irrigation. By allowing their cattle to graze year-round, rather than having to purchase feed, and by ensuring that the cows had sufficient drinking water, ranchers saved significant amounts of money, and protected themselves from some of the effects of drought. In the same report, Sandia asserted:

> *Tremendous opportunities exist in Mexico for growth in the use of renewable energy technologies. According to some estimates, more than five million Mexicans do not have access to grid electricity in 88,000 villages, while more than 100,000 rural communities are in need of potable drinking water. More than 600,000 rural ranches need water for livestock or irrigation. Given Mexico's abundant solar and wind resources, these rural needs represent a potential market for renewable energy technologies of over $1 billion.*[9]

FIRCO (Fideicomiso de Riesgo Compartido), the Mexican government's program to promote small-scale agribusiness has been an active and highly complementary partner in the MREP. In fact, a perusal of FIRCO activities in recent years shows the importance of renewable energy technologies as a central element in its work. A "Train the Trainer" program that ran from 1999-2001 was instrumental in building capacity within FIRCO to continue the work of the MREP far into the future. The impact of the MREP on FIRCO is undeniable; the work that continues today in PV applications can be traced back to the beginning of the MREP in 1994.[10] The institutionalization of the program within a Mexican federal agency can be cited as one of the greatest successes of the MREP. To quote Sandia Laboratories:

> *A significant outcome of the FIRCO/Sandia partnership is the level of support that the Mexican federal government has shown for the implementation of renewable energy technologies in other agricultural-related programs. This has required formalizing and enacting basic policy changes within several government programs in which FIRCO plays a role, such as Alianza para el Campo (Alliance for the Countryside), Empleo Temporal (Temporary Employment), and Sequías (Drought). Each one is a federal program aimed at increasing agricultural production, and each has enacted fundamental changes to include the demonstration of PV and other renewable energy technologies.*[11]

The MREP's projects bringing RE technologies to other areas are also important to mention, as they have promoted ecotourism, distance education, and the use of solar power in homes and small businesses lacking access to the grid. The replication of MREP-sponsored projects by Mexican government agencies can be seen across the board, with thousands of installations exceeding the hundreds put in place by the MREP.

As a final report on the MREP from Sandia states:

From the perspective of the DOE R&D program and US industry, the MREP experience has provided invaluable data and insight on why end users adopt (or reject) solar technologies and how solar projects abroad can be replicated on a much larger scale by others. MREP also has been an important proving ground for technology deployment and evaluation under trying tropical conditions. The Mexico experience has also shown how critical financing mechanisms are to the rapid growth of the global solar market. In the end, our program is committed to focusing on innovations that will significantly reduce the initial and life cycle costs of solar components and systems, while improving overall system reliability and user acceptance.[12]

Until 2005, the MREP continued to focus on PV applications in remote areas, but USAID also began to work closely with national actors in the area of wind energy. This work is covered in more detail in a later section. Since 2008, USAID has adopted a new approach to promoting renewable energy in Mexico. Now working through its competitiveness program, USAID has sought to promote renewable energy along three main axes. First, it has funded training and outreach programs to promote the use of microfinancing for renewable energy projects. Second, USAID has begun to examine the role of the *municipio* (municipal authority) as a promoter of renewable energy, with a particular focus on local electricity self-supply projects. Third, the agency is active in promoting dialogue with key actors along a number of lines, including conferences, training and publications. In this third axis, USAID has funded a book examining the current state of renewable energy in Mexico, which will be used as a text for training policymakers and legislative staff in Mexico.[13]

The role of the DOE in institutionalizing cooperation in renewable energies has also been crucial. The signing in 1998 of a U.S.-Mexico Bilateral Energy Cooperation Agreement included a focus on renewable energy. The agreement, extended in 2001 for two years, helped to bring together personnel from DOE, Sandia, and the Mexican CONAE, to encourage joint research, resource-sharing, training and the promotion of RE use by both public and private sectors. The agreement was to be superseded by the Trilateral Agreement for Cooperation in Energy Science and Technology (including Canada), however this agreement took a number of years to negotiate, and was eventually signed in 2007. It will be in force for an initial period of five years and will renew automatically every five years afterward if all parties agree. However, it seems as though bilateral mechanisms have worked much better than their trilateral counterpart, and the April 2009 U.S.-Mexico Bilateral Framework on Clean Energy and Climate Change offers hope of continued work and renewed vigor along those lines.

GEOTHERMAL ENERGY

Mexico's longest-standing, non-hydroelectric source of renewable energy is to be found in the geothermal sector. Because of the country's highly volatile geology and active tectonic plates, Mexico has estimated geothermal electricity potential second in the world only to Indonesia, and produces over 3 percent of Mexican electricity output from this source. Installed capacity stands at around 958 MW, the fourth largest in the world behind the United States (2687 MW), Indonesia (1970 MW), and the Philippines (992 MW). This potential has been estimated in recent years as being anywhere between 8 and 13 GW, although with existing technologies and cost structures, a more conservative estimate may be the most likely economically viable upper limit.[14] The remaining generating potential lies mainly in low- to middle temperature sites which, though the technology is still undeveloped in Mexico, could be used for private and industrial purposes, such as greenhouse heating, spas, and aquaculture.

The potential of Mexico's geothermal resources was first considered in 1937 by a young engineer named Luis F. de Anda, who joined the CFE and began work on exploring Mexico's geothermal capacity. By the late 1950s de Anda had put together a multidisciplinary research team to "locate, delineate, and characterize the geothermal system at Cerro Prieto field, Baja California," in order to develop a clear idea of the potential for extracting steam from Mexico's geothermal fields, thus inspiring the CFE to invest in further research.[15] This led to a pilot project in Pathe, Hidalgo, with a capacity of 3.5 MW in 1959, but more importantly to the identification of an important high-temperature geothermal system which went into production in 1973. The Cerro Prieto facility, located in the Mexicali Valley, Baja California, Mexico, about 19 miles south of the U.S. border, began producing geothermal electricity and became Mexico's first and still largest geothermal generating plant.

The success of the Cerro Prieto development and the area's geologic similarity to the geothermal fields of neighboring Imperial Valley in southern California, led to the signing, in 1977, of a five-year agreement between CFE and the U.S. Energy R&D Administration to conduct a joint study of Cerro Prieto. Under this agreement, the two countries committed themselves to collaborative activities to:

> *Develop a complete knowledge of the nature and magnitude of this energy resource, to research the best way to exploit it in accordance with the long-term needs of the Mexican energy program and to determine the impact of this on the subsoil surrounding the field.*[16]

The CFE worked closely with Lawrence Berkeley Laboratory (LBL), which coordinated U.S. technical activities. This brought close collaboration between the two sides and led to the signing of a later DOE/CFE agreement to study Cerro Prieto and other geothermal areas in Mexico. The exchange of expertise and information increased understanding on both sides of the border and can be seen as a model for fruitful bilateral technical collaboration.

The Cerro Prieto facility is a huge plant with four plants of 110 MW each, four of 37.5 MW, four of 25 MW and one of 30 MW, in total comprising 149 wells and an installed capacity of 720 MW. The facility was subject to a large scale upgrade in 2000, when the four units of plant IV (for a total of 100 MW) came online. Cerro Prieto is responsible for producing

Mexico's known geothermal fields

Reproduced with permission from: Arellano, V.M., Iglesias, E.R., García, A., "La energía geotérmica: Una opción tecnológica y económicamente madura", Boletín IIE, Vol. 32, Núm. 3, (ISSN 0185-0059), julio-septiembre 2008, pp. 102-114.

46.37 percent of the electricity consumed in Baja, California.[17]

Cerro Prieto is important because it is one of the great success stories of Mexican electricity production. Not only does the facility produce clean electricity, it does so at such a scale that there is sufficient surplus power generated to allow for exports to the United States. Until 1996, electricity produced at Cerro Prieto was exported to San Diego, but these exports ceased when electricity demand in Baja California grew to the point where no surplus existed. Since then, CFE investments in generating capacity in the region have permitted a surplus to re-emerge, and on Feb. 3, 2009, the CFE signed an agreement with the Los Angeles Department of Water and Power (LADWP) to allow for the purchase of up to 100 MW of electricity from Cerro Prieto.[18] In fact, exports of electricity from Cerro Prieto had begun a few weeks before the agreement, "with the city's utility buying 25 megawatts of around-the-clock geothermal power in December and 50 megawatts in January."[19] Los Angeles Mayor Antonio Villaraigosa said that "the deal is monumental because it allows the department to transition to using more renewable power. The deal enables LADWP to reach a milestone of 10 percent renewable power supply, on track for 20 percent renewables by 2010."[20] Whether or not Los Angeles in particular, or California more generally, can achieve their renewable energy goals, remains to be seen.

Although the exact value of the deal for the CFE is not known, it is estimated that the company will earn as much as $100 million in 2010 from clean electricity exports to the United States and to Central America (through the newly finished interconnection there).[21]

It is estimated that Cerro Prieto will enter a period of steady decline in coming years, leading to a reduction in generating capacity of around 125 MW by 2018. Although the field is not fully exploited, the proximity of local communities limits the possibilities for expansion of the facility. CFE is engaged in a search for other sources of geothermal activity nearby, which should lead to new capacity coming online to replace the predicted decline, although it is unlikely that an expansion of current capacity will be seen. Already the CFE plans to expand production at Cerro Prieto by as much as 100 MW, having launched a tender for the Cerro Prieto V geothermal plant.

