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093

Mexico: Technical Assistance for Long-term Program of Renewable Energy Development

February 2006

ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME (ESMAP)

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Energy Sector Management Assistance Program (ESMAP)

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Abbreviations, Acronyms and Units

AMEE	Asociación Mexicana de Economía Energética
ANES	Asociación Nacional de Energía Solar
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APEC	Asia Pacific Economic Cooperation forum
BAU	Business as Usual
Bbl	Barrels (of oil)
BOT	Build-Operate-Transfer Contract
CANAME	National Chamber of Electrical Equipment Manufacturers
CANAME	Cámara Nacional de Manufacturas Eléctricas
CCGT	Combined-Cycle Gas Turbine Electrical Generation Plant
CDM	Clean Development Mechanism
CEC	North American Commission for Environmental Cooperation
CEIP	Centre for Energy Information and Policy
CENACE	Centro Nacional de Control de Energía
CFE	Comisión Federal de Electricidad
CIEMAT	The Spanish Research Centre for Energy, the Environment and Technology
CINVESTAV	Centro de Investigaciones y Estudios Avanzados (Center for Advanced Studies and Research)
CNA	Comisión Nacional del Agua
CO_2	Carbon Dioxide
COMIA	Comisión Mexicana de Infraestructura Ambiental
CONACYT	National Council for Science and Technology
CONAE	Comisión Nacional para el Ahorro de Energía
CRE	Comisión Reguladora de Energía
CYTED	Iberoamerican Program of Science and Technology for Development
ERR	Economic Rate of Return
ESMAP	Joint UNDP/World Bank Energy Sector Management Assistance Programme.
EU	European Union
FAO	UN Food and Agriculture Organization
FDI	Foreign Direct Investment
FIRCO	The World Bank's Renewable Energy for Agriculture Project
GDP	Gross Domestic Product
GEF	Global Environment Fund
GHG	Greenhouse Gasses
GOM	Government of Mexico
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit GmbH (German society for technical cooperation)

GW/MW/kW	Giga/mega/kilo Watt ($1x10^9$/$1x10^6$/$1x10^3$)
HACIENDA	Ministry for Finance and the Budget
HFO	Heavy Fuel Oil
ICSID	International Center for Settlement of Investment Disputes
IEA	International Energy Agency
IIE	Instituto de Investigaciones Eléctricas
IPN	National Polytechnic Institute
IPP	Independent Power Producer
ISES	International Solar Energy Society
ITAM	Tecnología Autónomo de México
JICA	Japan International Cooperation Agency
LFC	Luz y Fuerza del Centro
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MEC	Marginal Energy Cost
MT	Mega Tonnes ($1x10^6$)
MTons	Mega Tonnes ($1x10^6$)
NAPCC	National Action Programme for Climate Change
NPV	Net Present Value
OECD	Organisatioin for Economic Cooperation and Development
OSG	Oaxaca State Government
PEMEX	The state-owned, monopoly oil company in Mexico
PJ	Petajoules ($1x10^{15}$)
PROFEPA	Procuraduría Federal de Protección Ambiental
PUE	Programa Universitario de Energía (UNAM's Energy Program)
PV	Photovoltaic
PVB	Present Value of Benefits
R&D	Research and Development
RET	Renewable Technologies
RTC	Technology-specific regional centres created with support from CONACYT
SEMARNAT	A coordination effort between SENER and the Ministry for the Environment and Natural Resources
SEMIP	Secretaría de Energía, Minas e Industria Paraestatal, now the Ministry of Energy, SENER.
SEN	Mexico's National Interconnected System; the grid covering most of the country except Baja California, with interconnections to the USA, Belize and Guatemala
SENER	Secretaria de Energía
SHCP	Secretaría de Hacienda y Crédito Público
SHS	Solar home systems
SIGER	A geographical information system developed by IIE
STAP	Scientific and Technical Advisory Panel
SWH	Solar water heaters

TcF	Trillion Cubic Feet ($1x10^{12}$)
UAM	Autonomous Metropolitan University
UNAM	National Autonomous University of Mexico
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
US	United States of America
USAID	United States Agency for International Development
USD	US Dollars
WB	World Bank
Wh	Watt hours – unit of energy equivalent to one Watt of power expended for one hour of time
WTI	West Texas Internmediate (reference crude used to measure the price of a barrel of oil)
WTO	World Trade Organization

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This Technical Paper Series consists of four papers prepared as part of the Energy Sector Management Assistance Programme's (ESMAP) "*Mexico Technical Assistance for a Long-Term Program for Renewable Energy Development*", and forms part of ESMAP's ongoing commitment to renewable energy.

Andres Antonius and Gustavo Merino of the *Instituto Tecnología Autónomo de México* (ITAM) Renewable Energy in Mexico, contributed a paper on "*Current Situation and Perspectives*"; Jorge Huacuz, of the *Instituto de Investigaciones Eléctricas* (IIE) contributed the paper entitled "*Plan of Action for the Large-Scale and Sustainable Implementation of Renewable Energy in Mexico*"; "*A portfolio approach to energy planning in Mexico*" was written by Shimon Awerbuch and Martin Berger, who were at the time at the IIE, and the Vienna University of Technology respectively; and Donald Hertzmark prepared the "*Economic Analysis of Mexico Wind Project*".

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Executive Summary

Overview of Papers

1. The four studies in this technical paper series deal with complementary themes and propose solutions to the same problems that all of them perceive in the Mexican electricity sector – yet each paper looks at the problem from a different angle, and proposes different actions that must be taken in order to bring about a significant increase in Mexico's adoption of on-grid renewable energy. These papers take us from the general overview of the policy and institutional context, down to the specific case of a hypothetical wind farm. They review the current situation, identify concrete policy and institutional changes that are badly needed to stimulate the sector, look at how new paradigms for valuation can help us to better account for the value of renewable energy capacity, and finally perform a thorough economic impact analysis of the hypothetical addition of a large wind farm to Mexico's grid.

2. In "*Renewable Energy in Mexico: Current Situation and Perspectives*", Andres Antonius and Gustavo Merino of the *Instituto Tecnología Autónomo de México* (ITAM) review the current state of renewable energy implementation in Mexico, as well as looking at some of the institutional and regulatory obstacles that are currently slowing down the sector's development. Dealing with the policy context, in "*Plan of Action for the Large-Scale and Sustainable Implementation of Renewable Energy in Mexico*", Jorge Huacuz of the *Instituto de Investigaciones Eléctricas* (IIE) details the legal, regulatory, institutional, financial and infrastructural elements of the new policy environment that must be created in order to foster the implementation of large-scale renewable energy in Mexico. In "*A portfolio approach to energy planning in Mexico*", Shimon Awerbuch, visiting researcher at the IIE, and Martin Berger of the Vienna University of Technology look at ways of moving beyond the traditional least-cost approaches to valuing sector capacity additions that have consistently undervalued the systemic benefits of fixed-cost renewable technologies. They show how portfolio theory, long a staple of the financial industry, can be used to evaluate renewable energy options as part of an optimal risk/return portfolio. Finally, "*Economic Analysis of Mexico Wind Project*" gets right down to the specifics; energy sector economist Donald Hertzmark looks at the economic costs and benefits of adding a hypothetical 100MW of wind capacity to Mexican grid, focussing specifically on the incremental cost and economic rate of return that such a project would produce.

Background of Mexican Sector

Mexican Energy Sector in General

3. Mexico's energy sector is one of the most important among emerging economies, ranking 8th in the world in terms of oil production and 9th in terms of oil reserves. Mexico's annual electricity production is little short of 40,000MW, and its electricity grids reach around 95 million people. Mexico is also an important emitter of greenhouse

gasses, responsible for 1.48% of the World's emissions and ranking as the 13th largest emitter worldwide. However, Mexico is still rapidly developing – while emissions are significant, it still ranks only 72nd in terms of emissions per capita, and land conversion and forestry remain the largest source of its emissions. This is likely to change, as electricity demand is expected to rise rapidly over the foreseeable future.

4. Institutionally, the Government of Mexico's (GOM) electricity sector policy is formulated by the *Secretaria de Energía* (SENER), with executing authority in the hands the *Comisión Federal de Electricidad* (CFE), and *Luz y Fuerza del Centro* (LFC), serving Mexico City. Constitutionally, CFE and CFL have the exclusive right to the production, distribution and sale of all electrical power to be used as a 'public good'.

Energy Mix

5. Abundant in hydrocarbon resources, low in per-capita energy consumption, and with environmental issues historically taking a backseat to economic growth in the governments' priorities, Mexico's power sector has historically relied heavily on hydrocarbons – a dependence that has been exacerbated by generous subsidies, both hidden and direct, to the consumption of fossil fuels.

6. Despite being well endowed with natural resources, renewables currently make up only 4.2% of Mexico's total energy supply, the lion's share of which (3.5%) is accounted for by traditional fuel use such as wood fuel for cooking. The remainder is almost entirely made up of large hydroelectrical and geothermal power. Mexico generated nearly 200GWh of electricity in 2001, of which oil accounted for 49%, gas for 19%, coal for 12% (total for hydrocarbon, 79%), with geothermal and hydro accounting for only 21%. Hydroelectric energy actually makes up around 26% of installed capacity, but only 14% of production due to the intermittent nature of its supply.

7. Fossil fuel production is almost entirely in the hands of the national oil company, PEMEX. As the source of 20% of government revenues (at around US$30 billion per annum) PEMEX has been seen as more as a source of funds then investment opportunity, and the sector's increasingly cash-strapped situation has lead to a rapid depletion of reserves in both the natural gas and oil fields. Natural gas output actually peaked some years ago, and has been steadily declining ever since; Mexico is now a net importer of natural gas from the US. Despite this, the economic efficiency of combined-cycle gas turbines in electricity production means that the Mexican power sector is fêted to become increasingly dependent on natural gas for its feedstock. Plans are currently underway to develop two large LNG regasification plants to facilitate seaborne gas importation.

Sectoral Growth and the SENER/CFE Expansion Plan

8. Electricity demand in Mexico is expected to increase rapidly over the next decade. SENER's forecast for the energy sector, *Prospectiva del Sector Eléctrico 2001-2010* (hereafter *Prospectiva*), shows energy demand growth of 6.3%, outstripping GDP growth (at an estimated 5.2%) over the next ten years. This will require very significant capacity increases over the next decade: over 32,000MW will need to be added to existing capacity over the 2001-2010 period. If one includes the planned retirement of

1,661MW[1] of ageing plant, this gives a net total increase of 30,558MW – an 89% increase over the present system in just ten years!

9. Under SENER's plans, as laid out in *Prospectiva*, this capacity increase will be met overwhelmingly by combined-cycle natural gas turbines, which will rise to 52.1% of total generation output by 2010 (compared to just 9.2% in 2001). Renewable energy is forecast to grow by only 699MW, a tiny number when compared to the large increases needed overall. Although the hydro/geothermal share of production is expected to rise to 30% by 2004/5 as new plants come online, this will fall to only 15% by 2011, and will be used mostly to satisfy peak demand. It is worth noting that these additions are mostly accounted for by increases in large-scale hydro, which represents 12% of planned capacity additions. A more ambitious target has been set by the Government of Mexico's *Programa Sectorial de Energía 2001-2006*, which specifically lays out the government's intention to increase this figure to around 1,000MW.

10. Current CO_2 emissions are 115 million tonnes per year (equivalent to 31MT/y carbon). *Prospectiva's* scenario involves a significant increase, with emissions rising to 192 million tonnes by 2010[2] – a 2.3 fold increase with respect to their 1996[3] levels. Although carbon intensity of generation would actually fall, due to the use of the more efficient combined-cycle capacity and the retiring of old fuel oil plants, the net effect when combined with overall increases in capacity is very little change.

11. All four papers in this series highlight the ample renewable resources at Mexico's disposal. Mexico receives large amounts of incident sunlight (an average of 5kWh, double that of the US), strong yearlong winds in some regions, and a large potential for mini-hydro, piggy-backing on existing flood protection infrastructure. Early estimates put the total available wind energy at around 5,000MW (maybe rising to 15,000MW as technology advances), geothermal, small hydro at around 3,500MW, and more from many other sources such as solar energy, solid waste gas recovery, bagasse combustion and so on. Of these, geothermal energy, which currently stands at around 855MW, is the only one which has been significantly developed. The potential of wind (with only 2MW currently installed) and solar (perhaps as little as 1MW of off-grid installation) have hardly been touched.

Benefits of Renewables

12. The benefits of increased adoption of renewable energy in Mexico are summarised in the papers by both Huacuz, and Antonius and Merino: diversification away from an increasing dependence on a decreasing variety of fossil fuels, environmental improvement by reducing the carbon intensity of the country's power sector, as well as various developmental benefits associated with developing a renewable industry.

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1 This low rate of capacity retirement reflects government financial restrictions, and creates the need to maintain old units at high financial and environmental cost.

2 See Huacuz, but also see Hertmark who has a slightly different number of 149 million tonnes by 2011.

3 The Kyoto benchmark year

13. *Diversification*: whilst current SENER plans envisage a diversification away from Mexico's current dependency on fuel oil, it will do so at the expense of a new dependency on natural gas. In the long-term, both national and global hydrocarbon supplies are expected to diminish, pushing up the price Mexico must pay to satisfy its increasing demand for energy. In the medium-term natural gas prices have been shown to be the most volatile of all energy commodities, and an overexposure to this volatility could harm the electricity sector. Diversification away from fossil fuels could mitigate the impacts of both future price rises, and of volatility, thereby increasing the country's overall energy security. Renewable energy's low, or often non-existent, recurrent input costs mean that its marginal cost of production is much less exposed to commodity price fluctuations.

14. *Environmental*: Mexico has ratified both the UNFCCC and the Kyoto Protocol, and reducing emissions would help it meet the targets of both the National Action Program for Climate Change (NAPCC) developed in 1997, and the *Plan de Desarollo 2001-2006,* which explicitly lays out a commitment to sustainable development. Replacing older fuel oil and coal-fired plants could also have a significant beneficial effect on public health, by reducing harmful local emissions. If these renewable projects can be linked with carbon offset reductions, there might also be the possibility to benefit financially from the Kyoto mechanisms.

15. Other benefits include the possibility of reaching a great many more of Mexico's estimated 5 million people who currently have no access to electricity through the use of off-grid renewable development, significantly boosting living standards and spurring economic development in some of Mexico's poorest regions as well as alleviating the pressure on forest resources in these areas. Developing an indigenous renewable capacity manufacturing industry also has the potential to boost foreign direct investment (FDI) and create jobs in a high-technology sector.

Current Constraints

16. The power sector has the greatest possibilities for adopting renewable energy, yet despite the clear benefits there remain a number of significant regulatory, policy and institutional barriers to the development of a vibrant renewable sector.

17. The Mexican constitution; under article 27, give the exclusive rights to the nation to 'generate, transport, transform, distribute and supply energy with the purpose of providing a public service'. This condition was somewhat relaxed in the reforms of 1992, and the following are now exempted from this government monopoly: self-supply, independent power producers (IIPs) who sell exclusively to CFE, export-oriented production, imports for self-supply, and emergency backup generation. Notwithstanding these small changes, the state retains a practical monopoly on the whole sector. Yet as Huacuz points out, facing tight budgetary constraints, the state is unable to finance the commissioning of new renewable capacity, which typically has very high upfront costs and subsequently very low variable costs of production. Regulatory barriers and the perceived risks of an uncertain market with a monopsony buyer have all discouraged the private sector from making up this shortfall.

18. Antonius and Merino also show how one of the main regulatory challenges to private sector involvement is the pricing system which, as they explain, places a wedge between the price paid to private investors, and the price charged to the end user. Charges faced by the consumer reflect the average cost of supply, which in turn reflects the whole mix of generation plants. Since the rate of capacity retirement is extremely low, and there are consequently many outdated, high-cost, fuel oil and coal-fired thermal plants, this price is very high. Producers, by contrast, are paid based on the marginal or avoided cost, which is now determined by the low-cost, high efficiency, combined-cycle gas turbine plants. Antonius and Merino point out that, as a result, there are consumers paying prices at which is would be economically attractive to use renewables, but that IPPs are unable to realise these gains. Economic opportunities therefore exist where consumers' willingness to pay exceeds the cost of supplying them with renewable energy, but since the constitutional mandate prevents direct consumer-producer contact, they cannot be exploited.

19. Other regulatory issues also hamper private sector involvement. Antonius and Merino stress that even though self-supply is allowed under the 1993 reform, provision exists for CFE to purchase only up to 20MW of excess supply, and any larger-scale supplier has no other sale options. Even when such a sale is agreed, CFE pays only displaced marginal cost (i.e. no capacity charge), and does so only on short-term contracts, creating considerable uncertainty for suppliers.

20. 'Least-cost' legal barriers to renewable adoption are highlighted by Huacuz, and form the theme of the paper by Awerbuch and Berger. Specific articles in Mexico's Electricity Law mandate CFE to buy the cheapest electricity available on the market, and to give preference to firm, instead of intermittent, capacity for new power installations. Although the latter condition was relaxed in 2001, CFE's planning approaches still do not allow full integration of intermittent sources into the grid. Such least-cost approaches have been the centrepiece of power sector planning throughout the sector's history; the assumption being that if costs were minimised at each incremental stage, the overall system would be the cheapest that it could be. However, as Awerbuch and Berger point out, given today's broad range of technological and institutional options, with a dynamic, uncertain, and complex future, identifying long-term 'least cost' is nearly impossible. Huacuz also points out that Evaluation of a true 'least-cost' is also hampered by distorted prices within the system. On the one hand fossil fuels receive both hidden and direct subsidies thought to be worth US$250-300 billion annually worldwide, and on the other hand the environmental and social costs of fossil fuel consumptions (externalities) are not included as 'costs'. The 'cost' used in planning decisions is thus very far removed from, and much lower, then the true economic cost.

21. Lastly, though a large number of Mexican universities and research centres have been involved in renewable issues for a number of years, many of the authors in this series point to a lack of expertise and familiarity with renewable energy in the Mexican economy. They argue that a lack manufacturing know-how is preventing local industry from taking up the challenge of indigenous manufacture, a lack of renewable energy project experience in the financial sector is preventing would-be entrepreneurs from

getting access to funds, and a lack of regulatory experience is preventing renewables from proper integration into the system. Furthermore, whilst some preliminary resource surveys have been carried out in some areas by organisations such as the IIE, there is generally a lack of site specific, detailed information on renewable energy potential. A lot of work therefore needs to be done in educating relevant stakeholders about the needs and opportunities of the sector.

Positive Steps Taken

22. As has already been alluded to, there have been several legal and institutional reforms over the past decade or so, which removed some of the more egregious policy obstacles to renewable suppliers. Restrictions on generating were slightly relaxed in 1993, to allow generation for self-supply; then, as of 2001 new rules for CFE require that they give priority dispatch and discounted wheeling charges to excess power from renewable self-suppliers. In addition, CFE is also obliged to return unused energy to self-supplier when needed – in effect acting as a power reservoir for intermittent generators. Both Huacuz, and Antonius and Merino also draw attention to changes at the institutional level: the *Programa Sectorial de Energía 2001-2006* lays out the government's strategy for developing renewable energy, and is demonstrative of the very strong support from the highest levels of the current administration. It emphasises important ways of moving forward and contains ten sectoral objectives that include the development of a national fund for renewable energy, establishment of long-term contracts, and fiscal and economics incentives designed to foster the development of renewable sector.

23. Finally, there are ongoing collaborations with international agencies and organisations. For example, World Bank GEF collaboration currently includes a combined-cycle solar-thermal plant, which captures solar heat energy to minimise fossil fuel inputs, and a programme for recapturing biogas from solid-waste landfill sites. Other projects with the UNDP and the GEF include development of a 'plan of action for removing barriers to the full-scale commercial implementation of wind power in Mexico', and a 'small grid-connected PV systems' programme.

Future Scenarios and Improvements to the System

Portfolio Use

24. One of the major obstacles to renewables becoming economically competitive in their own right is, as we have seen, the way in which their addition to the system is valued. One interesting aspect of this valuation technique is dealt with in the paper by Awerbuch and Berger. As they point out, financial investors must constantly make investment decisions in the face of uncertain outcomes and risk. Portfolio theory has long been used by such investors to ascertain the value of a basket of diverse[4] assets as a way of maximising the risk/return combination of an investment portfolio. Investors, they note, 'would not conceive of investing all their money in one stock based on a thirty-year forecast" – and yet this is exactly how the 'least-cost' laws are currently interpreted.

4 Diverse in the sense of each having a unique combination of risk and return.

25. By applying portfolio theory to electrical utility capacity, the authors show that the widespread belief that adding renewable-based capacity will 'cost more' is usually not true. Since renewables have high up-front costs, but little or no ongoing input costs, by including a larger percentage of renewables in the production portfolio utilities can reduce their exposure to commodity price derived risk. Awerbuch and Berger show that for most countries' utilities, and certainly in the case of Mexico, a greater proportion of renewable energy could result in a production portfolio with a much more favourable risk/return ratio. Indeed with respect to Mexico's business as usual scenario (as laid out in *Prospectiva*), though the 2010 scenario envisaged will have a higher return (in the sense of smaller cost of production), it will do so at far greater risk due to its heavy reliance on natural gas.

Incentive-Based Mechanisms

26. Another theme that comes across strongly in the papers by Antonius and Merino, and by Huacuz, is the importance of using incentive-based mechanisms to spur growth in the renewable sector. Incentive-based (as opposed to more traditional 'command-and-control') policies have greater flexibility in responding to changing circumstances. Quantity-based targets are open-ended, and face a considerable dynamic inconsistency problem if governments renege on carrying out appropriate punishment if quotas or targets are not met. By contrast incentive-based policies are more flexible, often adjusting automatically to market changes; they can be transparently faded-out over time to wean developers on to the private market; and the can be used to ensure minimum cost, optimising scarce resources.