In addition to Cerro Prieto, there are currently three other large geothermal generating plants in Mexico: Los Azufres, Los Humeros, and Las Tres Virgenes, bringing total national installed geothermal-electric capacity to 953 MW.[22] This amounts to around 3.23 percent of total electricity generation in Mexico, but there is ample room for growth. According to the CFE, "geothermal energy potential in Mexico would allow the installation of another 2,400 MW,"[23] and feasibility studies have proved a potential for national reserves of 3,650 MW, whose generation could provide more than 12 percent of total electricity generation. Much of this depends on technological advances, but the cost of geothermal power, at around 3.986 U.S. cents per kWh, makes it highly competitive as a source of electricity.[24] What is lacking still is a more accurate estimate of Mexico's geothermal resources, and an adequate mapping of their location.

Already U.S. firms are benefiting from the geothermal sector in Mexico, providing services and maintenance. Working in collaboration with Mexican partners, U.S. companies, such as San Jose, CA-based Calpine Corp., have participated in geothermal steam production and well-drilling, as well as in repair projects at the Cerro Prieto plant, for example. With the expansion of the sector, such opportunities look set to grow in tandem.

A 2002 paper produced by the Border Energy Strategy Committee[25] noted that, in addition to further development of Cerro Prieto, the development of geothermal binary cycle technology that could use residual heat from existing operations could produce up to 260 MW more power. It remains to be seen if CFE will be able to fully exploit that potential. Less certain still, but even more potentially beneficial, is the prospect of the future development of "geopressurized deposits (high-temperature, high-pressure water located beneath the seabed) located in the northern part of the Gulf of California" that could offer a geothermal potential "tens of times greater than that of Cerro Prieto." A later study by the San Diego Regional Renewable Energy Study Group[26] confirmed this, stating that:

Geo-pressurized evaluations have been performed (Grijalva, 1986) in the northwest

Table 2. Current geothermal projects under development in Mexico

Project	Units	Power per unit (MW)	Units x Power per unit	State	Generation of annual average
Cerro Prieto V*	2	53.5	107.0	Baja California	745,000.0
Cerritos Colorados	1	26.6	27.0	Jalisco	186,000.0
Cerritos Colorados	2	26.6	53.0	Jalisco	372,000.0
Los Humeros phase A*	1	28	28.0	Puebla	186,000.0
Los Humeros phase B *	7	3.3	23.0	Puebla	156,000.0
Los Azufres III	2	50 & 25	75.0	Michoacán	559,000.0
Los Azufres IV	2	50 & 25	75.0	Michoacán	558,500.0
Total	**17**		**388.0**		**2,763,000.0**

Source: Government of Mexico, Secretaria de Energia (SENER), Programa Especial para el Aprovechamiento de Energias Renovables, 2009, p.79, http://www.sener.gob.mx/webSener/res/0/Programa%20Energias%20Renovables.pdf

> *area of the Sea of Cortez at the location known as Wagner Fossa. The tests show an energy potential 1000 times richer than that estimated at Cerro Prieto. If fully exploited, these resources of energy could supply Mexico with 20 times its current total energy consumption.*

The increased exploitation of geothermal power would, of course, represent a major contribution towards reducing emissions in Mexico, avoiding the consumption of as much as 40 million barrels of fossil fuels per year and the emission of approximately 16.5 million tons of CO^2.[27] But it also offers the prospect for increased exports of clean electricity to the United States. Although most of the sites that are being considered for future development of geothermal power are to be found in the center of the country, the prospective interconnection of Baja California with the rest of the national electricity grid would allow for the long distance transmission of this power. This would be made even easier to implement when smart-grid technology is applied, and this is an area where U.S. cooperation with Mexico could pay great dividends.

This brings us to the barriers that currently limit the export of more clean electricity to the United States and, in particular, to California. What is required is investment in increased transmission capacity from Mexico to the United States, either through Baja California to California, or from other border states to the rest of the United States. As we will discuss in a later section on wind power, transmission capacity remains the single largest obstacle to boosting RE electricity exports to the United States. Unlike wind power, however, geothermal power is constant and steady, providing the opportunity to transmit electricity without having to worry about intermittent fluctuations in power.

To boost the growth of geothermal capacity in Mexico, U.S. authorities might consider the potential benefits of providing technical assistance and funding for mapping out Mexico's geothermal resources. Although the general distribution of geothermal activity in the country is known, the specific location of the most appropriate sites for generation is not known. This will be of particular importance in the north of the country, with the predicted decline of Cerro Prieto, but throughout the country there is huge potential. With the future development of the Mexican national grid, such knowledge would be of enormous value to power authorities in both Mexico and the United States.

WIND POWER

The March 2007 inauguration of the "La Venta II" wind power project by President Calderon marked the coming of age of Mexican wind energy. From negligible amounts of wind power generation at the beginning of the decade, the "La Venta" project, involving three stages, would propel Mexico into the ranks of the world's leading wind energy producing nations. The Isthmus of Tehuantepec, located in the state of Oaxaca, has some of the best wind patterns in the world as far as wind generation is concerned, as they are strong and steady, providing a near constant supply of electricity-generating potential. What's more, Oaxaca is not the only state to be blessed with such capacity. Throughout Mexico there exists the possibility to exploit wind patterns of sufficient quality to make them eligible for efficient wind generation in the south, center, and north of the country. In total, it is currently estimated that Mexico's exploitable wind energy potential is between 9 and 12 GW,[28] although the U.S. National Renewable Energy Laborоratories (NREL) have estimated that those figures may grow up to 40 GW if all of Mexico's potential can be exploited using the latest advances in wind power technologies. By 2012, the installed generating capacity for wind in Mexico is hoped to reach 2.5 GW, making Mexico one of the world's leading wind energy producers.

Surprisingly, however, this potential had not been fully appreciated until relatively recently. In fact, as recently as 2003, the full wind power potential of Mexico had been estimated at a lowly 5 GW, but research and new technologies, as well as a heightened national and international interest in the sector has meant a steady upwards revision of these estimates. The beginning of Mexico's wind energy story, however, dates back to the early 1990s, with the beginning of collaborative work between the United States government, working through USAID and Sandia laboratories, and Mexican government agencies in rural areas of the country. This program, the MREP referred to earlier in this paper, concentrated on the use of renewable energies in remote areas lacking access to the national grid. As noted elsewhere, in the 1990s as much as 5 percent of the population of Mexico did not have access to electricity, and with a national population approaching 100 million at the time, this meant that as many as 5 million people were deprived of one of the most basic conditions of modernity.

Basing their program on the simple idea that access to renewable energy was a fundamental step toward sustainable development, and looking to develop a market for U.S. manufacturers of renewable energy technologies and the companies that maintain them, the MREP partners focused primarily on solar power but also pursued a number of different renewable energies. One of these was the application of wind power in remote rural locations, involving both mapping of wind patterns and the testing and application of different technologies in these areas. A key partner for USAID and Sandia was New Mexico State University (NMSU), through its College of Engineering, whose personnel became closely involved in the development of several wind projects in Mexico including the installation of small (1-10 kW) wind-electric water pumping installations in Quintana Roo, Oaxaca, Yucatan, and Zacatecas. NMSU also provided a survey of the wind resource at 20 sites in the states of Baja California Sur, Coahuila, Chiapas, Chihuahua, and Quintana Roo.[29] These projects continued for a total of 13 years, and laid the basis for further USAID work in wind energy in the country.

The development of Mexico's wind resources advanced significantly throughout the 1990s, although it was only in the last decade when the true potential of wind generation became clear. However, a pilot project that would later bear important fruit was undertaken in 1995 by NREL. The *Mexico Wind Resource Assessment Project* examined the potential for mapping out wind patterns across the country, an idea that was undertaken in the Oaxacan case in the next decade.[30] Also in 1995, the first stage of the La Venta wind project in Oaxaca was commissioned. Slightly over 10 MW of generating capacity was planned, with a further 83 MW to be installed at a second site nearby, known as La Venta II. This relatively small-scale development nonetheless marked an important advance in the wind energy sector in Mexico.

One issue that was holding back large-scale development of the resource was a lack of reliable information. Although it was well-known that the Ventosa area of Oaxaca had high winds (a fact shown by its name), the exact path, strength, and consistency of wind currents was more difficult to ascertain. A complete mapping of the area was required in order for companies to be able to make an informed decision about where and how to install their appropriately selected turbines. Whereas the state and federal governments showed little interest in funding such a project themselves, and the private sector could not coordinate well enough to provide an alternative source of financing, the mapping finally took place in 2002. In response to a request from the Oaxacan state government, USAID, working with the Department of Energy, the Bureau of Economic Growth and Trade (EGAT), NREL, USAID Mexico, and a range of Mexican government institutions, funded a study of the Oaxacan wind corridor. NREL, working through sub-contractors such as True Wind Solutions, set a goal of producing detailed wind resource maps of the entire state and a comprehensive "wind atlas" to be made available to the general public, and in particular to the wind power industry.

The project took one year to complete and incorporated wind data from a variety of sources, both national and U.S.-based. Working closely with the Foundation for Wind

Development in the Isthmus, and with the CFE and Conagua (Consejo Nacional del Agua, the Mexican government agency responsible for meteorological forecasting), NREL produced a 135-page Wind Energy Resource Atlas of Oaxaca that provides detailed maps and data covering wind strength, direction, and seasonal variability.[31] The major conclusion of the study was that western Oaxaca possesses one of the best wind resources in the world, due to a combination of mountainous topography and the narrow isthmus which produces a natural wind tunnel for air flows going between the Gulf of Mexico and the Pacific Ocean. This means that Oaxaca state has enormous potential for wind energy generation, much higher than previously estimated:

> *NREL estimates that there are about 6600 km² of windy land with good-to-excellent wind resource potential in Oaxaca. The windy land represents slightly more than 7% of Oaxaca's total land area (91,500 km²). Using a conservative assumption of 5 MW per km², this windy land could support approximately 33,000 MW of potential installed capacity. If only areas with the highest (Class 7) wind resource potential are considered, the estimated total windy land area is about 1200 km², and this land could potentially support about 6000 MW of installed capacity.*[32]

The atlas immediately came to be seen as a crucial resource for both government and business in the energy sector, and was instrumental in attracting new investment. As Pablo Gottfried of wind power company Fuerza Eolica put it:

"We use the USAID wind map to educate potential investors about the amazing wind resource in Mexico. The study confirms and expands on our own research, and the maps NREL produced make it much easier to understand … New companies are already using the assessment to plan projects without undertaking the many years of study that we had to undertake before USAID completed this wind resource assessment."[33]

The logic behind this involvement by USAID was two-fold. First it was to help the Mexican government and Mexican society take advantage of its natural endowments to boost the national renewable energy sector, and to help disadvantaged rural communities along the way. But it was also defended by USAID as a means of promoting U.S. wind energy firms in Mexico, both as generators and as suppliers of equipment and services.

In addition to the mapping of Oaxacan wind, USAID has adopted a multipronged strategy in the promotion of wind power in Mexico. Through conferences, studies, and engagement with key actors, not the least of which has been the Asociación Mexicana de Energía Eólica (AMDEE), USAID México has sought to:

- Promote the dialogue between political actors to advance legislative change in favor of renewable energies;

- Support the analysis of the regulatory framework in Mexico and the United States through conferences and visits to both learn from best practices in U.S. states such as Texas and to increase the possibilities for wind energy generating firms to export power from the north of the country to the United States;

- Identify and overcome economic and environmental barriers to promote investment in wind power projects;

- Improve the quality and quantity of information available on wind resources in other states in the north of Mexico and in the Gulf region.[34]

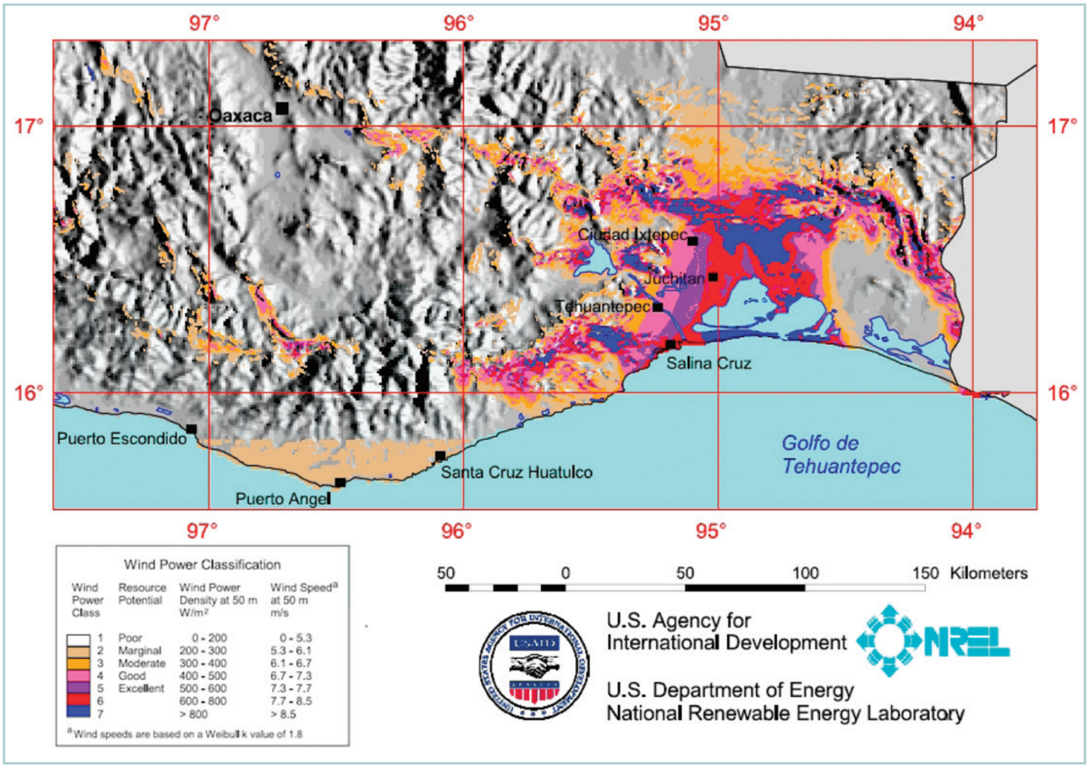
The second point mentioned here has been particularly important. In 2009, USAID México organized a visit for key actors in the wind energy industry to the United States to learn from best practices that have promoted the use of wind energy in California and Texas. USAID also published a report comparing the regulatory framework for wind energy in Mexico and the United States, which has become a valuable source for framing the debate over the future of wind energy legislation in Mexico.[35]

The March 2009 publication of a USAID report, "Elementos para la Promoción de la Energía Eólica en México," provided a thorough study of the wind energy sector in Mexico, focusing heavily on Oaxaca but also covering northern Baja California and the southeast of the country. The report recognized the continuing obstacles to the development of the wind industry in Mexico, emphasizing transmission, the lack of incentives or subsidies, and social and environmental factors. Though the report did not contain a great deal that was new to the wind energy community, it provided a useful reference point for the debate on how to expand opportunities in the sector. In addition to promoting the idea of investments in transmission infrastructure and the adoption of Production Tax Credits (PTC), the report recommended broadening the policy community to incorporate civil society and universities in a more comprehensive fashion. Furthermore, it asserted the need to find more adequate ways of addressing concerns of local landowners relating to land use and compensation.

Since 2003 Oaxaca has witnessed a wind power revolution. Growth of the sector has been unprecedented, and the government has embraced ambitious plans for expansion of wind energy in the country as a whole. In its energy sector program, SENER has established a target of producing 2.5 GW of electricity from wind in the Isthmus of Tehuantepec by 2012. An influx of generating companies, both Mexican and foreign, has seen a rapid development of the wind resource, for both sale to the CFE and for private consumption (*autoabastecimiento*). The dominance of European and especially Spanish firms is clear in Oaxaca. Gamesa, for example, registered its project with the UN in 2005 to seek financing under the Clean Development Mechanism (CDM). The Gamesa project has an estimated output of 200 MW, which was the largest registered CDM at that time. Just as significantly, the project is entirely privately run, with no involvement from the CFE. Gamesa followed up that success by initiating a second wind park that would generate 164 MW of power.

Another Spanish firm, Acciona, working from their North American offices, took a leading role in the next stage of the development process. In November 2009, the company completed construction of what would become Latin America's largest wind project, the 251 MW Eurus wind park. Built exclusively to provide electricity directly to Mexican cement producer CEMEX, the Eurus wind farm has enabled the company to drastically reduce its CO^2 emissions (by 600,000

Oaxacan wind resources



Source: National Renewable Energy Laboratories (NREL), "International Wind Resources, Mexico," http://www.nrel.gov/wind/pdfs/34519.pdf

tons a year).[36] Iberdrola, another Spanish power firm, is involved in a number of projects in Oaxaca. And the investment continues, with an estimated US$3 billion thought to be invested in Oaxacan wind projects over the next three years.

U.S. firms, however, have been largely absent from this boom in Oaxacan wind power. Given the important role played by USAID in the mapping of Oaxacan wind, the expected benefits for U.S. firms, and the rapid development of wind power in California and Texas, it is surprising that U.S. firms have not been more active. One company that has benefited is Clipper Wind Power, a California-based firm that produces wind turbines and is supplying equipment to a French-led project that will provide electricity to Wal-Mart in Mexico. This was largely made possible because Clipper benefitted from an $80.66-million loan from the U.S. Ex-Im Bank, which has recently embraced a new climate change strategy, putting in place a new $250-million facility to finance renewable energy exports, including solar, wind, and geothermal energy. But the list of Spanish, German, Italian, French, and, of course, Mexican firms is long. It seems as though U.S. firms have largely missed the boat when it comes to a golden opportunity in the region.[37] Part of the explanation for this is clearly that the European wind industry was up and running before its U.S. counterparts. Another partial explanation for Spanish success can be found in the linguistic and cultural familiarity enjoyed by Spanish firms.

It is unlikely that this story will be repeated in the north of the country, however, where USAID has once again played a key role in laying the foundations for the development of wind energy, this time with a view to exporting wind power to the United States. Working again with its partner, NREL, USAID has funded mapping of the wind resource in a number of states, such as:

- Baja California Norte Border Region
- Western Chihuahua Border Region
- Northwestern Mexico Border Areas
- Eastern Sonora Border Region
- Western Sonora Border Region
- Baja California Sur
- Quintana Roo and Yucatan

All of these maps are available online and free of charge to interested parties.[38] Of key interest to us here is the mapping work that was undertaken in the Baja California Norte border region, for it is seen as having been fundamental in promoting wind generation in the north. Combining the work of USAID in promoting a dialogue between Mexican and U.S. actors in the hope of solving the question of a functioning electrical interconnection between Mexican and U.S. border states, these maps have alerted a wider group of interested parties to the potential in Baja California.

One area in particular stands out. In large part thanks to the mapping of Baja California norte by NREL, the true potential of the La Rumorosa region has been noted by private and public actors. A 2003 report[39] prepared for the government of Baja California made extensive reference to the NREL maps, and inspired the state government to more fully investigate this potential.