27. Huacuz, and Antonius and Merino propose the establishment of a special fund to foster the development of a competitive, efficient, and cost-effective renewable power sector. The fund would, they suggest, provide an output-based subsidy as a temporary solution to the wedge that the current system puts between the consumers' willingness-to-pay for renewable energy, and the rates the utility pays to IPPs. The fund would provide these subsidies through a competitive bidding process, to be phased out over a clearly established timeline. This would ensure that only the most efficient renewable energy producers received the funding, and that they must have a clear plan for future self-sustainability. They also suggest that it would be desirable for the fund to include mechanisms for its replenishment, such as higher prices for consumers of renewable-derived energy. By Antonius and Merino's calculations an injection of US$95 million would directly stimulate 650MW of additional renewable capacity increases.[5] According to this scheme, technological progress, organisational learning (on the part of the utility and regulator), rationalisation of the tariff structure, and the ongoing increases in natural gas prices,[6] would combine to make the subsidy unnecessary by the 8th year. If synergies could be created with the Kyoto mechanisms, the contributions of the green fund could

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5 Huacuz proposes a similar scheme, suggesting the sum of US$120 would facilitate projects of around 1000MW over the next 5 years. This scheme would run for around 20 years, and be phased out over an established timeline.

6 Note that when this paper was prepared, wellhead prices were just under US$3/million Btu; at the time of writing, gas prices are in the range of US$7.6/m Btu.

be reduced, or made to stretch further. Given the relative lack of industry experience mentioned above, and the absence of detailed renewable resource potential surveys, such an incentive scheme would have to go hand in hand with an educational campaign to raise awareness of the business opportunities involved.

28. By fostering the development of a competitive market – with many consumers and producers – in the renewable energy sector, this type of mechanism could, they argue, increase efficiency, lower costs, and reduce the public sector burden of the electricity sector. It is, however, vital to carry such a scheme out in conjunction with a review of the arbitrary pricing arrangements and uncertainty in the sector. 'Attempts to promote renewables without also carrying out structural reform will', they warn, 'be more costly, as part of the resource used to create incentives for renewable energy would partially be used to offset the economic distortions currently present in the sector.'

A Hypothetical Wind Farm

29. Hertzmark looks at the issue from another angle, carrying out an economic analysis of the impact that the addition of a 100MW wind farm would have on the energy sector. This would be a one hundred percent increase over the current SENER baseline planning scenario, which envisages only 50MW of capacity additions. As Hertzmark points out, such an addition would be small with respect to the entire grid (0.33% of proposed capacity additions and, with only a 40% plant factor, 0.1% of total capacity over the *Prospectiva* period). Whilst this clearly expands total capacity, as an intermittent source it does not allow substitution for other construction, nor does it significantly change the system size. Economic impacts are therefore largely in terms of displaced energy production, or marginal energy cost (MEC) – in effect the value of the fossil fuel inputs displaced by renewable production.

30. The intermittent nature of renewable sources' production is a problem in assessing its value as new capacity. Thus where a 'firm' capacity addition has both an MEC value and the value of the additional capacity it adds to the system as a whole, the latter is much harder to quantify for intermittent capacity. Indeed, where distributors dispatch management is not sophisticated enough to adequately deal with such intermittent sources, this capacity value may in reality be very small, as renewable generators must be twinned with firm capacity additions. In Hertzmark's analysis, the value of this hypothetical 100MW depends, crucially, on how much capacity value it is possible to attribute to such a plant.

31. Hertzmark estimates that the initial generation costs of such a wind farm would be in the region of US$45-53/MWh, with a present value of the investment and operation costs of $120 million. The benefits depend on whether the capacity is valued purely in terms of the MEC (i.e. with no capacity charge), or whether it is valued at MEC plus some fraction of an equivalent firm producers' capacity charge. The value of this charge depends on a number of assumptions over hours of operation (including time of day of

peak production), type of plants displaced during operation,[7] fuel prices, and so on. Hertzmark estimates that the system avoided costs (in terms of displaced MEC) to be around \$41-63/MWh, assuming a cost of crude oil of \$18-34[8] per barrel. The value of 1MWh of capacity charge during the planning period is estimated at around \$17. If no capacity charge can be attributed to the wind farm (the most realistic scenario given today's operating environment), then the project has a negative rate of return at all oil prices considered (though see footnote 7, below). If the plant is attributed 50% of full capacity charge, the project can break even any oil price above \$24/bbl. As Hertzmark points out, whilst full attribution of the (partial) capacity charge is not realistic in the short run, such a scenario serves as an indication of the potential returns to the country if CFE and CENACE's understanding and management of wind energy's interface with the integrated national grid is improved over the next several years.

32. Finally, Hertzmark estimates that such a wind farm would displace an annual total of 230,000 tonnes of CO_2, or a possible 1.4 million tonnes over the SENER *Prospectiva* planning period, assuming management capacity improvements at CENACE/CFE allow them to distinguish in dispatch between fossil fuel and renewable plants.

Conclusions

33. These four, insightful papers therefore have two consistent messages on what is needed to move forward: the need to modernise and improve the regulatory system to level the playing field and put renewable sources on an equal footing with their hydrocarbon peers; and the usefulness, at least in the medium-term, of a fund to help foster the creation of a renewable sector through a subsidy aimed at making renewables competitive with well-developed fossil fuel capacity. Importantly, efforts must be made right away on the former, in order to get the maximum effect from the latter. The development of a fully-fledged renewable sector will also have a feedback effect on the quality of management and regulation as government agencies and utilities gain more experience in managing such capacity, and a better understanding of how to value its contribution to the system. Removing the subsidies to the hydrocarbon industry, better accounting for environmental externalities in the prices paid to electricity producers, and reflecting the additional portfolio value that renewables can bring to a grid, is all likely to make grid-connected renewable energy facilities highly competitive in the medium to long-term, and remove the need for future subsidies to the sector.

34. These conclusions of these papers therefore call primarily for two actions on the part of the international community: technical assistance (TA) to help Mexico's electricity sector institutions modernise, so that they may fully benefit from the system value created by renewables; and the creation of a 'green fund' to spur sector development. The insights these studies offered directly lead to the creation for the

[7] Which in turn depends on the time of year: during the wet season this may well be hydroelectric capacity, in which case the value will obviously be lower then during the dry season, when it would more likely displace gas or fuel-oil capacity.

[8] Again, at the time of writing oil prices seemed to have reached a new stable price of above \$50/bbl, so Hertzmark's analysis is likely to substantially underestimate system avoided cost.

World Bank's new "GEF Large-Scale Renewable Energy Development Project", now in an advanced stage of preparation, which attempts to address both these needs.

1

Renewable Energy in Mexico: Current Situation and Perspectives

Introduction

1.1 Mexico's energy sector is one of the most important among the emerging-economy nations. A major oil-producing nation, Mexico ranks 8th in oil production and 9th in oil reserves, while the total capacity of its electricity sector approaches 40,000 MW. In order to respond to increasing energy demand, and taking into account its existing resource base and potential, Mexico has decided to intensify the use of renewable energy sources over a 10 to 12 year horizon as part of its general energy strategy. Although no promising technologies are excluded, Mexico is exploring a strategy to accelerate the commercialization of large-scale grid-connected renewable energy generation technologies through market interventions.

Strategic vision

1.2 Currently, only a small portion of Mexico's total energy needs are met by renewable energy sources. In 2000, hydrocarbon-based generation accounted for 47.7 percent of electricity plants and for 60.7 percent of total installed capacity. This, in part, is explained by Mexico's abundance of hydrocarbon reserves and relative scarcity of water resources. The country's dependence on hydrocarbon-based generation is even greater, however, when taking into account that while hydroelectric power accounted for 26.2 percent of total installed capacity, it only accounted around 14 percent of actual generation, as insufficient water supplies exist for year-round production.

1.3 Electricity demand growth during the 2001–2010 period is expected to be strong and greater than the growth rate of GDP. The base case scenario estimated by the authorities using a GDP growth rate of 5.2 percent is that electricity consumption will grow at an annual rate of 6.3 percent and energy demand at an annual rate of 6 percent. These calculations take into account actual levels of electricity use, the rate of structural transformation of the economy, a gradual phase out of current price subsidies for residential and agricultural electricity consumption, and estimates of the income elasticity of demand.

Table 1.1: Installed Generation Capacity (MW), December 2000

			Hydrocarbon based								
Area	**Hydro**	**Thermal**	**Combined Cycle**	**Turbo gas**	**Internal Combust**	**Dual**	**Coal**	**Nuclear**	**Geoth**	**Wind**	**Total**
Northwest	941	2,162		281							**3,384**
North	28	1,074	722	253							**2,077**
Northeast	118	1,715	828	455			2,600				**5,716**
West	1,798	3,466	218	122		2,100			93		**7,797**
Central	1,524	2,474	482	374							**4,854**
East	5,210	2,217	452	43				1,365	42	1.6	**9,331**
Peninsular		442	696	343	1						**1,482**
Baja California		620		359	2				720		**1,701**
Baja C Sur		113		126	73						**312**
Other				5	39					0.6	**45**
Total	**9,619**	**14,283**	**3,398**	**2,361**	**115**	**2,100**	**2,600**	**1,365**	**855**	**2**	**36,697**

Note: Solar capacity is not reported, as it is not connected to the grid.
Source: Prospectiva del Sector Eléctrico 2001-2010, Secretaría de Energía.

1.4 These rates of growth translate into important capacity requirements. Government estimates indicate that it will be necessary to increase capacity by 32,219 MW during the 2001–2010 period, of which 10,854 MW are already committed or under construction. Private sector self-supply and cogeneration projects are estimated to account for only 4,862 MW of the total given the current regulatory framework, which will be discussed in detail in following section. The planning scenario presented by the government also considers retiring 1,661 MW of capacity during this period, for a net addition of 30,558 MW, which represents an 83 percent increase.

1.5 The low rate of capacity retirement estimated for this period, together with the low rate of retirement during the past decade (1991–2000), when only 816 MW of capacity were removed from the system, is a result of government budgetary and financing restrictions. These short-term constraints have led the public sector to conserve many generating units that have high operating costs and pollution emissions (due to their small scale, age, or both). The costs of these units raise the average cost of the system and are being passed through to consumers and the public sector, either in the form of higher tariffs or increased subsidies.

1.6 According to projections, the 27,357 MW of future required capacity to be built or contracted by the public sector during the 2001–2010 period will be overwhelmingly met via the employment of combined cycle gas turbines, given their relative efficiency and fuel price projections. This trend will result in gas-based generation accounting for 52.1 percent of total generation by 2010, up from 9.2 percent in 2001, while conventional thermal generation (fuel oil based) will reduce its participation from 46.6 percent to 13.8 percent. Renewable energy sources (including large scale hydro) represent around 12 percent of energy additions.

Table 1.2: Capacity Additions (MW), 2001-2010

	Committed	Not committed	Total	% share
Combined cycle	9,344	8,025	17,369	63.5
Repowering	272		272	1.0
Hydro	936	2,255	3,191	11.7
Coal		2,100	2,100	7.7
Turbogas	134	83	217	0.8
Internal Combustion	51	161	212	0.8
Geothermal	118	5	123	0.4
Undefined		3,874	3,874	14.2
Total	10,854	16,503	27,357	100.0

Source: Prospectiva del Sector Eléctrico 2001-2010, Secretaría de Energía.

1.7 In summary, Mexico's energy sector is large and rapidly growing. Future required investments are large relative to the current size of the system, and under the existing regulatory framework will be primarily contributed or financed by the public sector. Under said framework, the sector will continue to be largely dependent on hydrocarbon based generation, although there will be a very significant shift into natural gas and out of fuel oil via the construction of numerous combined cycle generating plants and the elimination of part of the current fuel oil driven capacity. Current renewable energy capacity is small relative to the rest of the system, and virtually nonexistent if large-scale hydroelectric dams are not taken into account.

1.8 The promotion of renewable energy, however, forms an important part of Mexico's energy policy for the future.[9] The reasons for this are numerous:

- Diversification (long term). Currently the Mexican power sector is heavily dependent on oil, natural gas, and coal. Fossil fuel-based generation accounts for 68 percent of installed capacity and an even larger share of production. It is forecast that under the current growth and regulatory scenario that the share of conventional thermal generation will fall from 47 percent to 13 percent of total generation over the 2000–2010 period, while the share of natural gas will increase from 9 percent to 52 percent. During this same period, hydroelectric generation is forecast to fall from 17 to 11 percent. Therefore, while Mexico will diversify out of traditional, fuel oil driven thermal plants, it will do so by creating a new dependency on natural gas via the construction of combined cycle gas turbines. The lack of a diversified generation base is largely the result of abundant hydrocarbon resources and scarce water resources; however, future trends clearly indicate that hydrocarbon supplies (especially natural gas) will diminish relative to total system consumption at increasing rates over the long term. A policy of energy diversification should therefore form part of overall energy policy, even though Mexico is an oil and gas-rich economy, as it will reduce the negative impacts of the medium term shift in relative prices. A

9 It is listed as an important objective in the National Development Plan 2001-2006 and the Energy Sectoral Program 2001-2006.

policy of non-diversification would transform a shift in relative prices into a shock, with potentially devastating costs and losses in sunken asset values.

- Diversification (short term). The high dependence of the electricity sector on hydrocarbons also translates into increased risk from price volatility. The prices of petroleum and natural gas are correlated, and shocks to the price of one frequently feed through to the other, as evidenced in the U.S. during 1999–2000, when a sharp rise in oil prices shortly preceded a shock to the price of natural gas. Past evidence also shows that the price for natural gas is the most volatile energy commodity price. Therefore, the promotion of renewable energy sources would allow the Mexican power sector to diversify its mix of fuel options, reducing its exposure to volatility in the fossil fuels markets without introducing additional volatility given renewable energy's stable, low, or in many cases non-existent input prices.

- Environmental. It is clear that renewable energy projects have clear environmental advantages, with reduced emissions relative to hydrocarbon fueled projects.

    - The Mexican Senate ratified the Kyoto Protocol in 2000, the first large world economy to do so. Further evidence of the commitment to reduce emissions can be found in the Plan Nacional de Desarrollo 2001-2006, which states that one of the explicit objectives of government policy is sustainable development, and that a strategy to be pursued is the promotion of the sustainable use of natural resources.

    - Mexico ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1993. It has moved rapidly to prepare a national communications report with updated national emission inventories and a National Action Program for Climate Change (NAPCC) prepared by an inter-agency committee integrated by the Environment, Energy, Foreign Relations, Commerce, Communications and Transport, and Agriculture ministries. Its population of nearly 100 million inhabitants is responsible for nearly 1.48 percent of global emissions of CO2 (13th worldwide). In contrast, per capita emissions (3.46 tons of CO_2/inhabitant per annum) place the country in the 72^{nd} position worldwide. Mexico's participation in the UNFCCC reflects that the country's increasing emissions profile is necessary in order to meet development needs, and in this respect Mexico will take actions that limit GHG emissions without restricting its economic development.

- Private sector participation. Renewable energy projects can currently be developed by the private sector for self-supply, and are generally of a sufficiently small scale to be feasible for individual consumers or small groups. If made attractive, they would allow for increased private sector participation in the sector and reduce public sector commitments for new capacity construction. In addition, the promotion of renewable energy projects in Mexico could potentially stimulate the development of domestic suppliers, contributing indirectly to the diversification of the sector (currently the vast majority of generation turbines are imported).

- Rural development. The few current solar and wind powered energy projects in Mexico today have been developed primarily for supplying remote areas for which demand is too small to justify the investments required to connect them to the national grid. Currently, five percent of the population (approximately five million people) lacks access to electricity. The Program for Rural Electrification in particular seeks to increase coverage in poor rural areas, which have a large concentration of indigenous population, for whom electrification would imply a significant boost in living standards and access to crucial public services such as water and sewerage. This program, which currently targets as a priority 1,200 communities, will be a major source of demand for the development of renewable energy.
- Opportunities in specific sectors. While renewable energy can benefit all users of electricity, it has the potential to become a major source of energy in some sectors, such as the water and municipal sectors. The water sector uses a large number of diesel generators as a source of backup power for water pumping stations. The redundant power supply requires large capital investments and sizeable budgets for operation and maintenance, and can be an important source of emissions to the atmosphere. Hence, the water sector can become a major user of renewable energy for the self-supply of electricity. The municipalities can also become major users of renewable energy for public lightning, solid waste management, and operation of water and sewerage services, among others.
- Experience and capacity A network of public and private institutions has experience with the development of renewable energy projects and the capacity to conduct research and develop technologies.

Current situation of renewable energy in the Mexican power sector

Current situation and potential for renewable energy

1.9 As seen in the previous section, renewable energy today plays a very small role in the Mexican energy sector. In the *Programa Sectorial de Energía 2001-2006*, the government recognizes the lag in the development of renewable energy in Mexico and stresses the importance of increasing its participation. It also lays out a comprehensive strategy aimed at correcting this situation, which is commented on in greater detail throughout this section.

1.10 As seen in the previous section, after taking into account large-scale hydroelectric generation, geothermal power is the second most important source of renewable energy in Mexico today, with a total capacity of 855 MW. It is followed by wind, with approximately 2 MW from La Ventosa and Guerrero Negro. Solar installed capacity, which is not connected to the grid, accounts for 13 MW.

1.11 While renewable energy currently plays a small role in the sector, a large potential for the development of renewable energy projects exists. The Ministry of Energy currently estimates that an additional 17,000 MW of renewable energy sources exist. Mexico receives large amounts of sunlight, 5 kWh per square meter on average, which is roughly double the level in the United States. There are also various regions of the country characterized by strong, year-round winds, and CFE has estimated potential wind-powered generation capacity to be 3,000 MW. Mini hydro projects also are very promising, both because an important potential exists (3,200 MW) and also because in several cases water control infrastructure is already in place (irrigation and flood control dams). Important opportunities for growth exist in biomass-driven generation, primarily in the sugar industry, where cane bagasse is already consumed for the production of steam, and also at the municipal level. It is estimated that cane bagasse alone could supply a capacity of 1,000 MW. Finally, Mexico has an important geothermal generation capacity currently in place, and it is estimated that an additional 837 MW could be added.

1.12 Current projections considering available resources and the existing legal and institutional framework estimate that renewable energy capacity will grow by 699 MW over the 2001–2010 period, a small number when compared to the 27,357 MW in total generation capacity which must be built during this period to meet demand.

Table 1.3: Renewable Energy Capacity Additions (MW), 2001–2010

	Cane bagasse	Mini hydro	Wind	Solar	Biogas	Total
2001	210	92	64	14	11	391
2002	210	152	64	15	11	452
2003	214	160	125	116	11	526
2004	218	168	132	17	12	547
2005	222	176	140	18	13	569
2006	227	185	148	19	14	593
2007	231	195	157	20	14	617
2008	236	204	167	21	15	643
2009	241	214	177	22	16	670
2010	246	225	187	24	17	699

Source: Prospectiva del Sector Eléctrico 2001-2010, Secretaría de Energía.

1.13 While the projections of a 699 MW increase in renewable energy over the 2001–2010 period are low, an explicit policy objective laid out by the government in the *Programa Sectorial* is to duplicate the capacity of renewable energy over the 2000–2006 period. This would be carried out via the addition of 1,000 MW of renewable energy to the CFE expansion program, an increase of over 140 percent from the current projected level. In addition, the national electricity research institute (IIE) has established a 10 year scenario for the development of renewable energy capacity, which attempts to present a feasible estimate of what could be built given the appropriate policies and regulation over the 2001–2010 period, which is substantially greater than either the projections described in the previous table or the more ambitious objective set out by the government.

Table 1.4: Renewable Energy Expansion Scenario, 2001–2010

	MW
Wind	2,000
Small scale hydro	300 – 500
Biomass	150
Photovoltaic (solar)	10 – 20

Source: IIE

1.14 Another important factor in gauging renewable energy potential is experience. CFE, IIE, and many universities in Mexico (both public and private) have over 25 years of experience in the development of renewable energy, and have carried out numerous pilot projects, the most important of which are described below. In-country experience with the development and manufacture of renewable energy technologies also exists.

Project	Description
Tonatiuh	30 kW thermosolar project financed with the support of the French government in 1975
UNAM experimental solar project	A 10 kW project designed and manufactured in Mexico at the beginning of the 1980s
Sonntlan	A development of solar houses in a fishing community in Baja California
La Ventosa	CFE 1.6 MW pilot project for wind power in Oaxaca
CFE rural electrification	Over 4,000 separate systems

Source: CONAE

1.15 The sharp contrast between the potential levels of renewable energy generation capacity and the forecast expansion in this area can be attributed to a series of factors, one of the most important of which is economic. Although significant technological steps have been taken in past years, renewable energy generation continues to be relatively more costly than other alternatives, such as combined cycle gas turbine, when costs are calculated without incorporating the effect of environmental externalities. Therefore, in the absence of explicit policy incentives, renewable energy alternatives are generally not considered viable options except in remote areas where no conventional distribution network exists. However, evidence from the international arena shows that policy incentives can have a very important impact on renewable energy development and use. According to the Ministry of Energy, the use of wind power in developed economies has increased by 30 percent annually over the past three years, while the use of solar power has increased by 15 percent annually since 1993.

Actors and stakeholders

1.16 Numerous actors, both public and private, play important roles in renewable energy:

- Ministry of Energy (SENER: Secretaría de Energía): SENER is responsible for policy, regulation, strategy and coordination of the energy sector.
- Energy Regulatory Commission (CRE: Comisión Reguladora de Energía). CRE is responsible for regulating private operators in the energy sector and interconnection with CFE. Among other functions CRE coordinates and

authorizes bidding processes and permits for energy projects, including electricity and gas, and is responsible for protecting consumer interests.