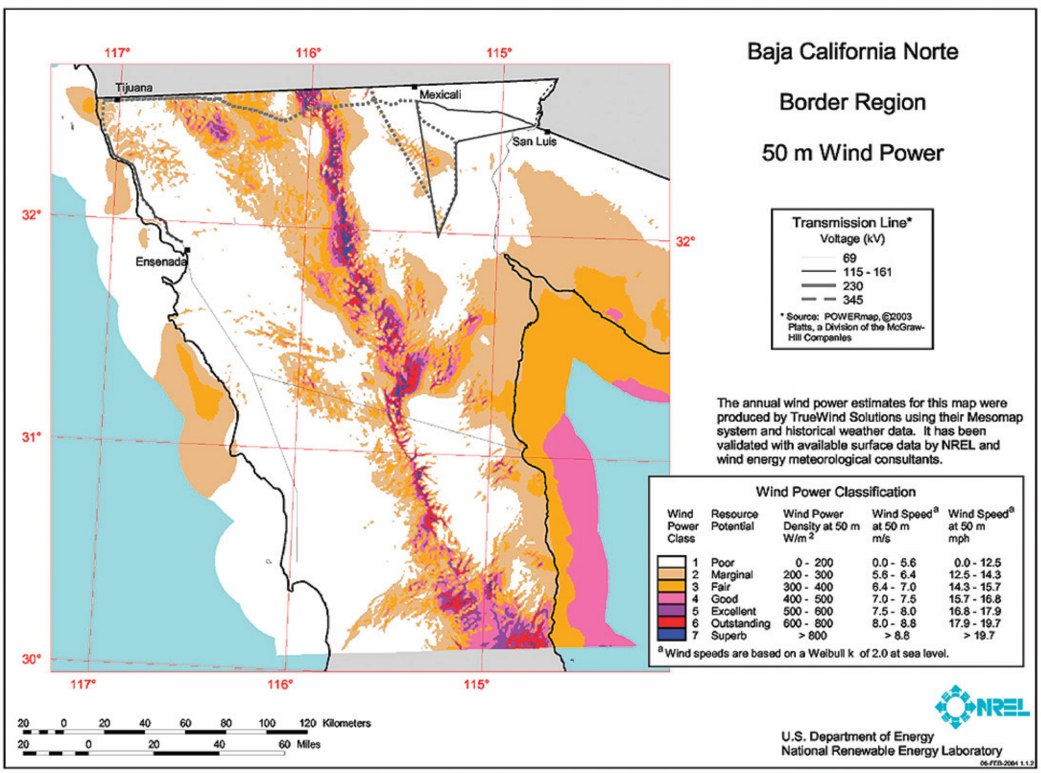
In 2009 work began on the La Rumorosa I 10 MW wind park, funded entirely by the state government of Baja California at a cost of just over US$26 million. This initial investment by the government confirmed the interest that already existed on the part of the private sector to exploit the potential of La Rumorosa and heralded the beginning of much larger projects. The Baja government's project is designed to produce electricity for consumption within the state, a decision that was based largely on the fact that Baja's electricity system is not yet interconnected with the Mexican national grid. This will change in the near future with CFE plans to connect Baja to the grid, as studies have recently been completed by the CFE that analyze the technical and economic dimensions of connecting Baja to the national grid. The interconnection should be completed by the end of 2014.

However, much greater economic potential exists in exporting the electricity across the border to California. As California and other U.S. states enact minimum renewable energy content legislation, they must rapidly find sources of clean energy that can be channeled into their electricity supplies. In the case of California, the Renewables Portfolio Standard (RPS) was established in 2002 under Senate Bill 1078 and accelerated in 2006 under Senate Bill 107, and mandates a minimum level of 20 percent renewable energy in electricity generation by the end of 2010. By 2008, the three largest Californian utilities operators had only achieved an average of 13 percent renewable energy in their portfolios, driving them to search for further sources. In the same year, California Governor Arnold Schwarzenegger signed Executive Order S-14-08, establishing a 33-percent minimum standard for the state by 2020.

The Renewable Energy Transmission Initiative (RETI), created in 2007 by the State of California, identified in-state renewable energy sources as well as those in neighboring states and produced a comprehensive analysis of the potential supply and costs of these. Baja California appeared in the top four out-of-state sources for RE in terms of cost, and was by far the leader in terms of easily accessible surplus capacity. The cost advantages of Baja wind energy is even more remarkable because providers in U.S. states are able to benefit from tax incentives and other subsidies; were firms in Baja to benefit from similar incentives, Mexican wind power would be far and away the most competitive in terms of price.

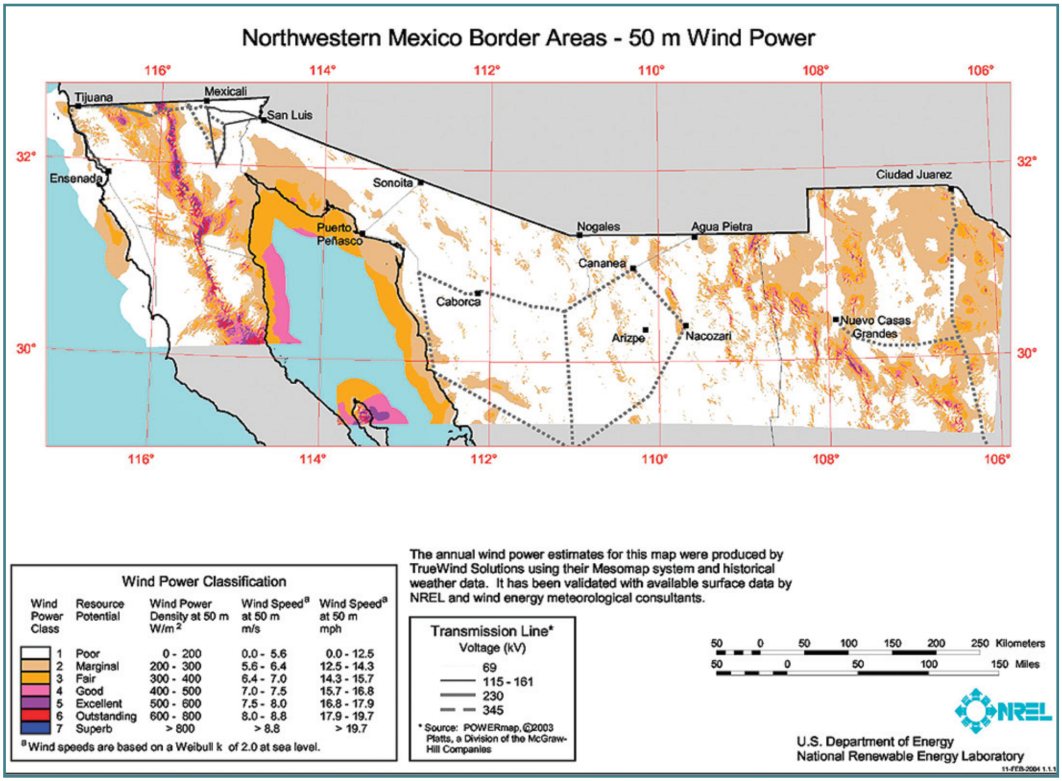
The notion of moving electricity across the border is, of course, not a new one, and already electricity, produced in Baja California, is exported to California from Sempra's 600 MW Mexicali-based power plant. Though this project was criticized by environmental-

La Rumorosa wind map



Source: National Renewable Energy Laboratories (NREL), "International Wind Resources, Mexico", http://www.nrel.gov/wind/images/map_mexico_baja.jpg

Northwestern Mexico Wind Resources



Source: National Renewable Energy Laboratories (NREL), "International Wind Resources, Mexico", http://www.nrel.gov/wind/images/map_mexico_nw_border.jpg

ists for exporting pollution to Mexico that will then return to the United States, the project has been a major success. The future of cross border power sales, however, will likely take on a much greener hue and Sempra itself is already heavily involved.

To meet the growing demand for renewable energy on the other side of the border, a host of private firms have entered La Rumorosa and have registered plans for wind farms. Again the Spanish electricity sector is well-represented, with Union Fenosa building a 1-GW park in two stages, and Mexico's Fuerza Eolica is planning a 300-MW plant. This time, however, U.S. energy firm Sempra has ambitious plans to participate, with an initial 100-MW plant that will eventually grow to around 1 GW.

A 2009 report on the future of the U.S.-Mexico border, prepared by the Pacific Council on International Policy (PCIP) and the Mexican Council on Foreign Relations (COMEXI),[40] identified the potential of the La Rumorosa region for wind power generation for export, although it greatly underestimated its full capacity, claiming that the region might eventually produce up to 1 GW, whereas more accurate assessments now put it at around 3 GW. This same report noted that there remain significant obstacles to the development of a true cross-border energy market, not the least of which was that:

Table 3: California's Renewable Energy Portfolio 2008 (GWh)

Fuel type	In-state generation	Imported power	Total	Percentage of total system power
Biomass	5720	657	6377	2.08%
Geothermal	12907	755	14662	4.46%
Small hydro	3729	687	4416	1.44%
Solar	724	22	746	0.24%
Wind	5724	1607	7331	2.39%
Total renewables	28804	3728	32532	10.61%

Source: Government of California, 2008 Net System Power Report – Staff Report, Publication number CEC-200-2009-010, July 15, 2009, http://energyalmanac.ca.gov/electricity/total_system_power.html

At present, however, there is no such a thing as an energy agenda for the border region: no true market for electricity across the border, no binational plan for electricity generation or transmission, and no program to develop new technologies or energy reserves.

One of the major problems facing the future development of the wind energy for export market is the lack of cross-border transmission lines. At present there is one transmission line that can accommodate the 10-MW state government wind project, but further expansion of capacity and possible export will necessitate significant investment, as well as cross-border cooperation.

This problem had been identified in previous studies, most importantly by a March 2009 report on the potential for wind energy exports to the United States prepared by USAID. Examining the future for wind projects in the north of Mexico, and the potential for exporting wind energy generated in Oaxaca and other regions, the report noted that the state of Baja California currently only has the following export transmission capacity:

- An 800-MW transmission capacity operated jointly by the CFE and San Diego Gas and Electricity (SDG&E), located between the sub-stations in Miguel-Tijuana and Imperial Valley-La Rosita

- Two privately owned transmission lines of 310 MW (owned by Intergen) and 1200 MW (owned by Sempra).