- National Commission for Energy Conservation (CONAE: Comisión Nacional para el Ahorro de Energía). While more focused on energy saving measures, such as Daylight Savings Time and the introduction of efficient lighting and air conditioning systems, the CONAE is also involved with the promotion of renewable energy projects. It serves as a center for information on renewable energy technologies, past experiences both in Mexico and abroad, and current efforts taking place. The CONAE plays an important role as spokesperson of the government with industry and potential end users and also organizes numerous conferences on renewable energy. It is also involved in the issue of Mexican Official Standards relating to energy.

- Ministry of the Environment and Natural Resources (SEMARNAT: Secretaría del Medio Ambiente y Recursos Naturales). SEMARNAT is responsible for environmental policy, regulation and the issue of Mexican Official Standards regarding environmental protection, many of which have implications for energy related projects. The Environmental Attorney (PROFEPA: Procuraduría Federal de Protección Ambiental), a decentralized agency of SEMARNAT, is responsible for compliance with environmental regulations, except those dealing with water, which are a responsibility of the National Water Commission.

- Ministry of Finance and Public Credit (SHCP: Secretaría de Hacienda y Crédito Público). Among its many responsibilities SHCP is responsible for setting taxes, subsidies and prices and tariffs of electricity, in cooperation with SENER and other agencies.

- Federal Electricity Commission (CFE: Comisión Federal de Electricidad). CFE is the publicly owned electricity company that generates 98 percent of the electricity considered a "public service" (that is, excluding self supply), and transmits and distributes 91 percent of electricity. Luz y Fuerza del Centro, the other publicly owned utility, serves consumers in Mexico´s central region (Mexico City metropolitan area and parts of Estado de México, Morelos and Hidalgo).

1.17 Other relevant actors include the National Waters Commission (CNA: *Comisión Nacional del Agua*) in charge of regulating the use of water resources, and the *Instituto de Investigaciones Eléctricas* (IIE) which is the national electricity research institute, and is where most work on renewable energy is performed. The IIE is also closely involved with the various renewable energy projects currently taking place.

1.18 The most important private actors in renewable energy in Mexico are the *Asociación Nacional de Energía Solar* (ANES), the *Asociación Mexicana de Economía Energética* (AMEE), and the *Cámara Nacional de Manufacturas Eléctricas* (CANAME). ANES includes among its members most of the national academic community involved in renewable energy issues, as well as some of the equipment manufacturers. AMEE represents the large, transnational energy companies present in Mexico, whose primary activity is the construction of combined cycle gas turbine plants under IPP contracts with CFE. Finally, CANAME is the national chamber of electricity equipment manufacturers.

1.19 In the academic sector, a large number of universities and research centers are involved in renewable energy issues. Of these the most important are the Center for Energy Research (Centro de Investigaciones Energéticas) and the Engineering Institute (Instituto de Ingeniería), both of which are at the National Autonomous University of Mexico (UNAM). The UNAM also runs the University Energy Program (Programa Universitario de Energía or PUE). Other centers are the Center for Advanced Studies and Research (Centro de Investigaciones y Estudios Avanzados or CINVESTAV) of the National Polytechnic Institute (IPN) and several schools within the Autonomous Metropolitan University (UAM).

1.20 The use of renewable energy in Mexico has also been promoted by international organizations. The World Bank has participated in GEF-related projects on solar thermal power plants, electricity generation with biogas from sanitary landfills and water pumping with solar and wind energy. The United Nations Development Program (UNDP) has advanced various project initiatives on wind farms, grid-connected photovoltaics, and biomass for agricultural processes, all within the framework of the GEF. The U.N. Food and Agriculture Organization (FAO) is working on the issue of firewood and looking into productive applications of renewable energy in rural areas. Bilateral aid agencies, such as the USAID and the German GTZ are also actively involved in this field. For almost a decade now, the USAID, with the support from the Department of Energy and other U.S. Government agencies and institutions, has carried out activities to foster the use of renewable energy in Mexico, mostly in off-grid rural applications.

1.21 In recent times, growing numbers of national and international private investors, financing institutions, technology manufacturers and project developers have made themselves present in the Mexican renewable energy arena, mainly in connection with the use of wind energy for power generation and small hydropower.

Regulatory and institutional issues

1.22 The Mexican constitutional and legal framework establishes that the State has the exclusive power to generate, conduct, transform, distribute and supply electricity related to the provision of electricity for "public service" (Article 27). Private sector participation is therefore limited to IPP projects where the totality of generation is sold to CFE, and self-supply and cogeneration projects.[10]

[10] Article 3 of the Law for the Public Electric Energy Service exempts from the definition of public service the following activities, thereby establishing the scope for public sector participation in the electricity business: (i) Generation of electricity for self supply, generation of electricity through co-generation processes, or small generation of electricity (under 20MW for sale to CFE or under 1MW for the supply of remote rural communities); (ii) Generation of electricity by independent producers for exclusive sale to CFE; (iii) Generation of electricity for export purposes, either from co-generation, independent power production, or small generation; (iv) Import of electrical energy by individuals or formally established entities, for the sole purpose of self supply; (v) Generation of electricity in case of emergency caused by the interruption of public service.

1.23 The legal framework also assigns the federal government responsibility for the formulation of policies relating to the energy sector, and to the national congress for legislation in these fields. State and municipal governments therefore have very few powers in this regard, except for those areas of government activity that can have implications for energy projects, including zoning restrictions, property taxes and some environmental regulations. Currently there is no decentralization process in the electricity sector contrary to other sectors, nor is such a process likely under the current legal and constitutional framework. However, decentralization processes currently in progress regarding some aspects of environmental protection and water-related services might have implications for energy projects.

Pricing issues: existing conditions, progress and challenges

1.24 There are other institutional and regulatory issues that have to be addressed for the development of renewable energy in Mexico. Of these, the most important is the pricing system for electricity, which places a wedge between the price paid to private generators and the tariffs charged to end users and also creates uncertainty for suppliers. If not corrected or if a market or a market-driven pricing system is not developed, the price wedge reduces the profitability of renewable energy projects.

1.25 While the Constitution limits private sector participation to IPP projects where all the electricity generated is sold to CFE, and to cogeneration and self-supply projects, no provision exists for the purchase of surplus energy by CFE in the case of self-supply, while in the case of cogeneration CFE is required to purchase surplus energy up to 20 MW.

1.26 If a self-supplier wishes to sell energy to CFE, several conditions apply. First, CFE is not required to purchase surplus energy above 20MW, and if it decides not to, no other option exists (by law). If CFE does decide to purchase energy, it does so without a long-term contract or capacity payments, and pays only avoided or marginal cost, which is equivalent to the marginal cost of a new (combined cycle) plant. This occurs even if the cost of the renewable energy alternative is lower than the average cost of the system. These conditions make the development of renewable energy (and almost any electricity plant, for that matter) economically unattractive.

1.27 End users of electricity, however, pay tariffs that are determined using the average cost of providing service (except in the cases of residential and agricultural irrigation tariffs, which are heavily subsidized). Given that the rate of capacity retirement is extremely low, a very important difference between system average and marginal costs exists. Therefore, tariffs paid by industry, commercial establishments, and municipalities are very significantly above the marginal cost of combined cycle gas turbines, and clear economic opportunities exist where the willingness to pay of these consumers exceeds the cost of supplying them with renewable energy. However, since the current constitutional and legal framework prohibits direct contact between private producers and consumers, these opportunities cannot be exploited and represent an important barrier for the development of renewable energy sources in Mexico.

1.28 Recent regulatory changes that partially offset the disincentives inherent in the pricing system are encouraging. In September of 2001, the CRE published special rules for interconnection contracts between CFE and suppliers of renewable energy. These rules benefit self-suppliers whose consumption point(s) are not geographically adjacent to the production site, and can be summarized as follows:

- Priority dispatch. Renewable energy providers often have little or no control over production, which is governed by the amount of sunlight, wind, water, etc. Therefore the rules establish that CFE must dispatch these renewable energy providers whenever it is required, and not subject to other considerations.
- Discounts. The rules establish discounts on the tariff levied by CFE for transporting the supplier's electricity as a function of availability, which can reach 50 percent.
- Storage. As the self-supplier in question may not require energy at the same time that its renewable energy source is providing it, CFE is obliged to "return" unused energy to the self-supplier at times where it is required. That is, CFE in effect stores the energy. In the case of a self-supplier with a mini-hydro plant, for example, the electricity generated during the night is supplied to CFE, who then returns it to the self-supplier during the day.

1.29 These regulatory changes form part of a global and comprehensive strategy for the energy sector, as laid out in the *Programa Sectorial*. The *Programa Sectorial* establishes 10 key objectives for the energy sector during the 2001–2006 period, of which the fourth objective is to increase the use of renewable energy sources. It lists a series of strategies that together should serve as an important incentive for the increase use of renewable energy in Mexico. Among them are the following:

- Development of a National Fund for the promotion of renewable energy
- Long term investment contracts
- Fiscal and economic incentives
- Regulatory incentives
- Increased resources for research and development
- Education

1.30 These proposals form part of a global and comprehensive strategy for the energy sector, as laid out in the *Programa Sectorial*. The *Programa Sectorial* establishes 10 key objectives for the energy sector during the 2001–2006 period, and the fourth objective is to increase the use of renewable energy sources.

1.31 In addition to the above changes, further reforms in the form of a market-driven structural change are needed to allow for the creation of a competitive market and the introduction of numerous suppliers and consumers. This would have very important benefits for the sector and the economy as a whole, as it would increase efficiency, lower costs and therefore tariffs, and reduce the public sector burden, among others. It would also be crucial for the development of renewable energy, as it would eliminate many of the arbitrary pricing mechanisms currently in place, and allow for prices to be determined through a market or transparent regulatory mechanisms instead of the current administrative system. A reform would allow renewable energy providers to exploit the difference between system marginal and average costs, and would also introduce the concept of consumer choice. It would also greatly reduce uncertainty and the possibility of creeping expropriation brought about by the current system's highly unequal distribution of bargaining power between a monopsony (CFE) and potential private suppliers.

1.32 The importance of structural change and the introduction of markets into the electricity sector can not be underemphasized. Without structural change, efforts to promote renewable energy will have a lesser impact and a much more uncertain future. The current restrictive legal and institutional environment also ensures that any efforts made without a prior reform will be more costly. In addition, any resources used to create incentives for renewable energy under the actual framework would partially be used to offset the economic distortions currently present in the sector.

Informational and Educational issues

1.33 A series of informational and educational issues related to renewable energy in Mexico need to be addressed in order for further development. First, site-specific, detailed information on renewable energy projects is limited, an important barrier that translates into longer lead times and higher project development costs. With the exception of geothermal energy, for which commercial exploratory work has been carried out for a number of years, evaluation of other renewable energy resources has been done primarily for academic and research purposes.

1.34 However, activities are currently under way to compile, screen, and organize data into a geographical information system, which has been under development for the past three years as part of a pilot plan to foster renewable energy in Mexico. This plan is being carried out by IIE in cooperation with the Ministry of Energy, and was originally supported by funds from CONAE. While the quality of some of the data continues to be low, this pilot plan represents a very important step, as the first systematic effort to quantify, organize, and divulge detailed information on renewable energy projects.

1.35 Other challenges are driven by the informational voids with regard to renewable energy. Given Mexico's relative lack of practical experience in this field, little understanding of renewable energy exists. Important incentives such as those established by the CRE to promote renewable energy need to be accompanied by concerted efforts to make their existence and significance known to all sector participants. In addition, a comprehensive national program to promote renewable energy awareness among the general public would create interest in projects and aid in introducing new participants (municipalities and small enterprise) to the sector. Efforts to expand and/or update the technical infrastructure of the national renewable energy R&D centers, closely linking them to the needs of the sector, as well as to develop a larger human resource base of experts, are important complements that should be carried out in order to close the information gap.

1.36 The lack of hands-on experience with renewable energy implies that Mexico has not yet acquired the benefits derived from organizational learning. Incentives aimed at promoting the development of renewable energy in Mexico will generate significant positive externalities in this regard. The investments made in learning about and researching different potential projects will have large benefits for the development of future projects. Other benefits will be associated with the configuration, design, scale, and implementation of these projects. Therefore, the transaction and development costs associated with renewable energy project design and implementation will drop over time as more of them are developed and learning takes place.

Instruments to advance the use of renewable energy

1.37 Previous sections have outlined both the importance of renewable energy to the Mexican energy sector and the current lack of development in this area, the latter due in great measure to the gap between the cost of renewables and the price at which they are sold. In past years, progress on the technological front has resulted in steadily declining costs for renewable energy options, albeit at levels still above the non–environmentally adjusted cost of fossil fuel options such as combined cycle gas turbines. However, consensus forecasts indicate that the growing scarcity of fossil fuel options as stocks are depleted, together with continued technological progress in renewable energy, will make renewable energy alternatives economically attractive in the medium term.

1.38 The Mexican energy sector and economy will greatly benefit if the transition toward a greater use of renewable energy sources begins more rapidly than projected under the current legal, regulatory, and institutional framework. By beginning earlier, Mexico would gain important preparatory experience in a field certain to grow in importance in the future, as well as reduce its dependence (and thus the shock to the economy) on fossil fuel–based energy options.

1.39 The above rationale justifies the introduction of policy instruments to promote the use of renewable energy in Mexico. Selective intervention is required to ensure that renewable energy is considered a viable option within the energy sector, with the consequent economic and social benefits. The direct benefits are clear, and were laid out in section 1. The indirect benefits are also of importance, in that investments in renewable energy will ensure a smoother transition to a new energy sector configuration and allow for learning and knowledge investments to take place before the occurrence of fossil fuel–driven shocks.

1.40 Any policy instruments employed to advance the use of renewable energy should be temporal in nature, as market forces (under the assumption of structural reform being carried out) will make renewable energy alternatives attractive in the medium term. Interventions are therefore not permanent, but serve as the seed for future growth.

1.41 Policies aimed at promoting renewable energy sources have been employed in different countries, and can be grouped into two categories: quantity targets, where a certain share of generation must be supplied by renewable energy, and price subsidies, where resources are used to make renewable energy economically attractive. Of the two, price subsidies are better suited for temporal interventions, as they allow for greater flexibility and adjustment than quantity targets.

1.42 Policies that mandate a quantity target are rigid in the sense that they cannot be adjusted to take into account changes in technology or the legal, regulatory, and institutional frameworks without seriously undermining their credibility. The determination of a quantity target is necessarily arbitrary, and may be markedly different from the first best outcome if uncertainty exists with regard to the behavior of certain key variables. Other problems associated with quantity targets are that they are open-ended (if a quantity is fixed a limit on the amount of resources spent cannot always be enforced) and suffer from problems of dynamic inconsistency (if the target is not met, the authority prefers to renegotiate the target instead of applying any pre-specified penalties).

1.43 Price subsidies, on the other hand, provide greater flexibility and transparency. Price subsidies are not fixed in time, and can be adjusted to compensate for the rate of technological change and the relative cost levels. These adjustments can be carried out via market forces through systems of competitive bids, and can be fixed to make a developer indifferent between conventional combined cycle technology and renewable energy sources, optimizing the use of scarce resources. The amount of the subsidy can be phased out over time, with clearly established targets and timeline.

Legal and institutional issues

1.44 The legal and institutional issues described in the previous sections will have to be addressed, if the private sector is to participate in developing renewable energy projects. Among others, the reforms should address the scope of private sector involvement and the mechanisms by which electricity is to be sold to CFE or to private parties, including the pricing structure.

1.45 Strengthening institutional capacity and providing technical assistance to the relevant authorities and utilities with regard to renewable energy is also considered a priority. In addition, support of renewable energy projects through IIE and research centers in academia and elsewhere will help improve policies and technologies. It will also increase public awareness of the benefits of renewable energy. Public awareness can also benefit form an information campaign among consumers and communities.

Financial mechanism to promote the use of renewable energy

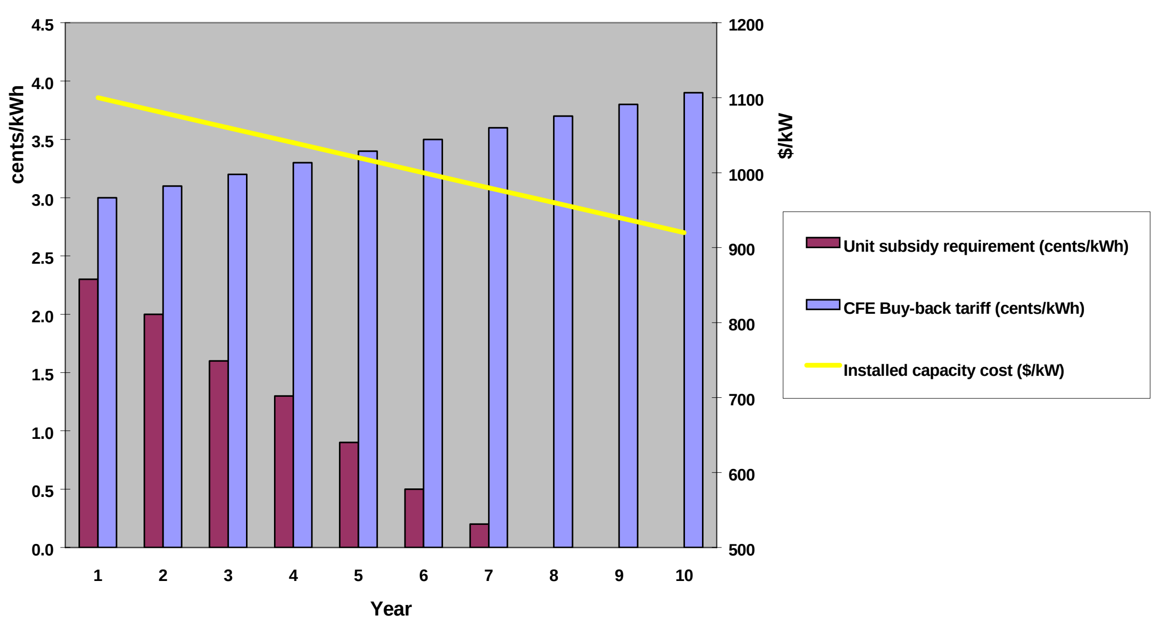
1.46 The development of renewable energy projects requires substantial financial resources. Creating a special fund for this purpose will provide a much needed boost to kick start new projects and strengthen existing ones. The fund will facilitate the transition towards the development of a competitive, efficient and cost-effective market for renewable energy in Mexico. This market will build upon the resources from the fund, other resources, international best practice, growing experience and know-how and an appropriate regulatory and institutional framework. In addition, synergies can be created between the market for renewable energy and the carbon market being developed.

1.47 An initial estimate is that the fund will require approximately US$100 million, of which 30 percent to 35 percent would be used in the first three years. The fund should include the following characteristics:

- The fund will provide subsidies through a competitive process and these subsidies will be phased out according to a clearly established timeline.
- The mechanism to define the amount of the subsidies should force recipients to reveal their true costs.
- The fund will include mechanisms for its replenishment, including resources obtained through bidding process for electricity generation and the development of “green certificate” programs for businesses that purchase electricity from renewable energy sources.

1.48 A preliminary exercise carried out for the analysis of wind power shows that a fund of US$95 million would directly stimulate 650 MW of capacity. In addition, technological change and organizational learning, along with proposed changes to the CFE powering purchasing tariffs and a projected increase in the price of natural gas, would effectively reduce the subsidy to zero by year 8. Therefore the fund, while directly increasing capacity by 650 MW, would also indirectly contribute to capacity additions by contributing to organizational learning and technological change, thus reducing the cost of installed capacity. If carbon offset sales were to be recognized (at an average price of US$6/MT of CO_2) the cumulative subsidy could be reduced from US$95 million to US$83 million.

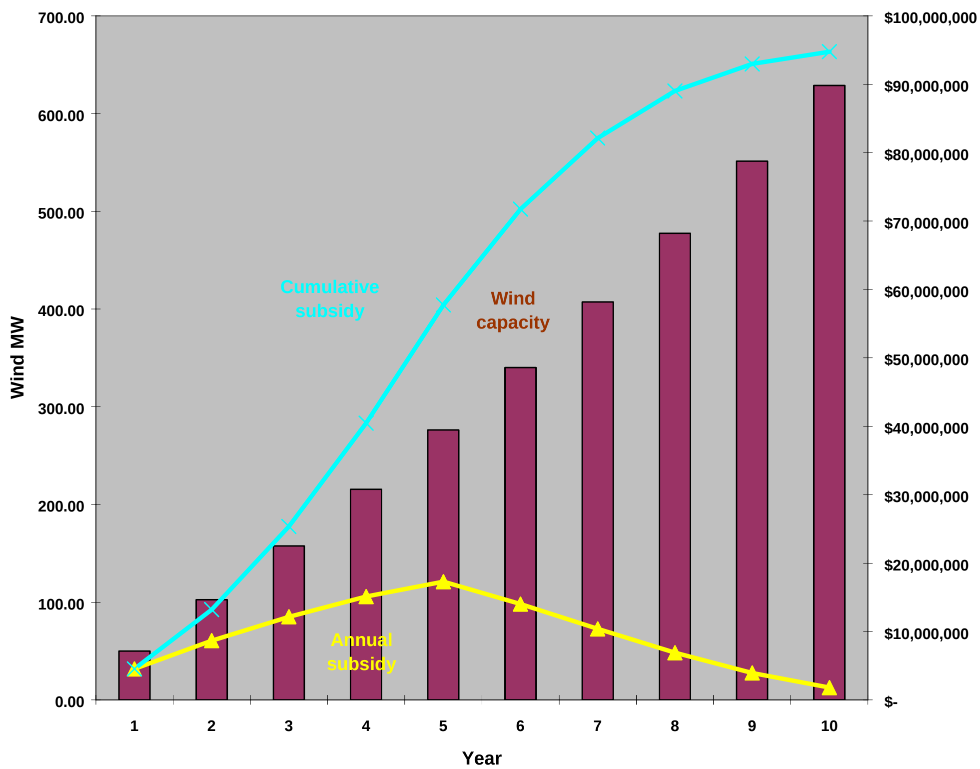
Figure 1.1: Wind Costs, Tariffs and Subsidies



1.49 The above calculations are based on the following series of assumptions: an initial installed cost for wind power of US$1,100/kW which would decline to US$900/kW over a 10 year period; and an increase in the CFE buy-back tariff rate from 3 to 4 cents/kWh over the same period. Given these assumptions, the unit subsidy requirements start out at 2.3 cents/kWh and then decline significantly and approaching zero by year 8.

1.50 The implications of the above scenario for fund operations are as follows: during the first three years 35 percent of the resources will have been applied, and the year with the highest annual subsidy would be year 5. After year 5, the annual subsidy would gradually fall towards zero for the rest of the ten-year period, as the declining installed cost and increased buy-back tariffs would start to take effect. The effect of the subsidy coupled with these cost and tariff trends would be to increase annual capacity additions by 5 percent per annum, and a final cumulative capacity of 650 MW.

Figure 1.2: Green Fund Flows and Outputs



1.51 This brief and preliminary exercise demonstrates that a targeted fund with clearly defined objectives and rules of operation will aid in creating renewable energy capacity in Mexico. This fund must form part of a global renewable energy strategy that incorporates the diverse pricing, regulatory, institutional, and informational issues outlined in this concept note in order to achieve maximum impact. In conjunction with these measures, the fund will provide the necessary impetus for expanding renewable energy, creating important benefits related to diversification, the environment, learning, and development.

2

Plan of Action for the Large-Scale and Sustainable Implementation of Renewable Energy in Mexico

Project Objectives and Rationale

2.1 The purpose of this project is to create the proper environment for the large-scale and sustainable implementation of renewable energy in Mexico. This will be done by introducing the proper legal, regulatory, institutional, financial and infrastructure elements to facilitate the creation of a competitive and sustainable market. Implementation of this project is expected to facilitate the operations of all stakeholders promoting the application of renewables in Mexico, and to help build consensus and synergy around common goals and objectives.

2.2 The development objective of this project is to reduce future CO_2 emissions in Mexico by about 10 Mtons per year, through the voluntary commercial installation and operation of renewable energy technologies to deliver electricity and/or process heat. The operational objectives include: removing identified barriers, reducing implementation costs, reducing long-term technology costs, raising consumer awareness, building capacities of public, private and social entities, strengthening/creating technology intermediation centers, developing strategies and policy frameworks, and helping to create new financing services and new institutions, in order to facilitate the installation and operation of the chosen renewable energy technologies.

2.3 Mexico is a country endowed with a large variety of natural resources. The main motivation to launch this project is that, while renewable energy resources are plentiful, with the exception of geothermal energy and large hydropower they remain virtually untapped. Reasons for this include: other sources of energy, such as oil and associated fuels, are also plentiful; per-capita energy consumption is still low for an OECD country; environmental concerns have not been traditionally high on the country's agenda; the cost of renewables has been higher than the cost of conventional energy technologies; and a set of direct and hidden subsidies are still in effect in the Mexican energy market. However, as the economy grows and the standard of living increases, and as increasing local environmental awareness turns Mexico into a major player in the international environmental scene, the need for more and cleaner energy will certainly grow.

2.4 In the medium and long term, Mexico's oil resources can be used to fuel the transition to a cleaner and more sustainable energy base, buying time to help local industry prepare for the new energy business, not only as users, but also as producers and exporters of the new energy technology. Revenues from oil exports can also help create the infrastructure (human, technical and institutional) needed to support this transition.

Mexico's role in the UNFCCC process

2.5 Mexico ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1993, and the Kyoto Protocol in 2000. It has prepared national communications reports with updated national emission inventories. In response to the requirements of Article 3 of the Kyoto Protocol, in 1997 Mexico implemented a National Action Program for Climate Change (NAPCC) prepared by an inter-agency committee.[11] The NAPCC includes the following energy terms: increased production and use of natural gas; increased fuel quality; use of economically viable renewable energy; and savings and efficient use of energy.[12]. Mexico's population of almost 100 million inhabitants is responsible for nearly 1.48 percent of global CO_2 emissions (13th worldwide). In contrast, per capita emissions (3.46 tons of CO_2 /inhabitant per annum) place the country in the 72nd position worldwide. The breakdown of CO_2 emissions by sector (1990) was as follows: land conversion and forestry (31 percent), transformation and energy industries (25 percent), transport (21 percent), other industry (15 percent), residential and commercial (5 percent), industrial processes (3 percent), other (1 percent). In the context of the UNFCCC, Mexico will take voluntary actions to limit GHG emissions without restricting its economic development.

Vision of the future

What Renewables Can Offer to Mexico

2.6 The large-scale use of renewables will bring potential benefits beyond kilowatts and kilowatt-hours, including an alternative path to development, more environmentally benign but retaining the goals of economic well being, social stability, environmental security, energy security; new and competitive energy markets, new energy technologies, and restructured energy industries.

2.7 Macroeconomic: Cost advantages can be gained by producing both useful forms of energy and new energy technologies. Renewables are the most cost-effective solution for power supply in remote areas, and could become cost-competitive for grid-connected and industrial applications, if all costs and benefits are included in the economic analysis. Renewables offer good opportunities for participation in the already expanding markets for new power technology, which will allow the creation of new jobs, reactivation of stagnant industries, and creation of new forms of the energy business.

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11 Integrated by the Environment, Energy, Foreign Relations, Commerce, Communications and Transport, and Agriculture ministries.

12 Fuentes C. Carolina. Energía Renovable para un Desarrollo Sostenible: El Protocolo de Kyoto. Experiencias Internacionales y el Caso de México. Master's Thesis. Universidad Nacional Autónoma de México (UNAM), January 2002.

2.8 Industrial Policy: Technological requirements for manufacturing renewable energy technologies are well within the already existing capabilities of the Mexican industry. The capital investment needed to build manufacturing plants for renewable energy technologies is within the reach of private Mexican investors, but foreign capital is also ready to enter the game as soon as the security of their investments is reasonably guaranteed.

2.9 Rural and Local Development: About 5 percent of the Mexican population (close to 5 million people) live in remote rural areas without access to commercial energy, and electricity-based services are not available to them. Local renewable energy resources can be used to improve the quality of life of these people and to foster their economic development through productive projects. Large-scale generation of electricity can benefit rural communities who could lease their land to developers of renewable energy projects.

2.10 Public Health Considerations: The use of renewables can be an important factor for improved health, by avoiding local emissions when substituting for conventional energy, and by improving the quality of services in rural health clinics and medical dispensaries where electricity is currently not available.

2.11 Energy Diversification and Security. Renewables can help the energy supply system move away from oil products and natural gas, to avoid future problems with the availability of these resources and their associated technology. Renewables can be a good instrument to help the energy sector expand its capacity to provide a reliable and secure supply, and hence to be in a better position to support any form of national or regional development. Renewables can also help increase the reliability of the power grid, avoiding economic problems derived from a poor quality power supply.

2.12 Sustainable Development: Renewables offer good prospects for sustainable development. On the economic dimension, the benefit/cost balance can be favorable when hidden subsidies to conventional energy are removed and renewable energy technology is locally produced. On the environmental dimension, renewables are virtually nonpolluting and they can help solve hard recurring local environmental problems.[13] On the social dimension, renewables are oftentimes the only reasonable possibility of providing electricity-based services to remote communities. Renewables can also constitute a "democratising force" to move away from centralized forms of energy supply, by providing opportunities for individuals to generate their own power and hence to contribute financially to the creation of energy infrastructure.

2.13 Clean Development: Renewables can help lower the carbon intensity index of the economy. This will put Mexico in a good position to honour any international obligations and to benefit from the economic mechanisms of the Kyoto Protocol and others.[14] This will in turn pay off in political benefits both at home and abroad.

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[13] For example, the final disposal of urban solid waste or the reclamation of already deforested land for use in the production of energy crops.

[14] The ability to trade carbon credits and to undertake joint emissions reduction projects are two of the inherent benefits Mexico can derive from the Kyoto Protocol through the use of renewable energy.

Where the road is leading

2.14 Under the present circumstance, renewables will need a push to move forward in Mexico. New energy policies and a variety of technical and nontechnical changes in the energy market will be necessary. Barriers that could inhibit progress need to be identified, and strategies to remove them in the short to medium term must be developed; new capabilities and infrastructure to identify and tap niches of opportunity where renewables are technically and economically viable must be created, so that enough experience is gained within the country in this new field, the energy business; finally, mechanisms to assure that the playing field is level enough for renewables to compete under equitable and transparent rules must be introduced.

Penetration of Renewables in 10 Years

2.15 No systematic study has been carried out to date to assess the effects of large-scale penetration of renewables in Mexico. Four scenarios have been suggested by different organizations. They are summarized in the following table. The business-as-usual scenario (low penetration) belongs to the latest prospective exercise for the power sector performed by SENER,[15] and basically represents CFE's expansion plan for renewables. The moderate penetration scenario derives from the Energy Program 2001–2006[16] of the present administration, which states that the use of renewables in Mexico by the year 2006 should double that for the year 2000, in addition to the expansion program of CFE. This is a scenario committed to by a government program and is likely to happen without further push. The enhanced penetration scenario was derived by IIE and relies on a modest push to introduce changes in the regulatory framework (for wind), stiffer environmental regulations (for biomass), programmatic elements (for small hydro), and lower technology costs (for solar thermal and photovoltaics). The high penetration scenario was developed by a panel of experts of ANES.[17] It suggests that renewables could have a penetration in Mexico of between 5 percent and 10 percent of the total national energy consumption by the year 2010, considering the power, rural, urban and transport sectors. This scenario assumes a major push in favour of renewables.

Associated Costs

2.16 The total required investment to reach the goals established in each scenario ranges from almost US$1,400 million in the low penetration case to almost US$8,400 million in the high penetration (see table). The average cost per kilowatt installed in each scenario will depend on the technology mix chosen

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15 Prospectiva del Sector Eléctrico. SENER, Junio de 2001.

16 SENER: Energy Program 2001–2006, October 2001.

17 Estrategias para Desarrollar el Aprovechamiento de las Energías Renovables en México. Asociación Nacional de Energía Solar. Septiembre de 2000.

Scenario (Time Frame)	Technology	Capacity (MW)	Unit Cost[18] (US$kW)	Total Investment (MUS$)
Scenario 1: Low Penetration (business as usual)				
Prospective Power Sector (10 years)	Wind	177	900-1,440	207.09
	Small hydro	229	800-6,000	778.60
	Photovoltaics	23	4,000-10,000[19]	161.00
	Biogas from sanitary landfills	16	600-1,170	14.16
	Sugar cane bagasse/diesel	257	900[20]	231.30
	Total	**686**		**1,392.15**
Scenario 2: Moderate Penetration (committed by program)				
Energy Program 2001–2006 (6 years)	Solar	Not specified	Assuming average unit cost of US$ 2,029.37/kW	Will depend on technology mix
	Wind			
	Small hydro			
	Geothermal			
	Biomass			
	Total	**1,000**		**2,029.37**
Scenario 3: Enhanced Penetration (with modest push)				
Prospective IIE (10 years)	Wind	2,000	900-1,440	2,340.00
	Photovoltaics	20	4,000-10,000[10]	140.00
	Solar thermal	50	2,000-4,000[21]	150.00
	Biogas from sanitary landfills	150	600-1,170	132.75
	Small hydro	500	800-6,000	1,700.00
	Total	**2,720**		**4,462.75**
Scenario 4: High Penetration (with strong push)				
Prospective ANES (10 years)	Wind	4,000	900-1,440	4,680.00
	Small hydro	200	800-6,000	680.00
	Biomass	300	600-1,770	265.50
	Solar thermal	250	2,000-4,000[12]	750.00
	Photovoltaics	250	4,000-10,000[10]	1,750.00
	Biogas plants (rural)	50,000	1,500[22]	75.00
	Solar cookers	100,000	800[10]	80.00
	Solar dryers	Not specified		
	Solar water heaters	200,000 m^2	2,000[23]	100.00
	Biofuels	Not specified		
	Total	**5,000[24]**		**8,380.5**

Niches for the Application of Renewables in Mexico

2.17 Technically speaking, the power sector offers the largest possibilities for the application of renewables, but at the same time shows the lowest flexibility due to the limitations imposed by the current electricity law. Other sectors could use renewables for

18 Source: Key Issues in Developing Renewables. International Energy Agency, 1997. Based on actual project costs, except where otherwise indicated. The mean values were considered to estimate total investment.
19 Estimated by the author from projects in different countries.
20 Estimated by the author.
21 Projected costs for fully commercial power plants.
22 Estimated by the author, per unit of bio-digester or solar cooker.
23 Estimated by the author, per each 4 m^2 solar collector installed, including storage tank.
24 Nonelectrical technologies excluded.

power generation without facing such limitations, or for other applications such as process heat.

The Power Sector

2.18 The Mexican power sector faces several issues, including the need for new capacity, increased system reliability, higher power quality, and modernization of its technology base. Total installed capacity in 2000 was 39 GW, distributed as follows: thermoelectric 60.1 percent, hydropower 26.5 percent, coal 7.1 percent, nuclear 3.8 percent, and geothermal 2.3 percent (plus a tiny portion of wind).

2.19 Growth scenarios: Electricity consumption is anticipated to grow at an average rate of 6.3 percent in the period 2001–2010, based on the expected rate of economic growth. Consequently, the National Electrical System will require an additional 27,357 MW for the next ten years, out of which 10,854 MW are already committed or under construction, and 16,503 will be obtained from not yet committed projects for additional capacity. An additional 4,862 MW in projects for private generation are also anticipated, which represents an additional total installed capacity of 32,219 MW.[25] The technology mix under consideration for this additional capacity relies heavily on the use of natural gas. Important geothermal and large-scale hydroelectric projects are also under consideration, but no other renewables are included. Heavy reliance on natural gas brings in questions about the security of future supply, price volatility and availability (and hence cost) of associated technologies such as gas turbines.

2.20 The business-as-usual scenario is mostly based on large central stations. Distributed generation is not under consideration. Since the Mexican power system is still under development, distributed generation could bring the following benefits: lower investments in transmission and distribution infrastructure, shorter lead investment times to build generating capacity, higher flexibility in the planning process, easier access to money markets, lower financial risks through a broader base of investors, lower technology costs through local manufacturing, and the use of local renewable energy resources. Renewables can attract new capital for investment and can help democratize the participation of private investments in the power sector through small, distributed self-generation projects.

2.21 Emissions: In the business-as-usual scenario natural gas represents 60% of all fossil fuels used for power generation by 2006. While new natural gas co-generation plants are efficient, their use to meet Mexico's additional energy needs would likely result in a significant increase in total GHG emissions. Under this scenario, CO_2 emissions from the power sector would rise to 192 million tonnes by the year 2010, a 2.3 fold increase over the 1996 level.[26] Projections indicate that while overall SOx, HC and TSP emissions would tend to diminish (23 percent less than 1995), important increases in

[25] SENER. Programa Sectorial de Energía 2001-2006, Septiembre de 2001.

[26] Barnés de Castro, Francisco. Energy and Climate Change: Opportunities for emission trading schemes in North America. SENER, September 2001.

CO_2 (53 percent), CO (86.9 percent) and NOx (86.4 percent) would most likely be registered.[27] The use of renewables could help relax this situation.

The Water Sector

2.22 From the availability, supply, and environmental points of view, water represents a potentially bigger problem for Mexico than energy in the medium to longer term. As the Mexican population and its economic activity grow, water demand also increases. A demand for electricity is necessarily linked to the supply and treatment of water. Since water is a critical commodity whose supply cannot be cut for more than short periods of time, the Water Sector in Mexico owns a large number of diesel gen-sets as backup power for water pumping stations. This redundant power supply requires large capital investments along with sizable budgets for operation and maintenance, and implies no negligible amount of emissions to the atmosphere. The Water Sector could become a major user of renewables for the self supply of electricity. Biogas recovery from water treatment plants and the use of mini-hydro turbines to tap the potential energy in the downhill sections of aqueducts, are only two of the most obvious possibilities.

The Municipal Sector

2.23 Municipalities in Mexico have to deal with a set of interconnected problems, which could be eased by the use of renewables. Large amounts of electricity are used for municipal services, creating a heavy financial burden for the administration since electricity tariffs for municipalities are among the highest in Mexico. On the other hand, solid waste disposal represents both a high cost for the municipality and a growing environmental problem. Programs are under way for the construction of sanitary landfills in medium size cities of Mexico. Additional investments could turn landfills into electricity generating facilities by using the biogas therein produced. Municipalities are entitled to generate their own power, by themselves or in association with private investors. Hence, solid waste, sludge from water treatment plants, and other renewable energy resources available in the municipality’s territory could be used for the self supply of electricity.

The Agriculture Sector

2.24 According to the National Energy Balance 2000,[28] the agriculture sector had the lowest final energy consumption (only 3 percent) of the whole Mexican economy and shows a declining tendency. Diesel fuel is the main energy carrier in this sector (68.8 percent), followed by electricity (24.7 percent) and LP gas (6.5 percent). This sector is badly in need of economic reform, but any program to boost its economy will demand increased amounts of energy. Electricity can be locally generated from forest residues, cattle manure, bagasse and other organic materials, or from energy plantations which could be developed in already deforested regions. Local/regional production and use of biofuels and other renewables can bring a number of benefits to the agricultural sector,

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[27] Rodríguez Padilla, V. Impacto de la reforma económica sobre las inversiones de la industria eléctrica en México: El regreso del capital privado como palanca de desarrollo. Serie Reformas Económicas 18, Comisión Económica para América Latina y el Caribe 1999.

[28] Balance Nacional de Energía 2000. Secretaría de Energía.

such as creating jobs, increasing the local turnover of money by avoiding regional imports of commercial fuels, and cutting harmful emissions to the environment.

The Rural Sector

2.25 This sector is closely linked to the agricultural sector. As such, it also shows limitations in the energy consumption patterns. Field studies carried out by IIE, SEMIP[29] and others, show that the rural sector relies basically on firewood (69.15 percent) for its energy supply. The use of commercial fuels is very limited. Gasoline represents 10.43 percent of the total energy in this sector, followed by LP gas (9.98 percent), diesel fuel (6.33 percent), electricity (2.53 percent), and kerosene (1.58 percent).[30] When available, electricity is used in a very limited manner.[31] Where electricity from the grid is not available, kerosene lamps, dry cells and candles are extensively used for illumination purposes. For this reason solar home systems became very handy for providing basic electricity services to the rural population in this country.[32] The use of renewables for productive applications represents an important opportunity to improve the economic conditions of the rural population.

Renewables in Mexico: the Current Situation

2.26 Interest in the application of renewables has grown steadily in Mexico over the past 10 to 15 years. Several project initiatives have been initiated and advanced beyond the planning stages. The number and importance of stakeholders promoting and supporting a diversity of renewable energy initiatives in Mexico has increased.[33] Firm steps to update and improve the institutional and regulatory frameworks to facilitate the

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[29] Secretaría de Energía, Minas e Industria Paraestatal, now the Ministry of Energy, SENER.

[30] Energía Rural en México. Secretaría de Energía, Minas e Industria Paraestatal. Comisión de las Comunidades Europeas. Noviembre de 1998.

[31] Only the wealthiest 10% of the rural population use electricity to power refrigerators, color television sets and other electrical appliances. The rest use electricity only to feed two or three light bulbs, to listen to some radio, and eventually to power small black-and-white television sets.

[32] Huacuz J, Agredano J: Beyond the Grid: Photovoltaic Electrification in Rural Mexico, Prog. Photovolt. Res. Appl. **6**, 1998. Huacuz J, Martinez AM: Renewable energy rural electrification. Sustainability aspects of the Mexican programme in practice. Nat. Res. Forum, **19**, No. 3, August 1995.

[33] Main stakeholders acting in México: **Non-government entities**: the National Solar Energy Society (ANES, the Mexican chapter of the International Solar Energy Society ISES); the Mexican Foundation for Rural Development; the Mexican Hydrogen Society. **Government agencies**: the Commission for Energy Savings (CONAE); the Federal Commission of Electricity (CFE) through its Rural Electrification Unit and its Geothermal and Renewable Energy Unit; the Electrical Research Institute (IIE). **Universities and research centers**: the Centre for Energy Research (CIE-UNAM); the Engineering Institute (II-UNAM), both at the National Autonomous University (UNAM); the Energy Program of UNAM (PUE-UNAM); the Centre for Advanced Studies and Research of the National Polytechnic Institute (CINVESTAV-IPN); several schools of the Autonomous Metropolitan University (UAM). **International organizations**: the United Nations Development Program (UNDP) and the World Bank (WB), both with GEF-related projects; the U.N. Food and Agriculture Organization (FAO). **Bilateral aid agencies**: the USAID, the German GTZ and the Japanese JICA. **Other**: National and international private investors, financing institutions, technology manufacturers and project developers, mainly in connection with photovoltaics, wind energy and small hydropower.

use of renewables have been taken by the Government of Mexico (GOM). Important projects have been carried out by government agencies and private companies, from which important lessons have been learned. However, progress has been slower than desirable for a number of reasons.

Regulatory Framework

2.27 The legal framework for energy matters in Mexico, and electricity in particular, is quite comprehensive and fairly transparent. It stems from the Mexican Constitution, whose Article 27 establishes the exclusive right of the nation to generate, transport, transform, distribute and supply electrical energy with the purpose of providing a public service. Article 28 states that the functions performed exclusively by the State in the diverse strategic areas under its responsibilities, electricity among them, do not constitute a monopoly. This article also entitles the State to establish the required organisms and enterprises for the adequate handling of the cited strategic areas.