Table 4: Analysis of renewable energy resources outside of California

	MW	GWh/year	US $/MWh
Nevada	427	2 ,976	-21
Oregon	392	2 ,848	-19
Baja California	2,368	7 ,633	-11
British Columbia	340	1 ,553	-9

Source: Black & Veatch Corporation, Report to the RETI Stakeholder Steering Committee, Renewable Energy Transmission Initiative, Phase1B, Draft Resource Report, B&V Project Number 149148.0020, August 2008.

The report pointed out that there are currently not enough projects underway to overcome the deficit in transmission and interconnection capacity, and the cost for wind power firms of building such capacity would compromise the competitiveness of their electricity when and if it reaches the California market.[41]

Considering the prospect of exporting wind energy from further south, the report also remarked on the fact that the CFE has yet to build the interconnection between the national grid and the state of Baja California (although this is now happening and should be operational by 2014), and that the interconnection with Texas was designed for emergency electricity transmission rather than ongoing commercial applications. What's more, the state of Texas has already met and exceeded its requirements for renewable energy by investing heavily in wind projects of its own.

Further barriers to the cross-border trade in wind power (and of course, all other forms of renewable-sourced electricity) that were identified by the report include the fact that in California, wind power receives a subsidy whereas in Mexico no such subsidy currently exists. This clearly reduces the competitiveness of Mexican wind power, although it may be possible for Mexican producers to access the $250 million fund set up under the 2008 LAERFTE. The regulatory burden will also be a complex barrier to overcome: cross-border wind power will have to meet environmental requirements in both Mexico and the United States. The USAID report suggested that harmonization of standards between U.S. and Mexican authorities would go a long way toward reducing that burden.[42]

The development of this market and overcoming existing regulatory, economic and infrastructure barriers has now become a priority in bilateral relations. The Woodrow Wilson Center Mexico Institute, working with USAID and the U.S. Embassy in Mexico, and recognizing the potential impact of the RPS on the energy sector in Mexico, called together key stakeholders and analysts to a meeting in Washington, D.C., in January 2010 to discuss barriers and incentives to the export of clean energy from Baja California to California.

One way to overcome the transmission barrier would be to repeat the experience of the Oaxacan wind projects. In order to meet transmission requirements there, the state government issued an "open season" for wind energy development wherein firms register their plans for constructing wind parks, establishing the extent of demand for transmission. This would then allow infrastructure firms to evaluate the economic and technical feasibility of building the transmission lines. Of course administering the transmission line would be much more complicated than in Oaxaca due to the cross-border dimension, and this is where cross-border inter-institutional cooperation becomes vital.

The common theme that emerged from all sides at the meeting was that there is a need to work bilaterally on the infrastructure needed to transmit electricity from Mexico to the United States, although the appropriate way forward has not yet been decided. The report from USAID that came out of this meeting stated:

> *An integrated approach to creating an energy region must look beyond generating power to export. Linking RE generation to economic development in Mexico requires a*

Table 5: Expert recommendations for encouraging wind energy exports

Linking RE generation to economic development in Mexico requires a focus on value chain creation for providers and services. Information needs to flow from developers to universities and authorities to develop training and certifications for technicians and engineers.
Coordination is needed between system operators on both sides of the border. Both federal governments can play an active role by creating a task force to address this and other concerns.
There is a need to carry out further resource evaluation (e.g., wind-mapping) as estimates vary widely

Source: USAID, "Creating a Regional Renewable Market in the Californias" Promoting the Cross-Border Renewable Energy Market Meeting report, Woodrow Wilson International Center for Scholars. Washington, D.C., Jan. 25, 2010.

> *focus on value chain creation for providers and services. Information needs to flow from developers to universities and authorities to develop training and certifications for technicians and engineers. Already local enterprises have responded to an expanding market but there is far greater potential.*[43]

Alongside industry representatives, also present at the meeting was Baja California's Energy Commissioner, David Muñoz Andrade, who has been a leading proponent of the wind sector in his state. Muñoz Andrade believes that existing institutional mechanisms will be of enormous help. Baja California is a member of the U.S.-based Western Electricity Coordinating Council (WECC), which, Muñoz Andrade has stated, "is a very good thing that we have begun to take advantage of completely."[44]

The institutional dimension is one that needs to be emphasized more strongly in the debate over renewable energy exports to the United States. Inclusion of Baja California in the RETI was instrumental in alerting public and private actors to the potential for wind power exports. Membership in the WECC has provided important support to Baja California in this case, but the Western Governors Association (WGA) may prove to be just as important in future work. Benefiting from $11 million in funding under the 2009 American Recovery and Reinvestment Act, the WGA created the Western Renewable Energy Zones Initiative (WREZ) to "identify and expedite cost-effective, environmentally sensitive transmission development to areas with high-grade, renewable energy resources in order to bring about the development of 30,000 megawatts of clean and diversified energy across the West by 2015."[45] Although Mexican states could not benefit from the funds already allocated, a future extension of these funds may permit spending them in planning exercises for cross-border transmission.

U.S.-MEXICO SOLAR COOPERATION

Mexico's sunny climate and geographical location make it a prime candidate for solar energy development. With nationwide solar insolation levels at around 5 kWh/day/m^2, Mexico's solar potential is ranked third globally. If, however, we look only at the north-west of Mexico, that number goes up to over 6 kWh/day/m^2, suggesting enormous potential for building up the solar energy industry, and for considering exporting that power to the United States. To give an idea of the enormous potential, a recent Mexican government report asserted that a 25 area of solar PV panels in the desert of Chihuahua or Sonora would be able to produce enough power to satisfy all of Mexico's national electricity demand.[46] This suggests tantalizing possibilities for the industry as technology, cost structures and demand for renewable energies are transformed in coming years.

As noted earlier in this paper, solar energy applications come in two main forms: photovoltaic (PV) and solar thermal. Solar thermal applications themselves can be divided into two: the generation of electricity through the heating of water to generate steam and then turn turbines; and the use of solar radiation to heat materials directly, such as water, food, or even smelting iron. By 2009 there were over 1 million square meters of solar thermal panels in Mexico, with that number projected to rise to 1.8 million by 2012. Advances in these technologies in recent years have been impressive, and costs have begun to drop, but the cost of generating electricity from solar power remains dauntingly high and means that subsidies from governments, or from the World Bank Global Environment Facility (GEF), or the CDM, are needed to make solar power competitive with other sources.

This has constrained the development of the solar power sector in Mexico to some degree. Due to regulations restricting the CFE to buying the cheapest available electricity, solar power has been uncompetitive as a source of large-scale generation. The only major solar project in which CFE has invested thus far is in the north of Mexico, at the Agua Prieta II development in Sonora. Linking together natural gas, combined-cycle generators with solar thermal panels, CFE originally planned on a solar capacity of 31 MW. The project was eligible for $49.35 million in funding under the GEF, approved in 2006. The generating capacity had to be reduced after two failed bidding processes in 2006 and 2008, when no bidders submitted bids that would have allowed the CFE to produce electricity at the "least possible" cost. The GEF agreed to continue funding the project at the approved amount, provided that the CFE reduced the capacity of the solar plant to between 12-15 MW. The final result was a 10-MW solar thermal capacity at the plant, and the CFE received the full original amount from the GEF, with construction due to be completed by 2013.

Cost then remains a significant barrier. Solar energy remains one of the most expensive ways of generating electricity, due to the high cost of infrastructure. Solar thermal plants require investments as high as US$2,200 per kW of capacity, meaning generating costs rise to between 12 and 18 cents per kWh. Photovoltaic plants are even costlier, requiring investments of US$8,000 per kW of capacity, giving costs of between 26-35 US cents per kWh. Natural gas and even wind can produce power at a fraction of that cost. For communities not connected to the national grid, solar (both thermal and PV) may be an acceptable alternative, given the massive cost of building infrastructure to grant them access to the grid, and this is where most of Mexico's solar capacity has thus far developed, thanks in no small part to the assistance received under the MREP.

The legacy of the MREP is to be seen today in the FIRCO's programs mentioned above, but also in the form of the Proyecto de Servicios Integrales de Energía para Pequeñas Comunidades Rurales (SIE), a Mexican government project in the southeast of the country, that will bring renewable-sourced electricity to 50,000 households, comprising around 250,000 people. Focused on largely indigenous populations in the states of Chiapas, Guerrero, Oaxaca, and Vercruz, which currently have no access to electricity, the program benefits from funding from the GEF, the Mexican federal government, and municipalities and states. Many of the technologies and applications are derived from work undertaken during the MREP.

Despite the absence of large-scale solar projects to date in Mexico, the growth in demand for solar power in California and the rest of the United States has already begun to have a beneficial impact on border communities. On March 5, 2009, Kyocera Mexicana, a subsidiary of Kyocera Manufacturing of Japan, opened a new photovoltaic cell production plant in Tijuana, projected to have a maximum annual output of cells equivalent to 150 MW of solar power. Other firms have also seen the border as a prime location for solar power manufacturing plants. In 2008, Q Cells, a German PV manufacturer, announced the building of a $3.5 billion thin film PV manufacturing facility at the Silicon Border industrial park near Mexicali. Citing the growth of the U.S. RE market, the plant's strategic geographical location, and the large number of Mexican free trade agreements that will facilitate exports, the firm noted that the Silicon Border site was "ideal for the American markets."[47]

The Kyocera plant opening was attended by Mexican President Calderon, who noted the growing demand for renewable energy in California, and committed his administration to increasing the opportunities for solar power in Mexico. In March 2010, Kyocera Solar, Inc., a Phoenix-based subsidiary of Kyocera, announced plans to build a similar, but smaller, plant in San Diego, citing the proximity to the Tijuana plant as a major reason behind the choice of location. Vice-President of Sales and Marketing Tom Dyer stated that the "site was chosen due to … the proximity of our managerial and technical staff that support our solar manufacturing operation in Tijuana, Mexico, which is about 20 minutes away."[48] This kind of cross-border integration of production processes in the RE sector will continue to be a central factor in pushing a bi-national agenda forward.