Current Electricity Law

2.28 The Law for the public electric energy service sets the operational rules for the electrical sector. It was reformed in 1992 to expand the possibilities for participation of private investors in electricity generation activities which do not qualify as public service. In December of 1993 new reforms were also introduced in order to give a more precise meaning to some of its articles. Article 3 of this Law now exempts from the definition of public service the following activities, where private entities are now allowed to invest:

- Generation of electricity: for **self supply**, by **co-generation** or **small generation**[34];
- Generation of electricity by **independent producers** for exclusive sell to CFE;
- Generation of electricity **for export**, either from co-generation, independent power production, or small generation;
- **Imports** of electricity by individuals or formally established entities, for the sole purpose of self supply;
- Generation of electricity in case of **emergency** caused by the interruption of the public electrical service.

Electric Tariffs Structure

2.29 Subsidies are applied taking into consideration the direct correlation between family income and the use of electricity. The use of subsidies has created a backlog in the price/cost of electricity in Mexico. At the end of 2000, the value of this backlog was 70 percent for CFE and 51 percent for LFC; this means a deficit of 30 percent and 49 percent, respectively, regarding the real cost of supply, which represented a total of

[34] Under 30MW for sell to CFE or under 1MW for the supply of remote rural communities.

56,800 million pesos[35] of total subsidy in the year 2000. The largest share is taken by the agricultural and residential sectors.[36]

Grid Interconnection Issues

2.30 Up until late 2001, one of the main stumbling blocks for grid-connected renewable energy projects was the need for a regular interconnection contract with CFE, under which renewables could not compete. To overcome this barrier the Regulatory Energy Commission (CRE) has issued new contract forms for the interconnection with CFE's electrical grid of intermittent sources of power, such as wind and small hydro and the wheeling of electricity from these sources. After the implementation of these contract forms, a number of wind farm projects are now moving forward. Although these contract forms represent a step forward in the right direction, they are mainly applicable to self-generation–type projects.

Technical Normative Framework

2.31 Availability of technical norms applicable to renewables is very limited in Mexico. A technical norm for solar water heaters is under development but some work still remains to be done. Technical specifications and guidelines for off-grid PV projects were developed by IIE and have been applied for the past 12 years in rural electrification projects financed with federal funds and are regularly updated[37]. Infrastructure for quality assurance of small PV systems was developed for the same purpose, but needs to be updated. Technical standards applicable to the GEF/WB-supported PV and wind water pumping projects (see below) are also under development, but much remains to be done. Much remains to be done in terms of developing, adopting and adapting technical standards, guidelines, norms and specifications, to guide the correct implementation of renewable energy projects. Guidelines for project development, follow-up and monitoring, as well as best practices manuals for project replication, are also necessary in preparation for market deployment.

Renewable Energy Policy

2.32 Energy, as an economic activity in Mexico, accounts for 3 percent of the GDP and 8 percent of all exports. Taxes on hydrocarbons amount to 37 percent of the Government’s tax collection, and almost 60 percent of public investment is used for energy projects. According to the National Development Plan for the period 2001–2006, one of the main goals of the energy sector is to increase its contribution to the country’s economic and social development. This will have to be accomplished with full respect to the environment, by strongly encouraging the efficient use of energy, widely promoting energy diversification and the use of alternative and renewable energy sources, and firmly supporting research and technological development. The Energy Sector Program

[35] US$6,140.5 million at the current rate of exchange (March 2002)

[36] Programa Sectorial de Energía 2001-2006. Capítulo 6 Electricidad. Septiembre 2001.

[37] Working in close cooperation with international organizations such as the International Electrotechnical Commission, the Expert Group of the Photovoltaic Power Systems Agreement of the International Energy Agency, and other laboratories abroad

2001–2006[38] acknowledges the possibility of an increased development of the nation's renewable energy resources, and sets as one of its main objectives "***To increase the use of renewable energy sources and to promote the efficient use of energy and energy savings***." The strategy to achieve this objective is to develop programs, projects and plans of action for the use of renewables. Some of the specific actions are described in the Policy section of the Instruments chapter of this project proposal.

Institutional framework

2.33 Renewables are still far from becoming a major energy source in Mexico, but a favourable institutional framework is emerging, both in the public and private sectors.

The Energy Sector

2.34 Secretaría de Energía, SENER, is the sector head. It was recently restructured and a new under-secretariat for Energy Policy and Technology Development was created. This new under-secretariat has strongly emphasized the development of renewable energy, and is building the necessary policy and planning instruments to facilitate the large-scale introduction of renewables in Mexico, which are partially reflected in the present project proposal.

2.35 Comisión Nacional para el Ahorro de Energía, CONAE, acts as a technical consulting body for the federal administration in matters of efficient use of energy, energy savings, and the use of renewable energy. In a joint initiative, CONAE and ANES, created in 1996 a consulting body named COFER,[39] to foster the use of renewables.

2.36 Comisión Reguladora de Energía (CRE) regulates the activities of both public and private energy operators. CRE has recently been paying attention to the renewable energy aspects of its duties, with the results previously mentioned.

2.37 Comisión Federal de Electricidad (CFE). The Unit of Geothermal and Renewable Energy, an agency of the CFE, is doing work to assess the potential of wind energy, and has built over 2 MW of grid-connected wind generators. It has also built some off-grid PV-wind hybrid projects in remote communities. The Unit of Rural Electrification has been implementing basic PV rural electrification projects and has acted as technical normative agency for other projects financed by the federal government.

2.38 Instituto de Investigaciones Eléctricas (IIE). Renewable energy activity is concentrated in the Unit of Non-conventional Energy, which for over 25 years has been

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38 Programa Sectorial de Energía 2001-2006. SENER, septiembre 2001.

39 COFER: Consejo Consultivo para el Fomento de las Energías Renovables. Its mission is to promote and strengthen the use of renewable energy in Mexico, under the premise of free market competition, and within the framework of the Law for Electrical Service. COFER is integrated by Mexican representatives from industry, academia, government and financing institutions and acts as a consulting body for project identification, as well as for the design and development of programs and policies related to the use of renewable energy. COFER also analyses the potentialities and barriers existing for the implementation of renewable energy projects, and carries out national and international events to promote the use of renewable energy as part of the energy mix in Mexico

actively working on the development and application of renewable energy technology, in support of CFE and other government and nongovernment entities.

The Environment Sector

2.39 SENER and the Ministry for the Environment and Natural Resources (SEMARNAT) are coordinating their energy and environmental policies, so that a long-term sustainable energy policy can be established. SEMARNAT has created an advisory body named COMIA to address critical environmental problems involved in the supply of municipal services, including energy.[40]

The Academic Sector

2.40 A critical mass of academic and R&D institutions in the field of renewable energy has been created in Mexico over the past 25 years, some of which are well known internationally for their scientific and technological achievements. Other local universities and research centres around the country are slowly undertaking renewables as a new field of activity. However, the number of specialized human resources in this field is still short, and is considered one of the most critical bottlenecks for the large-scale and sustainable implementation of renewables in Mexico.

The Nongovernment Sector

2.41 The Asociación Nacional de Energía Solar (ANES) is the Mexican chapter of the International Solar Energy Society (ISES), and has been actively promoting the use of renewable energy for the past 25 years.[41] Several other nongovernment organizations are also promoting the use of renewables in Mexico.[42]

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[40] COMIA: Comisión Mexicana de Infraestructura Ambiental, is an initiative jointly created by the public sector represented by SEMARNAT and the private industrial sector represented by the Coordinating Council for Private Enterprise (Consejo Coordinador Empresarial, CCE). The official members of COMIA include other government bodies, public research institutions, national financing organizations, industrial chambers representatives and private companies. COMIA is currently in the process of defining its program of work for the next 5 years, which will focus on water supply, solid and liquid urban waste disposal, and disposal of industrial and medical hazardous and infectious materials. The use of renewable energy whenever possible has been established as a goal by the Commission

[41] ANES organizes yearly technical conferences, topical workshops and short training courses, along with the publication of the only magazine specializing in renewable energy in Mexico (La Revista Solar). ANES also carries out work of its own or commissioned by other entities, to analyse critical issues around the implementation of renewable energy in Mexico. In September of 2000, ANES released the results of a prospective study carried out by a panel of national experts and the corresponding strategies proposed for the development of renewable energy in Mexico. Some sections of the present project proposal draw from the consensus reached by the ANES panel of experts, as indicated in the references

[42] The Mexican Foundation for Rural Development, a nationwide organization with the mission to promote economic activities in rural areas; the Mexican Electric Energy Association (AMEE), an association of independent power producers, with a chapter on renewable energy; the Mexican Chamber of Electric Equipment Manufacturers (CANAME) which has expressed interest in manufacturing wind generator components and other renewable energy technologies.

International Cooperation

2.42 The GOM formally interact with key international players in the field of renewables. In the framework of the International Energy Agency, Mexican institutions participate in five Implementing Agreements on renewable energy,[43] and collaborate with the Renewable Energy Working Party. Mexico also participates in the renewable energy working groups of the Asia Pacific Economic Cooperation forum (APEC) and of the Iberoamerican Program of Science and Technology for Development (CYTED). Bilateral cooperation agreements on renewables have also been signed with several nations. This international activity has been a good instrument for information exchange, knowledge and technology transfer, and joint implementation work.

Resources and Applications

Energy Resources

2.43 Renewable energy resources are abundant in Mexico. However, site-specific, detailed information is very limited and usually not good enough to support large-scale commercial projects. With the exception of high temperature geothermal energy, evaluation of renewable energy resources has been done mostly for academic and research purposes. Synoptic solar radiation and wind maps are available, but low temperature geothermal, small hydro and biomass are practically unexplored.

2.44 From the available information the following can be concluded: Solar energy: excellent availability, with average density around 5kWh/m2-day. Wind: several regions with good potential, indicative measurements show around 5,000 MW that could be now economically viable. Further exploration could add up to 15,000 MW in new inventories. Small hydro: full potential unknown; some estimates indicate that at least 3,550 MW could be harnessed.[44] Biomass: potential not fully assessed. Information on cattle waste, forest and agriculture residues, is not available in aggregate and useful form. Sugar cane bagasse is already fueling 210 MW and could support 36 MW more in the next 10 years[45]; 150 MW could be supported by the 90,000 tons of urban solid waste produced daily in all medium size cities in this country.[46] The potential for energy crops in Mexico is not known.[47]

2.45 A geographical information system (SIGER) is being developed by IIE as part of an agreement with SENER, which has the purpose of providing good and timely information to facilitate the development of commercial renewable energy projects.

[43] Geothermal, solar thermal, solar photovoltaics, wind, and solar heating and cooling.

[44] CONAE: Recursos de Energía Renovable en México. Reunión-Diálogo para Incentivar la Inversión en Energías Renovables en México. Febrero 2002. Studies by IIE indicate that around 10% if this figure can be found in irrigation channels.

[45] SENER: Prospectiva del Sector Eléctrico 2001-2010. Actual figures will depend on the development of the sugar cane industry.

[46] Arvizu, José Luis: Energía a partir de la basura. Boletín IIE, Vol. 21, Num. 6, Nov-Dic 97.

[47] Because of its tropical climate, regions in central and southern Mexico could be good candidates for energy plantations. Besides the energy potentially produced, energy plantations would offer the additional environmental benefit of recovering already deforested lands.

The Use of Renewables

2.46 Renewables represent 4.2 percent of the overall energy supply in Mexico, and 28.4 percent in the electric power sector alone. Most of this contribution comes from traditional sources (biomass, 3.5 percent of the overall supply) or established technologies (big hydroelectricity and high temperature geothermal, with 26 percent and 2.35 percent of the power supply, respectively Solar water heaters, off-grid photovoltaics, and grid-connected wind generators have only a modest penetration in the Mexican energy market.[48]

Grid-Connected Applications.

2.47 A Pilot Plan for the Development of Renewable Energy, launched in 1999, is currently operated by IIE. Criteria established by SENER to guide this Pilot Plan include close interaction with industry, international cooperation, shared financial risk and operational links with academia to foster the development of specialized human resources. The following projects are included:

- <u>Photovoltaics.</u> Pilot grid-connected PV systems (in the range of 1.5-2 kW each) are in operation in northwest Mexico, to test the viability of rooftops to shave peak power loads caused by air conditioners in cities with high summer ambient temperatures. A project proposal has been submitted to the GEF-UNDP to expand these activities, as a preparatory stage for the massive deployment of this type of system.

- <u>Solar Concentrators.</u> Work on parabolic troughs for process heat and dish-Stirling technology for remote power generation is under way. A cooperation agreement has been signed between IIE and CIEMAT,[49] for joint work in this field. A call for bids was recently issued to build a solar-assisted combined-cycle gas-fired power plant in north Mexico, financially supported by the WB-GEF.

- <u>Wind Farms.</u> Just a little over 3 MW of grid-connected wind generators have been installed, of which 2.28 MW belong to CFE and the rest to private companies.[50] Operational experience has been mixed, but valuable to show the potential for further applications. Several larger wind farm projects, in the range of 20–50 MW each, are at different stages of development, but up to now none of them has been built. The main barriers to the large-scale implementation of wind energy in Mexico are being identified as part of the Pilot Plan, and strategies to remove them are being developed. Development of technical support infrastructure, facilitation of project development, and local industry

[48] A variety of technologies (water desalinating units, solar coolers and ice makers, grain dryers, solar concentrators for different purposes, biodigestors) have been researched on and off for almost 25 years in various Mexican academic and technology research centres, but have not advanced beyond the prototype or pilot stages in the best cases.

[49] CIEMAT, the Spanish Research Centre for Energy, the Environment and Technology

[50] This includes a 550 kW generator installed in 1997 by the cement company Apasco, in north-central Mexico, and a 250 kW machine installed more than 10 years ago by the company Exportadora de Sal, in Baja California.

participation are among the specific objectives of this project. Some state governments have taken the lead in facilitating institutional and local policy changes to foster the use of wind power in their territories.[51] Over a dozen wind energy companies, plus increasing numbers of investors and financing enterprises, wind project developers and engineering companies, both from Mexico and abroad, are actively seeking to implement the first large-scale wind energy projects in this country.

- Biogas from Sanitary Landfills. A portfolio of projects is under development, where municipalities, private investors and technologists team up to form joint ventures for the self supply of electricity to the municipality. Preliminary studies have been carried out for two of the most promising sites, while a number of foreign and local investors and technologists have expressed their interest to participate in the projects. A similar project is in progress in the city of Monterrey, supported by the WB-GEF.
- Geothermal Energy. Mexico is currently the third largest user of geothermal power in the world, with an installed generating capacity of 855 MW, based on high temperature reservoirs. Geothermal energy has been commercially exploited by CFE for over 25 years. Private investors are now participating in the heat supply side of the cycle. Plans to install 120 MW more by the year 2005 already exist.[52] Low temperature geothermal, estimated to have a large potential, are only used for recreational purposes. A project to assess and map the full potential of low enthalpy geothermal reservoirs is included in the Pilot Plan.
- Off-Grid PV. A market a little greater than one MW per year of PV applications is already well established in Mexico, and growing basically for remote power supply. All PV modules currently being installed are imported.[53] Balance of system components[54] for solar home systems (SHS) are now manufactured in Mexico. A small local manufacturing industry is growing under the umbrella of the official programs for PV rural electrification; some of these companies are now exporting their products to other Latin American countries.
- Rural Electrification. A program to alleviate poverty in rural areas, which allows the use of renewables to provide basic electrical services for remote communities, has been in effect since 1989. SHS are the preferred technology, but a couple dozen mini-grids powered by small hydro and PV-wind hybrids have also been built. Over 13,000 PV-powered rural telephones have been installed, and over 2,500 rural communities are now electrified with

51 Participating states include: Oaxaca, Baja California, Baja California Sur, Nuevo Leon, Tamaulipas, Hidalgo, Veracruz and Quintana Roo.
52 SENER: Prospectiva del Sector Eléctrico 2001–2010.
53 The technology for manufacturing PV solar cells and modules was indigenously developed in Mexico in the early 1980s. A pilot manufacturing plant was built, but commercial production never took place.
54 Charge regulators. batteries, small inverters, compact fluorescent lights and other small appliances.

renewables[55]. Preparations are under way to establish a new program to deliver electricity and electricity-based services to all native Indian communities above 400 people currently without access to the electrical grid.

- Water Pumping. Tens of PV water pumps are being installed in a program partially financed by the GEF, FIRCO[56] and the user. An undetermined amount of small wind generators have also been installed for water pumping and other productive applications.
- Professional Applications. Electricity supply in off-shore oil rigs, cathodic protection, signalling and telecommunications, are currently the main applications of PV in Mexico aside from rural electrification. Other applications (eco-hotels, natural preserves and forest surveillance posts, electric fences, emergency telephones, and so forth) are becoming common practice.

Non-electrical Uses

- Water Heating. Solar water heaters (SWH) have been produced in Mexico for more than 50 years, but with little market penetration. Some 50 companies are known to manufacture and/or retail SWHs[57]; the total area of solar collectors installed is a little over 373,000 m^2, mostly for heating swimming pools. The energy supplied is comparatively very small, only 1.8 Petajoules[58] (PJ). Industrial process heat and other higher temperature applications of solar energy are not common in Mexico. Studies are under way to assess the environmental, energy and economic impacts from the potential massive installation of SWH in the metropolitan Mexico City area.[59] Another study by IIE showed the large market prospects and economic advantages of implementing solar water heaters as part of new housing projects[60].
- Traditional Uses. Renewables, solar energy in particular, have been traditionally used in Mexico for a variety of low tech applications, such as drying of agricultural products, but the total amount of conventional energy saved by this practice (and emissions avoided thereof) has not been estimated. Firewood is used in a yearly amount equivalent to 2.6 percent of the total energy supply. Serious environmental concerns, such as deforestation and the corresponding impact on biodiversity, call for improved technical and resource management schemes for future use of firewood. Co-generation from sugarcane

55 Over 60,000 SHS have been installed, and hundreds of rural schools, medical dispensaries, and communal buildings are being supplied with PV electricity. Additionally, over 30,000 SHS and a large number of systems for professional applications have been privately sold by commercial companies established in Mexico.

56 Fideicomiso de Riesgo Compartido, a trust fund of the Mexican Secretariat for Agriculture, created to support the development of infrastructure to support agricultural productivity.

57 Estrategias para Desarrollar el Aprovechamiento de las Energías Renovables en México. Asociación Nacional de Energía Solar. Septiembre de 2000.

58 SENER: Balance Nacional de Energía 2000.

59 Estudio PUE.

60 Medrano VC, Huacuz JM: Calentadores Solares de Agua para el Ahorro de Gas LP en el Sector Doméstico. IIE/01/14/10407/I001/F Febrero 1996.

bagasse contributes an estimated 88 PJ to the national energy balance.[61] Some 7 million tons of common salt are produced annually from evaporation of sea water at the salt works in Baja California, where solar and wind energy do the basic job. It is estimated that the amount of renewable energy used in the process is equivalent to around 1% of the total commercial energy supply in Mexico.

Renewables and the Power Sector

2.48 According to the National Energy Balance,[62] the total final energy consumption in Mexico in the year 2000 reached 4,029 PJ, 89 percent of which is supplied by fossil fuels. The rest is electricity of nonfossil origin (hydropower, nuclear power, geothermal and wind energy) which amounts to 5.1 percent, biomass 3.5 percent, and coal 2.4 percent. In the electric power sector, slightly over 67 percent of the total generation comes from fossil fuels. The rest is hydroelectric (26 percent), nuclear (3.75 percent), geothermal (2.35 percent), and a tiny portion of wind power (only around 2MW). In 1999 Mexico contributed about 360 million tons of CO_2 emissions to the global greenhouse problem.[63]

2.49 CFE generates, transmits distributes and sells electric power in Mexico to 19 million customers, equivalent to about 76 million people. By October 2001, CFE had a total of 154 power plants, 35,078 kilometres of transmission lines, and an installed generating capacity slightly over 37,000 MW. Projects with an additional 7,118 MW of new capacity are at different stages of development. Luz y Fuerza del Centro is the second state-owned electric company that generates and distributes electric power in Central Mexico. It has 3,431 kilometres of transmission lines, 53,000 kilometres of distribution lines and a generating capacity of 827 MW. These two companies form the National Electric System, which currently provides electricity to 95 million people, equivalent to about 95 percent of the Mexican population.[64] The remaining 5 percent is rural population living in remote and hardly accessible places. Over 80,000 small and dispersed rural communities of under 100 people each have no access to the grid.

2.50 CFE has been instrumental in applying renewables for rural electrification as mentioned before. CFE installed the only wind farm in Mexico as of this writing,[65] and the single largest wind generator (700 kW), both for pilot purposes. CFE is the executing agency of a World Bank-GEF project that integrates a solar concentrating field into a gas-fired combined cycle power plant.

Renewables and the International Agencies in Mexico

The World Bank

2.51 Three WB-GEF projects are being implemented: A) Construction of a gas-fired combined cycle power plant with capacity between 198 and 242 MW, with a GEF grant

[61] SENER: Balance Nacional de Energía 2000.
[62] Ibid.
[63] CO2 emissions from fuel combustion 1971-1999. IEA-OECD.
[64] SENER: Mexico's Energy Sector. Brochure.
[65] Seven wind generators, 225 kW each, operating since 1997 in the La Ventosa region in south Mexico.

of almost US$50 million to incorporate no less than 25 MWe from solar heat produced by parabolic trough concentrators. As of this writing, CFE has issued a call for bids.[66] B) Electricity production using biogas from sanitary landfills in the city of Monterrey, in northern Mexico. This project titled **"Methane Gas Capture and Landfill Demonstration"**[67] is being executed by the municipal government of Monterrey. Contracts for construction have been awarded to a consortium of private companies. C) Water pumping for small agro-industrial operations and cattle raising are the objectives of the **"Renewable Energy for Agriculture"** or FIRCO project as is commonly known, which has three sources of financing,[68] including a GEF grant of US$8.9 million. The FIRCO project is in its early stages of field implementation with several PV pumps already installed. Small wind powered pumps are also contemplated for future projects.