What is the prospect for encouraging large-scale solar projects in Mexico? The answer may lie in what is currently taking place in the southwestern United States and in looking for possible synergies. A major project that could provide just such an opportunity is currently being developed in southeastern California, near the border with Arizona and Mexico.

In June 2008, Arizona-based Stirling Energy Systems (SES) announced plans to develop a huge solar power plant in southeastern California through its new solar energy outfit, Tessera Solar. The project would involve Stirling's own patented Suncatcher system, which employs Concentrating Solar Power (CSP) technology that is highly efficient and cost-effective. The Suncatcher system uses mirrors to concentrate sunlight onto hydrogen gas in tubes in the power conversion unit

(PCU) and the gas runs through a heat exchanger to power a four-cylinder engine. The engine then drives a generator to produce electricity. This use of hydrogen rather than water makes the technology appropriate for desert locations as it uses only small quantities of water (for cleaning the mirrors).

The project facility, originally named SES Solar Two but now renamed Imperial Valley Solar, will have an installed capacity of 750 MW, and would be constructed in two phases, costing $2.2 billion. Phase I employs 12,000 SunCatchers, with a generating capacity of 300 MW. Phase II would consist of around 18,000 SunCatchers, to produce the final 750 MW capacity. The project is located on over 6,000 acres of federal (Bureau of Land Management) land 14 miles west of El Centro and close to the border with Arizona and Mexico. This project will take advantage of the Sunrise Power link when it is completed, to transport its electricity to markets in western California. San Diego Gas and Electric has already contracted to purchase 300 MW of this electricity.

Although the project had to be cut back from 900 to 750 MW because of "cultural resources" located at the eastern end of the site, it is still a massive solar energy plant. The success of the Imperial Valley Solar projects raises the possibility of expansion across the border into Mexico, where land costs are much lower and construction costs should decrease. This would allow for greater economies of scale, provided the electricity could be transmitted across the border. The proximity of the site to Mexicali means that there is a source of labor, and the nearness of La Rumorosa is intriguing. If authorities begin to think about the full potential of combined renewable energy generating capacity in the region, the logic for a cross-border transmission link becomes much clearer.

The benefits for the local Mexican community would be enormous in terms of employment and investment. Looking at the Imperial Valley Solar project, between 300-700 construction jobs will be created over a three-to-four-year period, injecting more than US$60,000,000 into the local economy in the form of payroll.[49] The project also promises to create jobs in the automobile sector, as the four-cylinder engines that are used are produced in automotive plants. Beyond construction, around 160 permanent jobs will be created through the project.

At present, no formal plans exist for this expansion into Mexico, and, given the lack of available subsidies for renewable energy, there will be a serious obstacle for the development of large-scale solar facilities. Plants in the United States can benefit from a number of federal- and state-level grants and subsidies that lower final generating costs, thereby making solar power more competitive relative to other RE sources. Mexico needs to come up with a similar incentive structure to encourage RE. However, fiscal incentives to firms in the PV manufacturing sector has proved important in attracting investment in the cases of Kyocera and Q Cells, and innovative thinking on the part of federal and state governments in Mexico is needed to try to find mechanisms to provide similar incentives for energy generating plants. The logic is essentially the same:

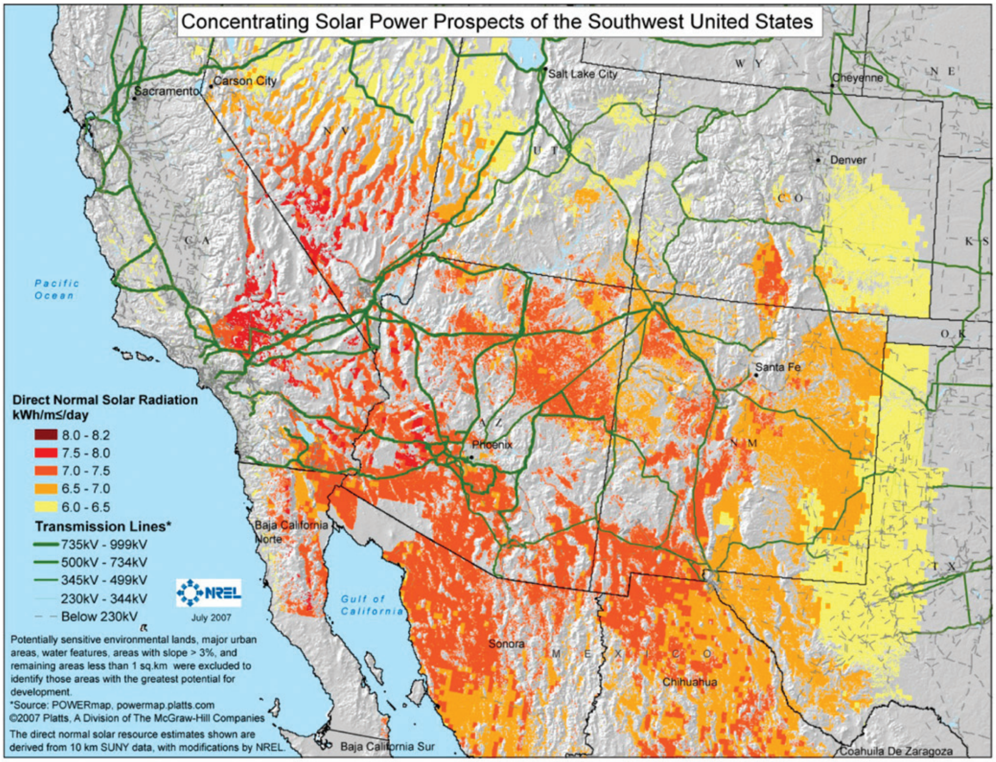
Sterling Energy System's SunCatcher Solar Energy Generator

Reproduced by permission of Stirling Energy Systems, inc. and Tessera Solar.

investors will benefit from fiscal incentives and Mexico benefits through jobs and income from exported energy. What's more, a representative of Tessera Solar commented that an expansion into Mexico makes perfect business sense, and that the problem of transmission would likely not be a major obstacle.[50]

The notion of cross-border energy parks also received a boost in April 2009 when Mexican newspaper *El Financiero* reported that the Imperial Valley Economic Development Corporation (IVEDC) has developed a plan to become the "Renewable Energy Capital of the World," with the expansion of geothermal, solar, and wind power. Andy Horne, Imperial County's deputy chief executive officer for natural resources development, noted that there is good reason to integrate the Mexican side of the border adjacent to Imperial Valley thanks to its similar natural endowments.

Solar power resources in the U.S. Southwest and Mexico



Source: National Renewable Energy Laboratories (NREL), "Southwestern U.S. Maps - 3%-slope NREL Map," http://www.nrel.gov/csp/images/3pct_csp_sw.jpg

BIOFUELS

Though underdeveloped at present, the biofuels sector in Mexico is likely to experience a massive leap forward in coming years. In February 2008, the Mexican Congress approved the Ley de Promoción y Desarrollo de los Bioenergéticos which in turn led to the creation of the Programa de Producción Sustentable de Insumos para Bioenergéticos y de Desarrollo Científico y Tecnológico, a program projected to run from 2009-2012 that would both promote biofuels production in Mexico and at the same time protect food supplies and the environment. Operated through the Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA), the program stresses the huge potential in Mexico for the production of biofuels:

Mexico is a country with vast natural resources for the production of biofuels, resulting from its agricultural diversity and geographical and climatic conditions that are ideal for this purpose. Our country has a great potential to become an important world producer of biofuels. [51]

The program has identified a number of priority areas, including:

- Providing incentives for feedstocks for biofuel production
- Promoting scientific development and cutting-edge technologies for crops with potential
- Encouraging the use of integrated technology approaches
- Providing advice to producers for the creation of feedstock firms
- Providing coordination and collaboration among key actors

To date, however, there has been only minor cooperation between the United States and Mexico at the governmental level. The United States Department of Agriculture (USDA) has worked with SAGARPA on a number of technical issues, and prepared a report on the Mexican biofuels sector in 2009 that pointed to the potential for growth in the market and to the changing regulatory landscape for biofuels in Mexico. This report highlighted the prospect of higher levels of demand for biodiesel thanks to the setting of a national goal to introduce at least 5 percent of biodiesel in the transportation sector by 2012.

But the main interest has come from the U.S. private sector, which is looking to invest in biofuels production in Mexico with an eye to exporting the product either back to the United States or to Europe. With small-scale projects popping up across the country, U.S. firms have begun to evaluate the potential for large-scale production of biofuels. Global Clean Energy (GCE), a Los Angeles-based firm that specializes in feedstocks for the production of biofuels, has recently invested in two jatropha farms in Mexico and one in Belize. Jatropha, a hardy shrub that produces a nut with very high oil content that can be processed into biodiesel, is seen by many as a perfect biofuel feedstock for Mexico. Native to the Mesoamerican region, the plant grows on marginal land, is not edible either for humans or animals, and thus does not generate a food-vs.-fuel controversy, and can be planted on land that is also used for grazing goats or sheep. In addition to being a feedstock for biofuels, the harvest can be used as a source of biomass for producing energy and the nuts themselves can be detoxified and processed for animal feed after their oil has been expressed.

GCE has 5,000 acres under cultivation in Yucatan, and has adopted a sustainable business model that has resulted in jobs, fair wages and community development in the local area.[52] This is one of the dimensions of the biofuels industry that is only infrequently mentioned but that is important to note. It is increasingly common for businesses focusing on biofuels production to develop a model that emphasizes both profitability and sustainable development. Pioneer Global Renewables, a U.S. firm from San Francisco that has already invested in jatropha plantations in the Dominican Republic, is also looking to expand into Mexico and has a similar model to GCE, focusing on local community development, fair prices for harvests, and minimal negative impact on the environment.

Jatropha, however, is only one of a multitude of biofuels that has potential in Mexico. Sugar, a long depressed industry in the country, could receive a significant boost if large scale ethanol production were contemplated. A large number of sugar mills are currently lying dormant, and could be retrofitted relatively cheaply to produce ethanol. For example:

> *According to the Mexican Sugarcane Producers Association, only two mills have the capability of producing ethanol with the technical requirements specified by PEMEX, equating to about 10 million liters per year. If these mills upgraded their facilities and operated at full capacity and efficiency, it is calculated that total production capacity for ethanol could reach 170 million liters per year.*[53]

The sugarcane-to-ethanol industry will also have to overcome labor and taxation issues if it is to become commercially viable in Mexico. At present ethanol is subject to a luxury tax of 50 percent, which makes the production of ethanol for fuel uncompetitive at the moment.

Another option exists in the incipient algae to ethanol industry, which is receiving considerable attention because of the potential for using algae cultivations as a way to capture carbon dioxide, and can be located in almost any climate. U.S. firms that possess the technology to increase efficiency in this field, such as Phyco2, a California-based firm, are already looking into the possibility of bringing their product to market in Mexico.[54]

Biofuels innovations indigenous to Mexico will also be of interest to U.S. firms. Recent research into the potential of succulents and, in particular, agave show enormous promise. The agave plant has very high concentrations of sugar and produces more sugar per acre planted than sugarcane. A research team working at the Universidad Autonoma de Chapingo has estimated that the variety *Agave tequilana weber* can yield up to 2,000 gallons of distilled ethanol per acre per year and from 12,000-18,000 gallons per acre per year if their cellulose is included, whereas:

> *Corn ethanol, for example, has an energy balance ratio of 1.3 and produces approximately 300-400 gallons of ethanol per acre. Soybean biodiesel, with an energy balance of 2.5, typically can yield 60 gallons of biodiesel per acre while an acre of sugarcane can produce 600-800 gallons of ethanol with an energy balance of 8.0. An acre of poplar trees can yield more than 1,500 gallons of cellulosic ethanol with an energy balance of 12.0, according to a National Geographic study published in October 2007.*[55]

In addition to the impressive potential for producing ethanol, agave is an attractive crop as it can grow in harsh environments, requires relatively little water, can be used to produce a wide variety of products, such as paper, textiles, and rope, and is common across Mexico.

One final area of biofuels production that is attracting considerable interest in Mexico is the generation of electricity from methane captured from municipal or agricultural waste. During Secretary of State Hillary Clinton's visit to Mexico in 2009, she visited the SIMEPRODE/BENLESA municipal waste processing plant in Monterrey that is run by Sistema Integral para el Manejo Ecológico y Procesamiento de Desechos (SIMEPRODE), a dependency of the Nuevo León state government. Private investment and technical assistance in the project came from a private corporation, Sistemas de Energía Internacional, S.A. (SEISA), part of Bioenergía de Nuevo León, S.A. (BENLESA), which has a sister firm in the United States named American Gentor, which operates energy projects across the world.

Costing approximately US$7 million, and entirely self-financed, the plant manages over 19 million tons of garbage on more than 70 hectares of land, which will produce methane gas for over 20 years. This results in an electrical generating capacity of over 7.4 MW, with about 40,000 MWh generated per year and supplying 40 percent of public lighting in the metropolitan area of Monterrey. Carbon credits from the plant's activities have been bought by the government of Denmark.[56] Given the growing problem of municipal waste, as well as that of methane emissions from agricultural waste, which contributes to overall levels of greenhouse gases, the development of plants throughout Mexico and indeed the United States would mark a significant contribution to climate-change mitigation strategies.

FUNDING RE AT THE BORDER: THE ROLE OF THE NADB

The North American Development Bank's (NADB) impact on questions of environmental management on both sides of the border is undeniable. Working across a broad range of issues, from water management, to paving, to waste management, the NADB's work has resulted in millions of dollars in infrastructure spending at the U.S.-Mexico border, defined territorially as a 200-kilometer swath straddling the border, 100 kilometers into Mexico and 100 kilometers into the United States. The 2002 expansion of funding and mandate for the NADB resulted in the bank taking on new areas of interest including clean energy. This opened the door for funding for border infrastructure and has resulted in a number of projects that have benefited from bank loans (see Table 6). NADB has also provided almost US$1.5 million in technical assistance grants for feasibility studies relating to a range of clean energy projects throughout the border region.

Two recent projects stand out. In the first, a biodiesel project in El Paso, beef fat and cooking oil are being processed into a diesel fuel that has much lower emissions than conventional diesel.[57] This kind of project, though it is located on the U.S. side of the border, has enormous potential for expansion into Mexico due to the prevalence of fried foods in popular Mexican cuisine. Collecting used oil on the Mexican side of the border and transporting it to El Paso for processing would develop economies of scale and provide public health and financial benefits to the people of Ciudad Juárez. A replication of this kind of project in cities along the border offers the prospect of large-scale production of clean biodiesel.

The second recent project that deserves attention here concerns the capture and processing of methane gas from bovine waste at a dairy farm in Delicias, Chihuahua. A bank loan of US$2,111,538 was authorized to fund the installation of an anaerobic digester, lagoon cover and liner, and power generator. Previously the dairy cattle waste was stored in pools that were uncovered and unlined, causing a range of environmental problems. The first, and most obvious, was the terrible smell coming from the pools of waste at the farm, but there was also a growing problem of groundwater contamination, and of course the

The BENLESA/SIMEPRODE power plant in Salinas Victoria, Nuevo León

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methane that was escaping from these pools constituted significant greenhouse gas emissions. The methane capture will allow the gas to be used to produce clean electricity sufficient to render the dairy plant self-sufficient, increasing profitability at the plant. The project will also conserve water as the effluent will be clean enough after passing through the anaerobic digester to mix with irrigation water to be used in local farms.

Despite the growth in clean energy projects and the potential for meaningful investments in all areas of RE, the proportion of loans given to these projects as a percentage of total NADB lending remains small. An overview of active bank-funded projects shows that the vast majority in Mexico are related to conserving wastewater and municipal landfills. Renewable energy projects at the border deserve more attention from the bank as they offer not only much needed assistance in environmental improvement, but bring jobs, increase profits, and satisfy a growing demand.

Even more worrying is the fact that the NADB's grants are in decline because of declining allocations. Although the number and total amount of loans is being maintained, grants have shrunk in recent years. This is due to the fact that the grants come from the U.S. Environmental Protection Agency (EPA), and congressional allocations for EPA grants have been reduced in recent years. From the 1990s until 2006 they were allocated by Congress at a rate of between US$50-US$100 million, but in 2007 this number dropped to US$25 million and in 2008 that number fell again

Table 6: NADB-funded renewable energy and energy efficiency projects in Mexico, 2007-2010

Wind Energy	Biofuels	Mini-hydroelectric	Energy Efficiency
Large-scale project in La Rumorosa, B.C.	Biogas projects from animal waste in northern Mexico	Mini-hydro project in northern Tamaulipas (15-20 MW)	Street lighting replacement project in Nogales, Sonora
Self-generation project in Tamaulipas (21 MW)	Dairy waste-methane recovery in Chihuahua (<1 MW)		Industrial Park Energy Efficiency project in Nogales, Sonora
	Landfill gas-to-energy in Ciudad Juárez, Chihuahua (7 MW)		Industrial Energy Efficiency projects in B.C.
	Landfill gas-to-energy Nuevo Laredo, Tamaulipas (2 MW)		

Source: Scott D. Storment, North American Development Bank, "Developing & Financing Clean Energy Projects in the U.S.-Mexico Border," presentation made to The North American Institute (NAMI) Santa Fe, N.M., May 30, 2007.

to only US$10 million. At a time when more financing is needed at the border, this is a worrying tendency.[58] A recent upsurge in interest in the border, however, with a particular focus on development and employment and economic opportunities, suggests that things are turning around.

Other institutions that have become important in the area of RE include the Border Governors Conference (BGC), which in 2002 created an energy committee and immediately seized on the potential for renewable energy in the border states. Its 2009 meeting in Monterrey, NL, had a significant emphasis on renewable energy at the border. The energy worktable, for example, committed itself to the following three broad goals in the area:

- Identify and promote a U.S.-Mexico border region program for renewable energy by exchanging information on policies and financial incentives;
- Work with federal bi-national organizations, the Border Environment Cooperation Commission, the North American Development Bank, and international organizations to facilitate project development;
- Identify financial opportunities for at least one renewable energy project before 2010

More importantly, in terms of the long-term vision of the BGC, was the presentation of a Border Master Plan, co-authored by El Colegio de la Frontera Norte and the Woodrow Wilson Center Mexico Institute. The Plan, titled "Strategic Guidelines for the Competitive and Sustainable Development of the U.S.-Mexico Transborder Region," included a number of references to both the importance of renewable energy on the border as a source of environmental improvement and prosperity, and to the potential for cross-border RE flows.

The Plan emphasized the further development of border renewable energy projects, and laid out a number of policy proposals (see Table 7), including the creation of a "geo-referenced database of renewable energy resources" as a necessary step on the road to fully developing RE along the border. But, perhaps the most important contribution of the Plan was to redefine the scope of the border region:

> *The Plan contains an innovation regarding space: Rather than limiting itself to the area around the international line and its numerous cities, the Plan expands its scope to a strip that is 300 km wide on the south side of the border and 100 km on the north. Thus, in addition to the full territory of the 10 member states, the Plan contemplates a transborder region that is 2.68 million km² in size, with a population of 84.7 million inhabitants, and a combined GDP of US$3.3 billion, equivalent to third-largest national economy in the world.*[59]

This redefinition of the border region is of vital importance for expanding renewable energy activities that might be brought within the purview of the BGC, and in thinking about the potential for RE exports to the United States. Given the potential for future development of solar and geothermal energy in Mexico, and the possibilities for innovations in biofuels production, this would greatly increase the scope of renewable energy projects that could benefit from assistance from the NADB and from the BGC.