The UN Development Program

2.52 The following projects are being promoted by the UNDP within the Climate Change Initiative of the GEF: a) "**Plan of action for removing barriers to the full-scale commercial implementation of wind power in Mexico**"[69] is a multi-year project with a programmatic approach to remove barriers to the large scale implementation of wind energy. The project is due for final approval by the GEF Council; b) "S**mall grid-connected photovoltaic systems**s"[70] is already in the GEF pipeline. Its objective is to advance the identification and solution of the main technical and non-technical issues currently affecting the application of photovoltaic technology for electric peak shaving during the summer months in north and northwest Mexico. As of this writing, the project brief is being prepared; c) A third project aims at the use of agricultural residues in rural areas for the on-site generation of electricity, with the additional purpose of avoiding negative environmental impacts caused by such residues. This project is still in the early stages of concept development.

Other Agencies

2.53 The UN Food and Agriculture Organization (FAO). For a number of years the FAO has been supporting activities in Mexico to foster the efficient use of firewood. Possible cooperation within the GEF programs, concerning the application of renewable energies for productive projects in rural areas, is under discussion.

2.54 The North American Commission for Environmental Cooperation (CEC).[71] CEC is exploring the feasibility of applying renewable energy in specific niche markets. With financing from CEC, IIE carried out a pre-feasibility study for a 150 MW wind farm in

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66 Licitaciones Obra Pública. Central Mexicali II. www.compranet.gob.mx

67 Projects. www.worldbank.org

68 Besides the GEF grant for capacity building and partial system subsidy, the FIRCO project operates with funds from the "Programa para el Campo" (Procampo) program of the Mexican Federal Government, plus contributions from the project beneficiaries.

69 Proposed by IIE with support from SENER, the local UNDP office, and the GEF-SEMARNAT liaison office in Mexico City

70 Same as above

71 This body was created within the framework of the North America Free Trade Agreement (NAFTA).

La Ventosa, Oaxaca. The CEC also financed CONAE to study the willingness to pay for green energy among the 100 largest users of electricity in Mexico.

2.55 Bilateral Cooperation. Bilateral development agencies, including the USAID, the German GTZ, and the Japanese JICA, are actively promoting and financially supporting activities to foster the implementation of renewables in Mexico. Other agencies, such as the German bank KfW, the Canadian Office for the Clean Development Mechanism, the Shell Foundation, the Spanish Araucaria Program for the preservation of the biosphere, the Centre for Clean Air Policy and the Texaco-Ovonic joint venture for renewable energy, to name a few, are also involved in the promotion of renewables in Mexico.

Renewables in Other Sectors

Government Entities[72]

2.56 Oaxaca. The state Government (OSG) has taken the lead in developing its vast wind energy resource.[73] International wind technology companies and investors in association with Mexican counterparts are taking action to develop this resource. The OSG is facilitating these initiatives by ironing out critical issues such as land ownership and the local legal framework. Interested companies are being requested not only to establish electricity generating facilities, but also wind technology manufacturing operations. IIE is technically supporting this effort by assessing the wind resource and advancing new initiatives such as the creation of a regional wind energy technology centre.[74] The OSG is also leading the application of photovoltaics and other renewables in rural areas.

2.57 Baja California Sur. The state Government developed the programmatic elements for the application of renewables to promote sustainable development of the fishing communities within the preserve of the biosphere called “El Vizcaíno.”[75] These communities have no access to electricity and other services. Renewable energy projects are being developed with technical support from CFE and IIE.

Capacities Installed

2.58 Mexico is a fairly well developed economy and, as such, already has in place a variety of capabilities that could support the deployment of renewable energy. However, most of these capabilities have to be expanded and updated in the context of renewables.

2.59 In the public sector, human resources and institutions are already available in the traditional fields of energy planning, policy making, regulation and research. New topics

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72 Other states where important renewable energy activities, mainly wind, are taking place include: Hidalgo, Tamaulipas, Nuevo León, Baja California, Aguascalientes, Chihuahua and Quintana Roo.

73 It is estimated that more than 2,000 MW could be generated by wind in only one portion of the Tehuantepec Isthmus, where strong and sustained winds are available during most part of the year.

74 These activities are part of the UNDP-GEF project proposal mentioned earlier.

75 This is a vast desert region in the Peninsula of Baja California with no access to the conventional supply of fuels and electricity. The region is endowed with abundant natural fishing resources and breathtaking beauty that could be sustainably developed by means of renewable energy.

such as the Clean Development Mechanism and the carbon economy need to be incorporated.

2.60 In the private sector, large numbers of energy consulting and engineering companies are also available, but with very limited knowledge about renewable energy technologies and the opportunities in the renewable energy business. Local capabilities for commercial project identification, development and implementation need to be developed. Analyses show that most renewable energy technologies could be locally manufactured by Mexican companies, using the already available industrial infrastructure. Over 200 Mexican companies have been identified[76],that could manufacture and supply parts and components for wind generators.

2.61 The banking system has mature and experienced institutions, but with few or no mechanisms to financing renewable energy investments.[77] First floor financing mechanisms need to be developed to support the massive introduction of these technologies. BANOBRAS[78] is developing criteria to finance municipal renewable energy projects.

2.62 Academic and research institutions are either well established or freshly entering in the field of renewable energy. Work being done in most of these institutions is first class, but mostly with an academic orientation. There is need to complement these capabilities by developing institutions and R&D groups closely linked to industry and with a strong vocation for applied research and product development.

Barriers to the Implementation of Renewables in Mexico

2.63 Barriers of different kind have to be removed to facilitate the large-scale introduction of renewable energy in Mexico.[79]

Legal, Institutional and Policy Issues

2.64 The current legal framework in Mexico does not favour the commercial expansion of renewable energy for power production (hydropower and geothermal notwithstanding). Specific articles in the Electricity Law mandate CFE to buy the cheapest electricity available in the market, and to give preference to firm instead of intermittent capacity for new power installations (to ensure reliability and stability of the electric system, since the precise effects of intermittent sources on the grid have not been

[76] Mejía Neri F. et al.: Base de datos de Empresas e Instituciones que podrían integrar la Plataforma de una Industria Eoloeléctrica Mexicana. IIE/01/14/10819/I003/A4/F/V2. Diciembre1999. One Mexican company is already manufacturing and exporting large state of the art electrical generators for wind machines assembled abroad

[77] Commercial financing is readily available in this country for a number of durable goods (housing, cars, domestic appliances, and so forth), but no lines of credit can be easily found, for instance, for solar water heaters, photovoltaics and other renewable energy technologies at the consumer level or for project developers.

[78] The national bank to finance municipal infrastructure.

[79] Jorge M. Huacuz: *RE in Mexico: Barriers and Strategies.* Renewable Energy Focus. The International Renewable Energy Magazine, pp.18-19 Jan/Feb 2001.

adequately explored). The latter limitation has been relaxed with the new contract forms for interconnection and transmission of intermittent sources of energy.

2.65 Renewables lend themselves to the introduction of new concepts such as distributed power generation. Introduction of such new concepts within a centrally structured electric utility may face crucial barriers, including the perceived notion of losing political control of the electricity business and the fear of third parties affecting the integrity, safety and quality of the grid. Mental barriers, such as opposing the change for the change itself, could also be met. The availability of fossil fuels and large scale renewables such as hydropower and geothermal puts additional question marks on the wisdom of locally developing new renewable energy sources.

2.66 Facilitation of project identification, permitting, evaluation, certification and technical support, requires effective institutions, not currently available in sufficient quantities and with enough knowledge of the subject in Mexico.

Financial Limitations

2.67 Due to budgetary constraints it is unlikely that the GOM will finance capital-intensive renewable energy projects. Thus, in order for commercial projects of this type to grow successfully, diverse funding and project supervision capacities—both national and international—must be provided to create confidence in the renewable power market. Experience in commercial renewable power development does not exist in Mexico, and hence, the potential financial network needs to be identified and strengthened. The incumbent business opportunities and risks associated with renewable power development must also be identified to know the size and risk of this new energy technology market. Regulatory barriers, as outlined above, turn into financial constraints by perpetuating perceived high investment risks associated with elevated project preparation costs, without any guarantee that the project can be implemented within a reasonable time frame. There is a critical need to cultivate a confident and stable business environment that provides appropriate guarantees and certainty to international and national financial institutions on renewable energy project viability and profitability. International experience shows that success is contingent upon private sector involvement. Experience also shows that government participation in the early stages of market development, while vital to overall success of renewable energy deployment, should concentrate on providing adequate institutional support and setting long-term goals. Removal of subsidies now applied to conventional energy is also critical to increase the economic viability of renewable energy projects.

Regulatory Issues

2.68 Much still remains to be done in Mexico to tackle regulatory issues negatively affecting the introduction of renewables. Examples include needed mandatory measures to use solar water heaters in substitution/backup of gas-fired water heaters, rules for awarding capacity credits to intermittent power sources, schemes for the internalization of environmental, social and other costs associated with the conventional generation of electricity, tougher environmental measures, and so on.

Incremental Costs

2.69 One of the main barriers to the widespread use of renewables is their perceived higher costs. The higher capital costs involved usually overshadow their life-cycle costs, which are often lower than for other alternatives, but difficult to perceive. The lack of accounting for both the environmental and social costs associated with the combustion of fossil fuels works against renewables when comparing alternatives. Finally, the substantial and continuing hidden subsidies to fossil fuel technologies, which are estimated at over US$250–300 billion a year worldwide, make any comparison inequitable.[80]

2.70 The average price for electricity during 2000 in Mexico was estimated at 6.0 US¢/kWh. This is close to the payback price required for some renewable projects, such as wind and biogas from sanitary landfills, to reach economic feasibility. However, most renewables do not compete with conventional power on the basis of conventional investment and/or generation costs alone. This is further complicated by the fact that payback prices usually depend on location, generation voltage, time of day, and other factors difficult to obtain by the financial analyst under common circumstances. Furthermore, availability of good renewable energy resources does not often coincide in location or time of day with the most favourable conditions to get a cost-effective buy-back price for electricity. No credits for capacity are currently granted for intermittent power production facilities in Mexico, and CFE is under no obligation to purchase any renewable energy production within its energy mix. The regulatory framework is such that power regulations are issued by the Regulatory Energy Commission, while payback prices for electricity are based on consumer rates determined by the Secretariat of Economy (formerly SECOFI). Hence, in the commercial environment, CFE cannot unilaterally grant exceptions or provide incentives for renewable energy, unless the legal framework is modified or alternative attractive market-based solutions are identified.

Political

2.71 The current high political support for renewables on behalf of the federal administration and some state governments is unprecedented in Mexico. This is best exemplified by the Energy Program 2001–2006. However, regulatory and institutional changes to level the playing field cannot go beyond the limits set by the current Law. Further legal and regulatory changes will require approval of Congress, where some political barriers may need to be removed.[81] Land ownership issues, for instance for the implementation of wind farms or energy plantations, may represent important political barriers to be dealt with.

Market Structure and Human Resources

2.72 Much needs to be done to ensure a healthy domestic industry that can supply renewable energy technologies on a competitive commercial basis. Broader exchange and closer practical cooperation must be fostered between the Mexican manufacturing

[80] More than Power. International Energy Agency. Forthcoming.

[81] As of this writing, the Green Ecologist Party of Mexico submitted an initiative in the Senate to modify the Law to favour the use of non-polluting energy sources.

industry on one side, and the Mexican R&D and academic institutions involved in assimilating and developing renewable energy technology on the other, in order to consolidate national capacities.

2.73 There is a significant lack of personnel trained in developing and implementing renewable energy projects. The same is true about personnel with experience in operating and maintaining large renewable energy systems. Training programs and activities to solve this problem are under way, but they are still very limited. The considerable theoretical and empirical knowledge that exists in Mexico's academic and research institutions need be transformed into practical applications and national training programs. Important but limited efforts have been made in this respect.[82] Such efforts need to be expanded and replicated in other parts of the country. This is fully consistent with STAP recommendations on capacity building in the alternative energy market, and has been documented as a best practice by the Centre for Global Change.

Technical and Information Barriers

2.74 Activities are under way to compile, screen and organize available data into the geographical information system SIGER. Availability of good quality information is very limited, and further actions need to be carried to upgrade the databases, to improve prediction models and to expand the geographical coverage of monitoring stations.

2.75 On the technical side, international standards, technical specifications, and recommended engineering practices need to be assimilated by local organizations to strengthen the local technical capacity for further development. Lessons from international demonstration projects need to be incorporated and adjusted to local needs, while local pilot and demonstration projects are needed in several areas to build local capacity. There is a generalized lack of knowledge about the potential market for renewable energy in Mexico and the economic benefits that could derive thereof. Beyond CONAE's efforts at the national level in this regard, outreach initiatives are still limited, basically by the lack of funding necessary to launch promotional campaigns and awareness building activities. Adequate mechanisms and comprehensive programs are required to collect and distribute objective and updated information about the national and international experience on renewable energy, including the key factors for success or failure of renewable energy projects.

[82] Worth mentioning are the topical refresher courses offered regularly by ANES; the Master's Degree program on solar energy of CIE-UNAM; the Engineering Diploma Degree on wind power, recently instrumented by IIE with a consortium of engineering colleges in south Mexico, supported by the Oaxaca State Government. Foreign aid agencies have also made a significant effort to back the development of human resources in Mexico, either by financing the work of Mexican students abroad, or by offering training courses in Mexico, on their own or in association with the programs of the Mexican institutions.

Interagency Coordination

To fully realise the benefits from the large-scale implementation of renewables, an effective coordination among different agencies in the three levels of governments, and among other stakeholders, is necessary. Lack of interagency coordination represents an important barrier towards a more dynamic renewable energy activity in Mexico.

Strategies to Move Forward

2.76 The large-scale implementation of renewables in Mexico could be achieved with the following strategies:

- An enabling policy and regulatory framework to level the playing field, so that mature renewable energy technologies can compete on equal grounds with other alternatives;
- Adequate and effective institutional and technical settings to support the deployment process;
- ad hoc financing mechanisms to help advance precommercial renewable energy technologies into the market;
- Concerted action plans to coordinate energy issues with other government sectors, so that renewables have opportunities for participation in infrastructure projects equal to conventional technologies;
- Appropriate mechanisms to facilitate a growing participation of the private and social sectors in the development of energy projects;
- An effective coordination among all national and international stakeholders interested in the promotion of renewable energy in Mexico.

2.77 Operational mechanisms and considerations for each of these elements are discussed below.

Strategy 1: Enabling Policy

2.78 An important policy baseline has already been established in objective 4 of the Energy Program 2001–2006, which calls for the increased use of renewable energy. The following elements and actions are considered therein as necessary to meet this objective[83]:

- Energy tariffs and prices that reflect the costs associated with environmental impacts, on top of those from generation, transmission, storage and distribution;
- Medium and long-term programs (national and regional) for energy conservation and the use of renewable energy, according to the structural changes of the energy sector;
- A set of norms and mechanisms for the promotion of cogeneration and renewable energy;

[83] SENER: Programa Sectorial de Energía 2001-2006, septiembre 2001.

- A national system for the evaluation, registration and diffusion of renewable energy resources;
- Financial support mechanisms for energy conservation and renewable energy projects;
- Financial resources for research activities on energy conservation and renewable energy;
- An active and permanent bilateral and multilateral link of Mexican institutions with similar international organisms in other countries.

2.79 Other elements, such as an adequate legal structure for the protection of consumers against faulty and low quality renewable energy goods and services, and a clear definition of targets for the introduction of zero emissions regulations applicable to motor vehicles, might be necessary.

Strategy 2: Institutional Setting

2.80 Already existing infrastructure will be complemented with new investments—human, technical and physical—to assure high operational standards of the renewable energy programs to be established. The institutional framework will focus on developing and implementing operational rules, technical and nontechnical, to create a healthy renewable energy market. The following actions are contemplated:

Centre for Energy Information and Policy.

2.81 SENER has identified a need to improve the national capacity for long-term planning and the research capacity to carry out prospective studies on energy and the environment.[84] There is also a permanent need to create and operate large databases, and to support its use by third parties. To build these capacities, the creation within SENER of the Centre for Energy Information and Policy (CEIP) is being proposed.[85] CEIP will focus on the following areas: a) long-term modelling of the interrelated issues on energy, the environment and the economy[86]; b) research on the effects of the energy sector on climate change and acid rain[87]; and c) development of the most viable scenarios for the penetration of renewables and to assess its impacts on the economy. CEIP will establish and operate as the hub for thematic networks among the research centers of the energy sector and the universities, to increase their strength and create synergy. A national energy information system is currently being set up by SENER with the support of the companies, commissions, and institutes of the sector, as a first step in this direction.

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84 Some of these activities are already underway at research institutes of the energy sector and at several universities, but with limited coordination. SENER itself is doing part of this work, but with some shortcomings, including the limited expertise and time availability of its personnel.

85 Project proposal: Center for Energy Information and Policy. Internal document, SENER.

86 Some work is already in progress with support from the World Bank and the International Atomic Energy Agency.

87 This work is intended to devise market mechanisms to reduce the emissions of environmentally damaging emissions, in the context of the clean development mechanism of the UNFCCC and other international instruments.

Operational Framework for CDM

2.82 The GOM has decided to play an active role in the worldwide implementation of the Clean Development Mechanism (CDM), as defined in the Bonn and Marrakech Agreements. The institutional setting and the operational framework for project approval, monitoring, verification, validation, and eventual certification will be developed. The National Authority for project approval is being defined. Guidelines for project development and methodologies for establishing the Base Line, and for project approval, monitoring and verification, will be developed.

Technical Support Infrastructure

2.83 A cadre of world-class scientists and engineers, with an average experience of over 15 years in the development and implementation of renewables, is already available at IIE. From the quantitative point of view, this capacity will not be enough to support the full process of sustainable market deployment. Therefore, these capabilities will have to be cloned and multiplied as necessary. Plans to upgrade the Non-Conventional Energy Unit at IIE to become a Center of Excellence for renewables are being implemented. Several new technology-specific regional centres (RTCs) will be created, with support from the National Council for Science and Technology (CONACYT). These RTCs will operate in close networks with local universities and engineering schools, and will basically serve the needs of industry. They will have a strong focus on capacity building, including technology development and technology transfer. Among other tasks, the RTCs will train project developers and implementing agents. Permanent programs for training and certification of human resources on the subject of renewables will be implemented. Other important tasks of the RTCs include: Development of guidelines and best practices for project development and implementation; adopting and/or adapting technical norms, standards and specifications; development of engineering tools, such as spreadsheets, databases and handbooks; technology testing and characterization; measurement and characterization of renewable energy resources; and support to develop precommercial technologies of interest to local industry. Once in full operation, the RTCs will have to become at least partially self-financed from the fees paid by industry for the goods and services received. The network of RTCs will be coordinated by IIE's Center of Excellence, which will assure high quality standards and compliance with international best practices. Plans for implementing the Regional Centre for Wind Technology in the windy state of Oaxaca are already included in the UNDP-GEF project proposal mentioned earlier.

Strategy 3: Financing Mechanisms

2.84 The current Law in Mexico rules out the possibility of directly adopting many of the financing mechanisms that have proven effective in supporting the penetration of renewables in other countries. Hence, a relatively short-life instrument with the following elements to transform the market is being proposed:

- A Green Fund, as the main vehicle to remove financial barriers for electricity projects;

- Long-term power purchase contracts, to give financial security to the investments;
- Fiscal, contractual and economic incentives to foster market entrance of precommercial projects.

The Green Fund.

2.85 Objective: To provide supplemental financing for the purchase of electricity from renewable energy.

2.86 Concept: Conceptually, the Fund will operate as follows[88]: Independent power producers of electricity from renewables will sign long-term (to be determined) power purchase contracts with CFE, subject to the economic terms and conditions established in the current Law. CFE will sell that electricity (green electricity) to consumers at the established tariff for the dispatching period. Consumers of green electricity will pay a premium fee (to be determined) over the established tariff. This premium fee will go to the Green Fund. The Green Fund, in turn, will sign medium-term (to be determined) contracts with the producers of green electricity, awarding them an incentive to help cover incremental costs and leave margin for profit.

2.87 Operational Rules; Operational rules for the Green Fund will be developed as part of the project proposed here. A few indicative ideas follow: Clear policy objectives and flexible operational criteria are required; only new projects are to be considered; large scale hydro (size to be determined) and high temperature geothermal are to be excluded; established shares for other renewables incentives are to be awarded in terms of the maturity of the participating industry; the Green Fund cannot be used to provide capital for plant construction; awards are to be based on plant performance, to be limited in time after plants come on line, and to be gradually phased out in accordance with the economics of the project. Plant size is to be limited to avoid depleting the Fund with only a few large projects. Competitive forces are to be used to make subsidies decline over time. Projects to be chosen by competitive bidding based on the lowest requirements for incentives. A period of time to established for projects to be built, after which defaulting projects will lose any right to the incentive. Defaulting low bidders to be severely penalized. Long-term power purchase contracts will be awarded to winning projects. Close cooperation between bidders and CFE is required. The Green Fund will look for sustainable results.

2.88 Size of the Green Fund. A minimum revolving fund of US$120 million will be required to facilitate projects with a total capacity of 1,000 MW over a period of 5 years. If sustained, the Fund could support implementation of an additional 4,000 MW in the next 5–7 years

2.89 Fund Replenishment. Several mechanisms to replenish the Green Fund are under consideration. They include the proposed premium fee for green electricity, carbon and green certificates, voluntary contributions, bilateral and multilateral financial assistance, and other international financing instruments, such as the GEF, the Prototype Carbon

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88 SENER: El cambio climático y las implicaciones en el sector energía. Agosto 2001.