UNIVERSITY-LEVEL COOPERATION

In October, 2009, USAID announced grants to fund five new university partnerships to support "Mexico's Competitiveness in the Environment and Energy Sector." Of these five grants, three were directly related to RE, and are focused on building up human capital in the area and on the promotion of alternative sources of energy. The U.S. government's Higher Education for Development program (HED), in conjunction with USAID, has for a number of years funded partnerships between U.S. and Mexican universities, and the TIES grants have been a successful mechanism for encouraging cooperation between US and Mexican universities in diverse areas related to development. While most partnerships have been provided with US$250,000 in funding, the 2009 grants were for US$300,000 each. The USAID/HED funds must be matched by contributions from the participating universities, and these funds can be spent in the form of scholarships, conferences, research, and networking.

Though the impact of these grants will not be felt for a few years, the creation of human capital in renewable energy and the further promotion of public awareness of the importance of alternative energies are crucial components in building the industry in Mexico.

THE FUTURE OF MEXICO-US COOPERATION IN RE

Over the past 15 years, contributions by U.S. government agencies to the development of renewable energy resources in Mexico have left a significant impact. Most obviously in the wind and solar sectors, Mexico has benefited from technical assistance, resource identification, and regulatory guidance. The work of USAID, DOE, Sandia Laboratories, and the National Renewable Energy Laboratories has helped to promote awareness of renewable energies and has built up human capital in Mexico.

Table 7: Border Master Plan Recommendations for Renewable Energy

Revitalize the Border Environment Infrastructure Fund (BEIF) to provide grants to local governments for projects that benefit low-income communities. NADB should explore partnerships with the Inter-American Development Bank, World Bank, and the International Finance Corporation. This could lead to a shared vision and give NADB additional expertise in its role as a development bank.
NADB should require that proposed projects demonstrate environmental benefits by requiring broader environmental metrics.
Encourage investments in environmental technology and renewable energy at a time when the U.S. and Mexican governments are seeking ways of enhancing a bilateral partnership on renewable energy and climate change. NADB can play an even greater role in promoting this partnership by providing premium lending rates for projects demonstrating higher environmental standards linked with water or energy savings as well as natural resource enhancement.
Develop a more flexible concept of the geographic scope for BECC and NADB projects, by incorporating areas within clearly defined economic corridors. NADB should be allowed to finance some private infrastructure projects, which could, in turn, help generate interest that would further capitalize the bank.
Work out the differences in the legal frameworks, and design a model that can work with Mexico's Federal Electricity Commission (CFE) to extend permits to develop renewable energy. The goal is for federal action to streamline opportunities for electricity export that would benefit border communities.
U.S. states with aggressive Renewable Portfolio Standards (RPS) should accept electricity generated from renewable sources in Mexico to incentivize this binational market.
Creating a geo-referenced database of renewable energy resources and adopting those best practices that ensure the optimal management of energy demand, especially that of industrial and other high-volume users.

Source: Border Governors Conference, "Strategic Guidelines for the Competitive and Sustainable Development of the United States—Mexico Transborder Region," http://bordergovernors.org/en/pdf/Strategic_Guidelines_ENG.pdf

All of this, however, should be seen only as a prelude to what is coming in the near future. With rising demand for renewable energy in the United States and a limited capacity to generate it from national sources, Mexico's geographical proximity and its free- trade relationship with the United States make it an ideal source for green electricity and biofuels. If it can build up its renewable energy capacity, Mexico stands to benefit enormously from this opportunity in the form of employment, investment, and the sustainable development of underdeveloped regions.

Based on the evidence presented in this report, to help this capacity develop further, the United States should concentrate its efforts on a number of key issues in the renewable energy sector.

Financing:

- Create bilateral mechanisms, through both the NADB and new institutional mechanisms to assist in the development of renewable energy projects throughout Mexico. Special treatment should be given

Table 8: 2009 TIES Grant Partnerships in Renewable Energy

Appalachian State University and Fundación de la Universidad de las Américas Puebla: The partnership will promote efficiency of energy use and decreasing dependency on fossil fuels in Mexico.
Duquesne University and the Universidad Autonóma de Nuevo León: The partnership establishes cooperative programs aiming to empower students, faculty, professionals, and Mexican businesses to promote renewable energy and enhance energy efficiency.
University of Colorado at Boulder and the Universidad de Guanajuato: The main goal of this partnership is to develop a strong curriculum for a graduate program to promote energy efficiency and renewable energy in the built environment in Mexico

Source: U.S. Embassy Press Release, 3a. Conferencia Enlaces y Lanzamiento de Cinco Nuevas Alianzas Universitarias, http://www.hedprogram.org/LinkClick.aspx?fileticket=ofSilAYdl/s%3d&tabid=59

to projects that are aimed at the export of RE to the United States.

• Seed capital will be particularly important in the biofuels sector as it is currently comparatively stagnated due to lack of funds.

Wind energy:

• Continue to provide assistance in the mapping of wind resources in Mexico, and to build up an indigenous capacity for this service in the country.

• Investigate the viability of building new cross-border transmission lines from northern Mexico to the United States to assist in the development of wind energy exports from Mexico.

• Cooperate with Mexico to continue R&D in wind turbine technologies such as the work that is currently underway in Mexico to develop a wind turbine for extreme weather conditions.

Solar energy:

• The application of solar technologies in rural off-grid communities in Mexico owes a great deal to the MREP of the 1990s and 2000s. Continuing this work in the future and examining ways to combine solar, wind and biofuels applications will provide ongoing low-carbon benefits to rural populations.

• A comprehensive evaluation of the potential for solar power generation in the north of Mexico is needed, with indications of the relative advantages of PV, solar thermal, or CSP technologies, depending on the site location and local demand.

• A diagnosis of the possibility of extending solar power subsidies to Mexican producers if they export to the U.S. market. This would greatly facilitate the development of cross-border solar facilities.

• Facilitate cooperation among border states to smooth the way for cross-border solar facilities.

• Explore low-tech solar applications, such as the Mexican use of the heat-conductive volcanic rock tezontle to heat water.

Geothermal:

• Further mapping of Mexico's geothermal resources to include all national territory and low- to medium-level resources.

• Cooperation with Mexican companies, in particular the CFE, on geothermal drilling technologies.

• Cooperation with Mexican researchers on geothermal binary cycle technologies to recover secondary heat, which would increase geothermal production from existing facilities by up to 260 MW.

• Cooperate with Mexican researchers on technologies to allow for the exploitation of geopressurized deposits in the Sea of Cortez, which has the potential to dwarf current geothermal resources.

• Explore the potential for the harnessing of Mexico's low- to medium-temperature geothermal reserves as a source of hot water for tourism, business, and residential applications.

Biofuels:

• Support U.S. firms' investments in Mexican biofuels production through the Overseas Private Investment Corporation.

• Consider allowing subsidies to U.S. biofuels producers based in Mexico if their product is to be exported to the U.S. market.

• Support research through USAID and HED at the university level into new biofuels crops with high energy potential and low water requirements, such as succulents.

• Work with Mexican authorities and businesses to further develop the capture and use of methane from municipal and agricultural waste for electricity generation, throughout the country and particularly near the border.

• Work with CFE and PEMEX to explore the use of algae as a form of CO^2 capture that can then be used for ethanol production.

The Border:

• In addition to the transmission and mapping priorities already mentioned, it is vital that there is more coordination between institutions such as the BGC, NADB, and other groups among themselves and with civil society and private enterprise. This will help adapt renewable energy projects to the needs and capacities of the communities involved, and produce a wider distribution of their benefits.

• Mexican border states should be invited to participate (as either full members or observers) in the Interstate Renewable Energy Council.

• The CFE should be invited to attend meetings of the California Renewable

Energy Transmission Initiative to explore the need for transmission from northern Mexico and the impact of existing California transmission projects (such as Sunrise) on the Mexican grid.

- A full impact study should be undertaken to examine the positive (and potentially negative) effects of renewable energy projects in the border region on employment, infrastructure, environment, and human capital.

- Examine ways to reduce regulatory burden on renewable energy suppliers who wish to export electricity across the border.

CONCLUSIONS

Although Mexico's growing problems in oil production dominate discussions within the country's energy community at present, the enormous potential of its renewable energy sector deserves much closer attention and enthusiasm. The 2008 advances in defining the legal framework for renewable energy, and in providing financing mechanisms, though still insufficient, represent important steps forward on the path to a more comprehensive development of the sector. The Calderon administration's interest in climate change mitigation strategies and in renewable energy have helped to propel the sector forward since 2006, and by 2012 Mexico will have an installed capacity of almost 5 GW, up from 2 GW in 2008.

The explosive growth in renewable energy at the global, regional, and national levels seen in recent years is likely to be only the beginning of a prolonged surge in the development of green energy capacity. Thanks in part to sustained interest by various United States' government agencies in Mexican RE potential, Mexico has built up an impressive renewable energy portfolio in recent years, and will make further advances in both capacity and technology in the future. Mexico is ideally placed to export this energy to the United States thanks to geography, its free-trade agreement with the United States, and growing demand in a number of U.S. states for clean energy.

The remaining obstacles to growth in the RE sector are numerous, but they are far from insurmountable. With continued technical assistance from the United States and other foreign governments, and with burgeoning interest from the private sector, Mexico's federal and state governments are well-placed to develop innovative ways to overcome current barriers. The rewards for their efforts will be increased levels of green energy, new jobs that are sustainable in the long term, and much needed income from energy exports.

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