Fund, and those to derive from the Clean Development Mechanism. Willingness to pay for green electricity in Mexico has been explored,[89] with 94 percent of the 100 largest industrial electricity consumers expressing their willingness to buy green electricity, for which 54 percent would pay a surcharge of up to 11 percent of the regular tariff. Further studies will be carried out as part of this project to define in more clear terms the necessary mix of funds and strategies to support the operation of the Green Fund. NAFIN and BANOBRAS could establish special funds, earmarked for environmental and renewable energy projects,[90] to complement the Green Fund.

2.90 Duration and Exit Strategy. The creation of a market for renewables energy in Mexico could take more than two decades. The anticipated duration of the Green Fund would be 20 years. Renewable energy technologies reaching economic competitiveness would be gradually excluded from the benefits of the Fund. Green prices for the electricity from such technologies would also gradually diminish. At the end of the Green Fund lifetime, carbon credits and other financial incentives deriving from the Clean Development Mechanism and other bilateral and multilateral instruments would be treated according to the internationally agreed rules and time tables for such mechanisms.

2.91 Potential Show Stoppers. The strategy to implement the Green Fund could fail for one or several of the following reasons: a drastic change in policy towards renewable energy; lack of sufficient funds to constitute the Fund; lack of interest from industry to participate in the process; mismanagement of the Fund.

2.92 A number of issues will have to be resolved before the Green Fund is fully operational. International experience with similar mechanisms[91] will have to be reviewed. The Fund will have to be tailored to the particular conditions of the different market sectors where renewables will be applied, and it will have to be tested in a number of pilot projects.

2.93 Initiatives will be promoted to create awareness among commercial banks and financing entities, so that lines of credit are open to finance small industries and the general public towards the purchase of renewable energy goods and services. Credits of this sort could play an important role in opening the retail market for renewable energy technology.

Strategy 4: Concerted Plans of Action

2.94 The power sector offers the best opportunities for the massive application of renewable energy, but it is not the only ripe field for applying renewables in Mexico. Other sectors also offer good opportunities, and a concerted Plan of Action will be negotiated, so that renewable energy matters are collectively addressed among the main stakeholders from the different sectors. This will allow the creation of synergies and will

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89 CONAE. Aspectos relevantes de la encuesta realizada por Gallup sobre la demanda de energía verde en México

90 Projects such as municipal self-generation of electricity by using biogas from sanitary landfills, and others, could soon find sources of soft money within Mexico.

91 Ted Kennedy: Options for Supporting Clean Energy Investments. Reunión-Diálogo para Incentivar la Inversión en Energías Renovables en México. SENER, CONAE, CCAP, Colmex. February 2002.

create equal opportunities for the participation of renewables in the projects of the different sectors.

Renewable Energy and the Rural Sector

2.95 During the first years of the project proposed here a strong rural electrification activity is expected to take place. It is also anticipated that, complementary to the program for native communities mentioned earlier, the FIRCO project will step up its level of activity and will increase its geographical coverage. Both programs may eventually merge into each other to constitute the backbone for the application of renewables in rural areas. Private activities in rural areas are expected to grow in a business as usual mode, motivated by the higher costs of other conventional alternatives and the economic benefits that could derive from the new supporting instruments. Environmental reasons point to the need for a sustained program to improve the use of firewood in rural communities, by introducing advanced technology such as biomass gasifiers, solar cookers and efficient stoves. Programs for using forest residues from the timber industry and energy plantations for the local production of electricity in substitution of diesel fuel will be promoted.

Renewable Energy and the Municipal Sector

2.96 A program to foster the use of renewable energy for self-generation of electricity by municipalities will be implemented in coordination with state governments and BANOBRAS. This program will also be coordinated with COMIA, and will include the following activities: a) assessment of the impacts from electric tariffs on the economics of municipalities; b) identification and characterization of renewable energy resources available to municipalities; c) formulation of a portfolio of financially viable renewable energy projects for self-generation of electricity at the municipal level; d) promotion of this project portfolio among potential investors; e) implementation of strategies to remove institutional barriers impeding the implementation of these projects; f) leverage of shared financing for the implementation of a few pilot/demonstration projects (at least one each of solar, wind, biomass and micro-hydro) with innovative components in the nontechnical aspects of project implementation; g) evaluation of the pilot/demonstration projects and development and diffusion of lessons learned and best practices.

Renewable Energy and the Water Sector

2.97 A program under the title “Clean Water with Clean Energy” will be implemented in close coordination with SEMARNAT’s National Water Commission. The main objective of this program will be to foster the use of renewables in the operations of the Water Sector. Here, the overall potential for the self-supply of electricity will be assessed, and a number of pilot/demonstration projects will be identified and developed. Barriers specific to the participation of private capital for the supply of electricity in this sector will be identified, and policy schemes compatible with the overall policy for the promotion of renewables will be developed and implemented.

Renewable Energy and the Environment

2.98 SENER and SEMARNAT are developing policy instruments and operational mechanisms for implementing a carbon market in Mexico. This activity will be expanded and supported by the present project.

Strategy 5: Participation of the Private and Social Sectors

2.99 Extensive consultations will be carried out on program design with key organizations of the private and social sectors. Participation of private investors and the manufacturing industry will be intensively promoted. For this purpose, a portfolio of technically and economically viable renewable energy projects of different sorts will be prepared and publicized. A concerted effort will be carried out to expand and improve the quality of the database on renewable energy resources for Mexico. This will include: a) fine-tuning the prediction methods for solar energy and wind power; b) expanding the geographical coverage of reference measuring stations for these two resources; c) assessing the small hydroelectric potential using analytical methods and integrating a portfolio of potential sites for developing commercial projects; d) Compiling, organizing and analyzing available information on the various biomass sources, in order to assess the overall potential and identify promising projects by source; e) developing quality standards and methodological procedures to be applied in future and ongoing activities for resource assessment; f) laying the methodological foundation to assess the potential for ocean energy, in particular small tidal power. Work will be done to reach a consensus among organizations interested in assessing renewable energy resources in Mexico, so that individual activities adhere to standard protocols and international practice. The geographical information system SIGER will be used as the national clearing house for information on renewable energy resources, technology markets and project opportunities. For this purpose, standard practices for resource assessment and reporting will be established, and SIGER will be made available on the Internet for easy access by all interested parties. Information on policy and regulations will be also made available on a Web site. A well-structured program to develop local industries to produce renewable energy goods and services will be created. A practical scheme will be implemented to introduce energy crops as substitutes for traditional firewood for both domestic and agro-industrial uses, thus preventing further deforestation and helping to reclaim already deforested land. An appropriate legal and regulatory framework will be sought to foster the creation and successful development of rural energy services companies within the framework of the current Law. A mechanism will be created to foster the use by industry of environmentally friendly technology.

Strategy 6: Coordination among Stakeholders

2.100 Government and nongovernment organizations, international and bilateral agencies, financing institutions, and industrial agents promoting renewable energy activities in Mexico will be invited to join forces within the framework of the present project, to achieve the national goal of a mature market for renewable energy and the corresponding decrease in GHG emissions. It is expected that energy-related GEF-supported projects in Mexico, both those in progress and new approvals, will lead this effort of coordination. Coordination is essential to avoid duplicating efforts and repeating mistakes. It is also essential to create synergy among the different projects and to share lessons learned. Coordination will also facilitate implementing a comprehensive national program to promote renewable energy among the general public and to create awareness on energy-related environmental issues.

Expected outcomes: The First Three Years

2.101 The following results are expected in the first three years of project implementation:

Under Strategy 1, Enabling Policy

- Adequate public policies to remove the existing barriers in the energy market, to foster the large-scale implementation of renewable energy;
- Well-supported proposals to amend the existing regulatory framework of the power sector to facilitate the use of renewables.
- Advanced proposals to establish specific regulations in other sectors, such as mandatory use of solar water heaters in new housing and the use of PV in public buildings.

Under Strategy 2, Institutional Setting

- The Center for Energy Information and Policy will be created
- The operational framework for the Clean Development Mechanism will be established
- The Non-Conventional Energy Unit of IIE will be upgraded to become a center of excellence for renewable energy technology
- The first three Regional Centers for Renewable Energy Technology (wind, solar and small hydro) will be created
- A yearly program to foster the generation of electricity by means of renewable energy will be developed
- A national program for renewable energy technology research and development will be jointly established with the National Council for Science and Technology (CONACYT).
- Current activities to develop human resources specialised in the use of renewable energy will be reinforced. Implementation of diploma courses, workshops, seminars and graduate programs in the field of renewable energy will be fostered.

Under Strategy 3, Financing Mechanisms

- The proposed Green Fund will be designed and implemented. The Fund’s objectives will be defined, policies and rules for operation will be established, eligibility criteria to benefit from the Fund will be developed, a host institution for the Fund will be identified and properly staffed, and the operation of the Fund will be launched.

- Several commercial projects will be piloted as part of the operational tests of the Fund
- The availability of low-cost financial resources to be applicable to renewable energy programs, projects and activities will be increased
- A national fund for the promotion of renewable energy will be created
- Funds specifically to support R&D programs to develop renewable energy technologies will be allocated.

Under Strategy 4, Concerted Plan of Action

2.102 National and regional programs to apply renewable energies in different sectors of the economy will be implemented and operated, including the following:

- Renewable energy in the Power Sector
- Energy services for rural communities
- Municipal uses of renewable energy
- Clean Water with Clean Energy
- Industrial applications of renewable energy.

Under Strategy 5, Participation of Private and Social Sectors

- Permanent programs for the promotion of renewable energy will be launched
- A portfolio of potentially commercial projects will be created and continuously updated
- Development of capacities among energy users will be supported, so they will be able to design and instrument renewable energy programs
- A national program to register, integrate and process information on the potential for application of renewable energy will be implemented. Results will be made available on the Internet
- A program on biofuels and rural energy will be launched
- Teaching of renewable energy topics in a larger number of institutions will be fostered.

Under Strategy 6, Coordination Among Stakeholders

- Regular meetings will be held with other entities working in the field of renewable energy in Mexico, to promote the exchange of ideas and experience
- Mexico’s international links will be expanded and strengthened in order to take advantage of available low-cost financing, and exchange experiences and technical resources

- The transfer of experience and technology from other countries will be strengthened in order to promote technology research and development programs in the field.

Project Monitoring, Evaluation and Impact Assessment

2.103 A permanent activity to follow up the progress of this project will be implemented. At the end of the first three years the whole project will be reviewed. Progress will be measured according to pre-established performance indicators. Indicative triggers for subsequent phases will include:

- The Green Fund already set up and operational
- Several (to be defined) pilot projects implemented within the Green Fund and lessons documented
- A mechanism for carbon trading well defined and operational
- The creation of a facilitating regulatory framework in progress
- A reasonable level (to be defined) of social sector and private sector participation
- An improved database on Mexico's renewable energy resources available on the Web
- A portfolio of possible renewable energy projects accessible on the Web
- Improved technical/institutional infrastructure.

Implementing Costs (Thousands US$)

Table 2.1: Total Cost and Financing[92]

GEF	
Barrier removal and capacity building grants	45,000
Financial mechanisms (Green Fund)	90,000
PDF	1,500
Subtotal	**121,500**
Government of Mexico	332,500
Subtotal	**332,500**
Private Companies	
Equity for 5,000 MWe plus non-electric projects	2,514,150
Studies	5,000
Industrial infrastructure development	200,000
Subtotal	**2,734,150**
International Financing	
Commercial loans for up-front investment	5,866,350
Complementary financial mechanisms (Green Fund)	30,000
Sub-total	**5,896,350**
TOTAL PROJECT (with PDF)	**9,084,500**

92 Cost estimates made for the high penetration scenario.

Table 2.2: Summarized Breakdown Cost and Financing

Phase 1 (first three years)

GEF	
Institutional strengthening	4,600
IIE's Center of Excellence (infrastructure upgrading)	9,000
Regional Renewable Technology Centers (creation)	17,000
International consulting	3,400
Green Fund	40,000
Government of Mexico	
Estimated incurred costs[93]	3,750
Regional Renewable Technology Centres (operation)	6,000
Rural energy projects	180,000
Private Companies	
Equity for 600 MW plus nonelectric projects	292,500
Studies	600
Industrial infrastructure	70,000
International Financing	
Commercial loans	682,500
Total Phase 1	**1,309,350**

Phase 2

GEF	
Institutional strengthening	2,400
Regional Renewable Technology Centers (creation)	6,000
International consulting	2,600
Green Fund	50,000
Government of Mexico	
Estimated incurred costs	8,750
Regional Renewable Technology Centers (operation)	14,000
Rural energy projects	120,000
Private Companies	
Equity for 4,400 MW plus nonelectric projects	2,221,650
Studies	4,400
Industrial infrastructure	130,000
International Financing	
Commercial loans	5,183,850
Green Fund	30,000
Total Phase 2	**7,773,650**
TOTAL PROJECT	**9,083,000**

Implementing Structure

2.104 This project will be executed by SENER, through CRE, CONAE and IIE. Implementation of the project will be guided by a Steering Committee chaired by SENER and integrated by the following government bodies and private organizations: the Ministry for the Environment and Natural Resources, SEMARNAT; the Ministry for the Economy, SE; the Ministry for Finance and the Budget, HACIENDA; the National Council for Science and Technology, CONACYT; the National Chamber of Electrical Equipment Manufacturers, CANAME; the Federal Commission of Electricity, CFE; the

93 Yearly estimates are as follows: SENER (100), CONAE (100), IIE (1,000), CRE (50)

National Energy Savings Commission, CONAE; the Electrical Research Institute, IIE; and the National Solar Energy Society, ANES. The Steering Committee will be supported by technical committees as necessary, with representatives from the Steering Committee member institutions and other organizations which will deal with the technical and operational aspects of the project.

Regional Impact

2.105 This project is anticipated to have an important regional impact in Latin America for several reasons. Mexico plays a leading role in the concert of these nations. In particular, the so-called **"Plan Puebla Panamá"** launched by Mexico is a political instrument already available, which will facilitate sharing experience and supporting similar activities in the Central American countries. Once developed, Mexican renewable energy industries will seek to expand their operations to other Latin American countries.[94] For idiosyncratic and language reasons, Mexico is a place many professionals from further south choose for advanced training and education in energy matters, electricity in particular.

Strategic Partnership

2.106 The GOM has decided to submit this project proposal to the WB-GEF Strategic Partnership Program (WBGEF SPP) in order to benefit from the extensive experience these institutions have gained by facilitating the implementation of renewable energy programs and projects in many countries over the past 10 years. In particular, the GOM seeks technical and financial support from the WBGEFSPP in the areas of capacity building, creation of new institutions and financing services, development of market transformation initiatives, and development of strategies for the participation of the private sector. Support is also sought to improve the renewable energy resource database and to jointly coordinate and oversee development of the whole project.

[94] This is already happening with balance of system components for solar home systems.

3

A Portfolio Approach to Energy Planning in Mexico

3.1 Least-cost approaches have been the mainstay of electricity planning in most Western countries for at least a half century. The underlying idea is that by adding "least-cost" incremental capacities, planners will maintain a minimum cost generating system. Least cost probably worked sufficiently well in a previous technological era, marked by relative certainty, low rates of technological progress, homogeneous generating alternatives and stable energy prices.[95] Today's electricity planner, by contrast, faces a broadly diverse range of technological and institutional options for generating electricity and a future that is highly dynamic, complex, and uncertain. In such an environment, attempting to identify long-lived "least-cost" alternatives is nearly impossible. Clearly, more powerful techniques are required if we are to develop robust generating strategies that remain economical under a variety of possible future outcomes.[96]

3.2 Financial investors are used to dealing with uncertainty. They have learned that a *portfolio* of assets provides the best means of hedging possible future outcomes. Investors would not conceive of investing all their funds in a single stock on the basis of 30-year forecasts of market conditions and stock performance. Yet this is what least-cost procedures imply. Given the rapidly changing environment, it makes sense to shift our energy policy from its current emphasis of evaluating alternative *technologies*, to evaluating alternative generating *portfolios* and *strategies*.

3.3 Portfolio theory, an established part of modern finance theory, is based on the pioneering work of Nobel Laureate Harry Markowitz nearly 50 years ago. Portfolio theory has been applied to various aspects of capital budgeting and project valuation,[97] as

95 Awerbuch, S. "Market-Based IRP: It's Easy!" *Electricity Journal*, Vol. 8, No. 3 (April), 1995, 50-67;

96 Awerbuch, S. "Getting It Right: The Real Cost Impacts of a Renewable Portfolio Standard," *Public Utilities Fortnightly*, February 15, 2000.

97 See Neil Seitz and Mitch Ellison, *Capital Budgeting and Long-Term Financing Decisions*, Dryden Press, 1995.

well as to valuing fossil fuel mixes and offshore oil leases.[98] Recently, the approach was used to value generating alternatives and energy diversity and security objectives.[99]

Applying Portfolio Theory to Renewables Valuation and Energy Security Issues

3.4 In Europe and the U.S. policy makers are considering or have already implemented renewables targets or portfolio standards. Underlying these targets is the widespread belief that their adoption will *increase* overall generation costs since renewables "cost more" on a stand-alone basis. However, portfolio-based analyses for the U.S. indicate that adding PV, wind and other fixed-cost renewable technologies (RETs) to a fossil generating portfolio serves to *lower* overall generating cost and risk, even though these alternatives may cost more on a stand-alone basis.[100] This counter-intuitive result stems from the *portfolio effect*,[101] which, in part, implies that all efficient (i.e. optimal) generating portfolios must contain some portion of fixed-cost renewable generation.

3.5 More recently, the present authors evaluated the EU renewables targets and energy security objectives[102] by comparing the risk-return properties of EU generating mixes to a set of optimal portfolios that minimize risk at any given overall generating cost level.[103] The results indicate that projected EU generating mixes are suboptimal in the sense that portfolios with lower cost and risk can be developed by including greater shares of wind or other fixed-cost renewables and by adjusting the conventional mix. This reduces cost while enhancing energy security.

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98 Bar-Lev, D. and S. Katz, "A Portfolio Approach to Fossil Fuel Procurement in the Electric Utility Industry," *Journal of Finance*, 31(3) June, 1976, 933-47; Helfat Constance E., *Investment Choices in Industry.* Cambridge (U.S.) MIT Press, 1988.

99 Awerbuch S. and Martin Berger, *Energy Security and Diversity in the EU:A Mean-Variance Portfolio Approach*, IEA Report Number EET/2003/03, Paris: February 2003; http://library.iea.org/dbtw-wpd/textbase/papers/2003/port.pdf; Berger, Martin, *Portfolio Analysis of EU Electricity Generating Mixes and Its Implications for Renewables*, Ph.D. Dissertation, Technischen Universität Wien, Vienna, March 2003. Recent application of portfolio optimization to electricity planning can be found in: S. Awerbuch, J. Jansen and T. Drennen, *The Cost of Geothermal Energy in the Western US Region: A Portfolio-Based Approach*, Sandia National Labs, SAND2005-5173, (September) 2005, www.awerbuch.com; Awerbuch, S. "Portfolio-Based Electricity Generation Planning: Policy Implications for Renewables and Energy Security," *Mitigation and Adaptation Strategies for Global Change*, 2005 Kluwer, In-press.

100 S. Awerbuch, "New Economic Cost Perspectives For Valuing Solar Technologies," in, Karl W. Böer (Editor), *Advances in Solar Energy*, Vol. 10, Boulder: American Solar Energy Society, 1995, and "Getting It Right: The Real Cost Impacts of a Renewables Portfolio Standard," *Public Utilities Fortnightly*, February 15, 2000.

101 See: Richard A. Brealey and Stewart C. Myers, *Principles of Corporate Finance*, any edition, McGraw Hill, or any other finance text.

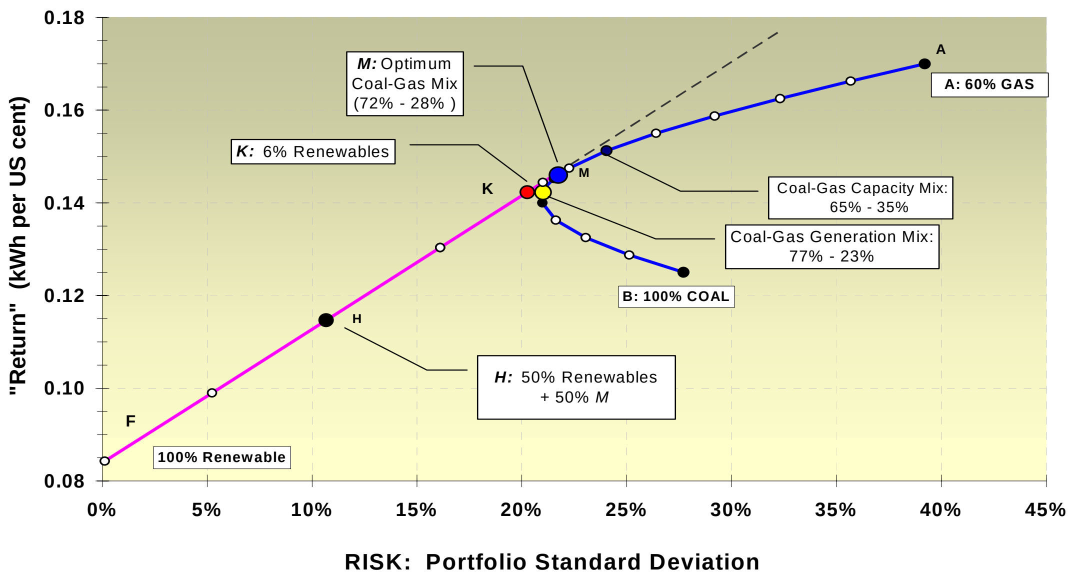
102 European Communities, Green Paper: Towards a European strategy for the security of energy supply, Brussels, 2001.

103 S. Awerbuch and M. Berger, 2003 op. cit. and Berger 2003 op. cit.

Figure 3.1: Adding 12 cent/kwh Renewable to U.S. Generating mix reduces Cost and Risk

Risk and "Return" for Three-Technology US Generating Portfolio

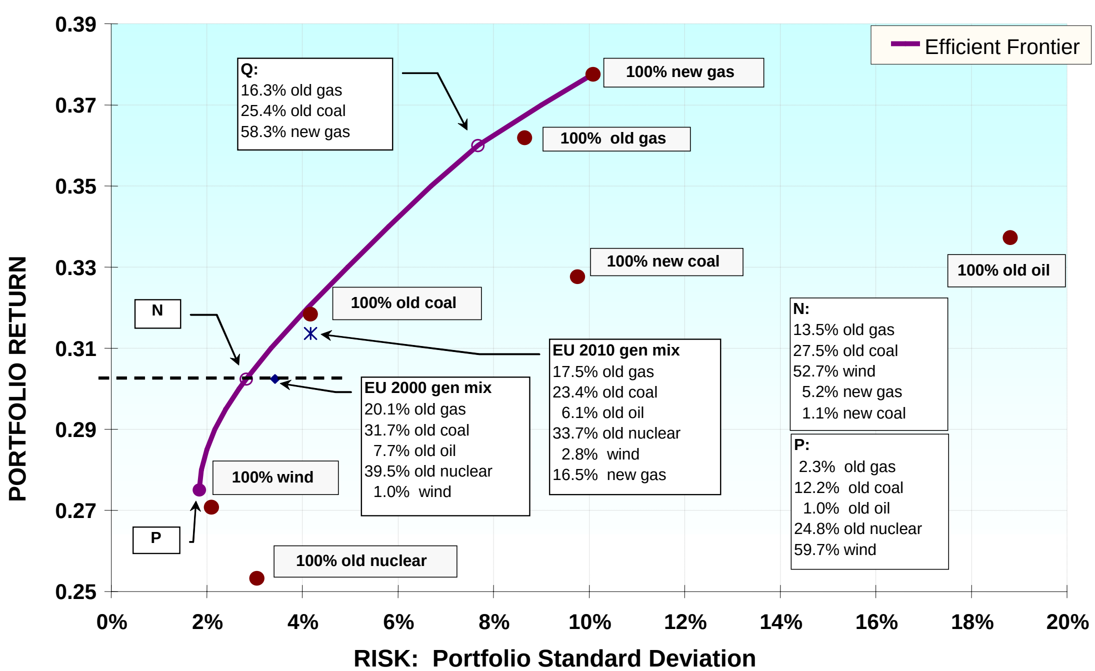
Assumed Cost for Riskless Renewable: $.12/kWh



Source: S.Awerbuch, "Getting it Right: The Real Cost Impacts of a Renewables Portfolio Standard", Public Utilities Fortnightly, February 15, 2000

Figure 3.2: Cost and Risk of EU *Business-as-usual* generating mixes can be reduced by adding wind

Portfolio risk and return



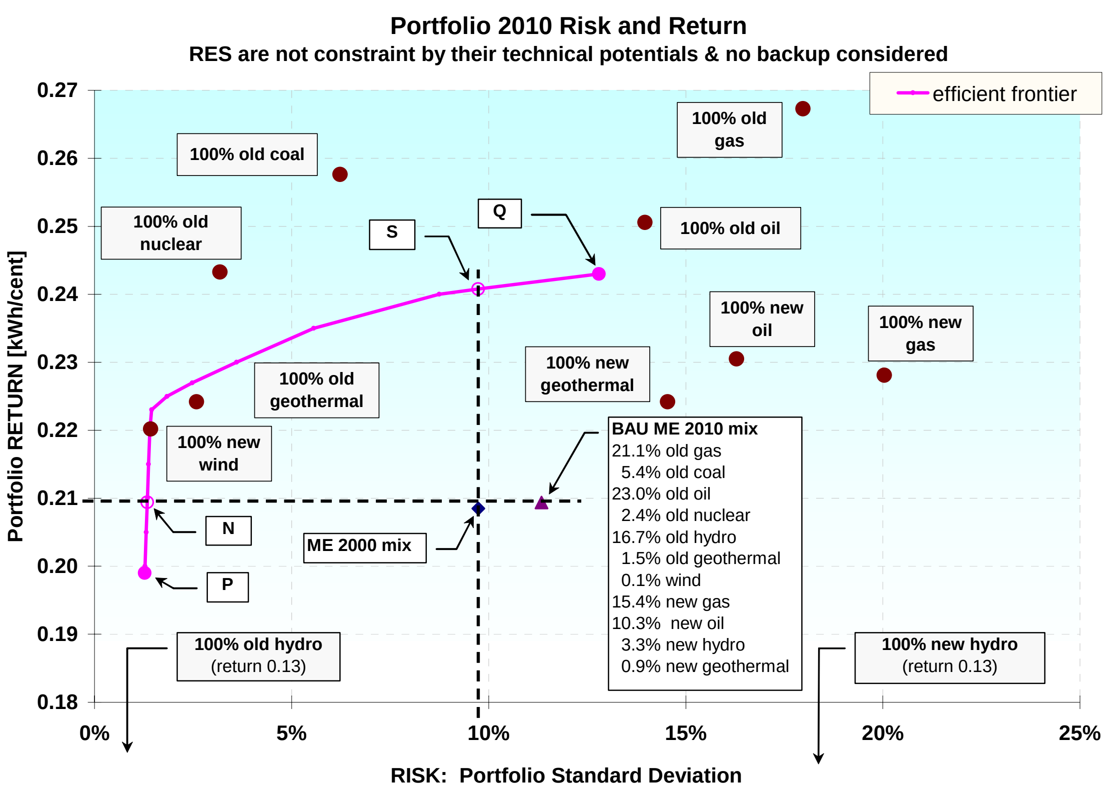
Illustrative Evaluation of the Mexican Generating Mix

3.6 This section presents some preliminary, illustrative results that, with refinement, could help policy makers evaluate existing and projected Mexican generating mixes. Figure 3.3 shows the risk and return (the inverse of cost) of various generating portfolios as well as the unconstrained *Efficient Frontier*— the location of all optimal portfolios, when no renewable resource constraints are imposed.

3.7 Observe that Mexico´s Business-as-usual (BAU) 2010 mix (ME-2010) costs the same as the 2000 mix, but has moved to the right indicating that expected overall generating costs become riskier or more volatile on a year-to-year basis. Both the ME-2000 and the ME-2010 mixes are inefficient in the sense that there exist virtually an infinite number of portfolio combinations that lie to the left and above these mixes. Any of these portfolios will exhibit higher returns (i.e. lower generating costs) and lower expected cost volatilities.

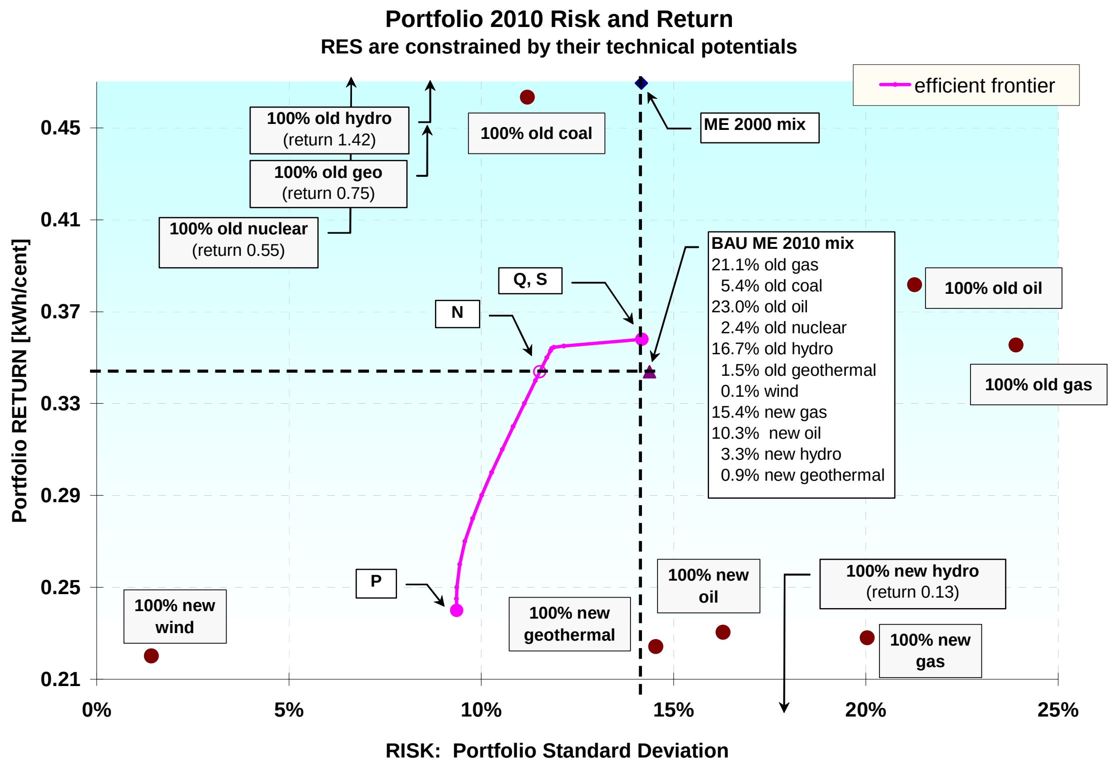
3.8 For example, though not technically feasible, Portfolio *N*, consisting of 80 percent wind, plus small quantities of hydro, nuclear, and coal, exhibits significantly reduced volatility as compared to the BAU ME-2010 mix although expected cost is the same. By comparison, costs for Portfolio *S*, which consists of about 25 percent wind, 20 percent geothermal, and 50 percent oil and gas, are lower than ME-2010 and so is their risk.

Figure 3.3: Risk-Return for current and projected Mexico Generating Mixes



Showing "Unconstrained" Efficient Frontier

Figure 3.4: Risk-Return for current and projected Mexico Generating Mixes Showing "Technically Feasible" Efficient Frontier



3.9 Figure 3.4 shows the *Technically Feasible Efficient Frontier*, which reflects practical Mexican resource constraints for wind and other renewables. Along this line lie all *technically feasible*, optimal generating mixes. The feasible portfolios are riskier and costlier than the unconstrained possibilities suggesting that greater emphasis on locating and expanding renewable resources, which would allow additional wind, geothermal and other capacity additions by 2010, could serve to reduce generating cost and risk. This idea is also reflected in Figure 3.5.

3.10 Finally, Figure 3.6 gives an optimal transition path showing the particular capacity additions that would transform Mexico's generating portfolio from the current ME-2000 mix to an optimal mix, such as the one represented by *Portfolio N* (in Figure 3.4), which has the same expected cost as ME-2010, but with lower volatility.

Figure 3.5: Changes in the optimal Mix Along the Efficient Frontier: Most RETs are Resource Constrained; Lower Cost/Higher Risk mixes contain more gas and less hydro

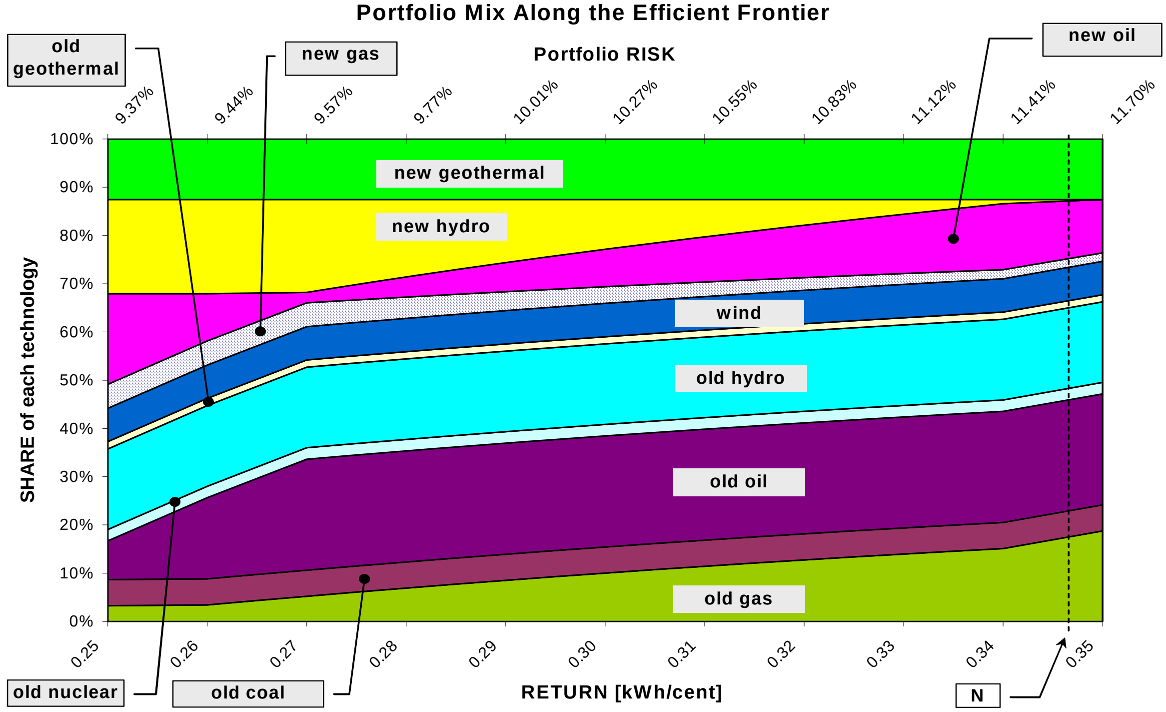
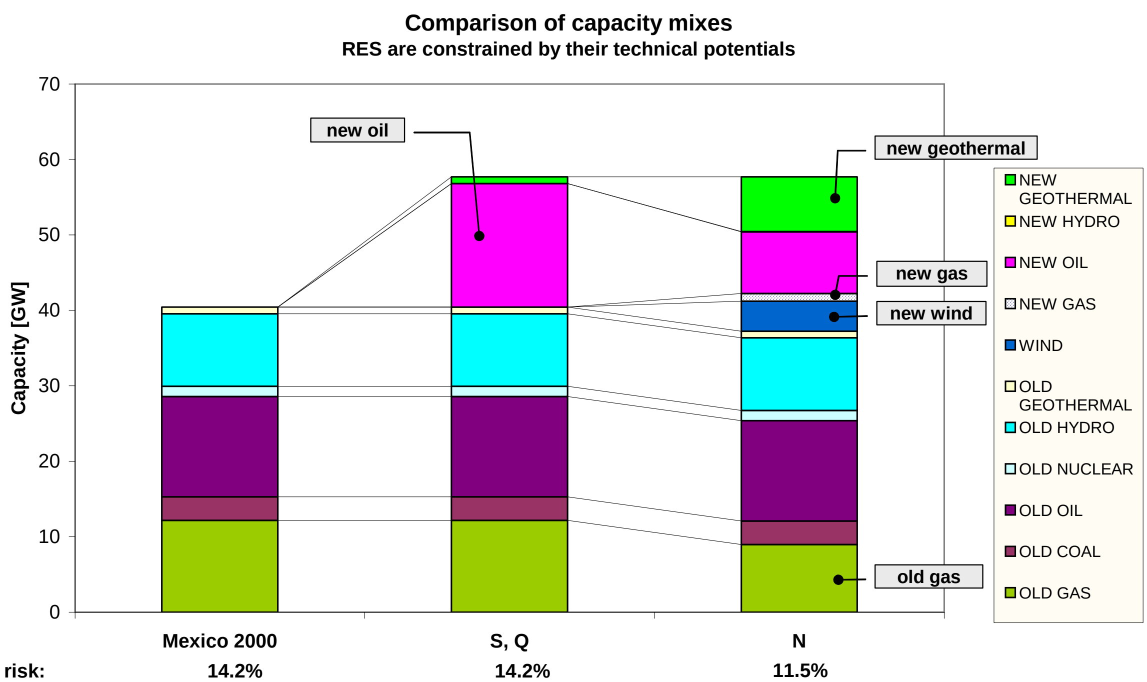


Figure 3.6: Optimal Capacity additions to shift from the Mexico-2000 Mix to an efficient portfolio



4

Economic Analysis of Mexico Wind Project

Introduction

4.1 This analysis of the economic costs of adding 100 MW of wind power to the Mexican electricity system highlights the potential for fuel savings and greenhouse gas reduction.

There are two important measures of merit for this analysis. The first is the incremental cost of the wind generation in the system. The second is the economic rate of return for the proposed wind generation plants, given the alternatives to those plants in the Mexican system.

Background Information on the Energy Sector in Mexico

4.2 Energy policy in Mexico has been marked by overall stability. In recent years a series of small steps toward liberalization has resulted largely in additional purchases of electricity and fuel (mostly natural gas) by the national electricity entity, CFE. Early efforts at liberalization have slowed, leaving the current structure of both fuels and electricity likely to remain stable for the foreseeable future. Until the past few years Mexico's abundant energy reserves were sufficient to provide both self-sufficiency in all forms of energy and significant export earnings. The country is still a major exporter of oil, but those exports represented less than 20 percent (~$32 billion) of the country's total exports of $165 billion in 2004.

4.3 Virtually all of the country's hydrocarbons production is in the hands of the state-owned Pemex. The Government relies heavily on Pemex for income, netting about $50 billion from the sector in 2004, about 40 percent of government revenues. Little progress has been made in liberalizing the country's hydrocarbons sector, and investment decisions for new exploration and production are largely in the hands of the Mexican Congress. That Congress has not yet decided whether and to what extent to allow new participants in the country's hydrocarbons sector.

4.4 The reliance on the hydrocarbons sector to supply cash to the Government has resulted in a 30–40 percent reduction in the country's proven oil reserves over the past decade, to less than 30 billion barrels.[104] Natural gas reserves have also stagnated over the past decade, and stand at 26 trillion cubic feet (Tcf), about 22 years of production at current rates. Current gas production has proved inadequate for the needs of Mexico's industry and electricity generation sectors, and gas and imports from the U.S. now represent almost 10 percent of current demand. The Government of Mexico projects growing gas imports in the future, primarily through LNG regasification terminals on the Gulf and Pacific coasts of the country.

4.5 In the 1990s there was an effort to open up some segments of Mexico's gas industry. Private firms are permitted to supply services to Pemex, the sole producer, and also may invest in transmission and distribution. As domestic supply is inadequate, these incentives have proven insufficient to dramatically restructure the gas sector. The other major energy sector opening has been to provide electricity to CFE and local distribution companies through independent power producers (IPPs). A more extensive restructuring of the electricity sector planned for the fall of 2002 was postponed and is unlikely to come up again during the term of the current President.

4.6 Energy policy decisions in Mexico are the responsibility of the Secretaria de Energia (SENER), with executing authority in the hands of the Comision Federal de Electricidad and Luz y Fuerza Centro for electricity, and Pemex for oil and gas. Regulatory authority in the energy sector is in the hands of CONAE for electricity and CRE for fuels.

Electricity

4.7 Mexico generated about 199 gigawatt hours (GWh) of electricity in 2002, 21 percent of which was geothermal and hydropower. About 73 percent of Mexico's installed power generation capacity of 44 GW is fossil-based, with oil-fired plants, including combustion turbines, responsible for the largest share of both capacity (43 percent) and generation (49 percent). Coal plants account for 12 percent of total generation and 7 percent of capacity. Combustion turbine plants comprise less than 8 percent of total generation and are used largely for meeting demands at peak and in isolated areas. Gas-fired plants represent more than 19 percent of generation, about the same share as hydro, with just under 14 percent of total generation capacity.

4.8 The sector is organized around two state enterprises, CFE and Luz y Fuerza, with 92 percent and 4 percent of generating capacity, respectively. Pemex controls another 2 percent of generation capacity and the remaining 2 percent is in private hands. There are three distinct grid systems in the country. One system covers the northern end of the Baja peninsula, and the second covers the southern end of the Baja peninsula. The remaining national interconnected system (SEN) covers the rest of the country, with interconnections to the USA and to Belize and Guatemala.

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[104] There is some controversy over the actual levels of oil reserves, with the Oil and Gas Journal putting the December 2001 figure at just over 26 billion bbl., a significant drop from December 2000. The U.S. Department of Energy places Mexico's December, 2002 reserves at 30.8 billion bbl., a drop of 1.8 billion bbl. from the previous year. Mexico does not publish official reserve totals.

4.9 Peak demand has risen steadily in recent years, moving from about 18.6 GW in 1990 to 31.5 GW in 2000, an average annual growth rate of just over 5 percent. With reserve margins declining throughout the 1990s, the country has found it necessary to obtain new generating capacity from private sources. Initially CFE made use of the build-operate-transfer model (BOT) and obtained about 1,100 MW of new combined cycle capacity in the mid-to-late 1990s. Since then, the private investors have preferred the IPP approach, especially with the relative ease of using an approved contract model for purchase of power and building permits. Of about 6,200 MW of new generating capacity under construction, more than 60 percent uses the IPP contracting model. More telling, no new BOT plants have been contracted since 1998.

4.10 The total capacity of all plants in the construction or permitting process through 2005 is approximately 10,854 MW, about the same as the expected increase in peak demand. In other words, if *all* plants in process are completed before 2005, the system reserve capacity will not fall. However, not all plants in process can be completed before 2005 and the increase in peak demand is likely to be greater than the increase in generation capacity.

4.11 With a declining reserve margin as a most likely case, the Government continues to encourage the construction of new power plant projects, most of them IPPs based on either new Pemex gas output or imported natural gas. To meet projected demand for electricity and gas to fuel new generating capacity, the country is currently putting two LNG regasification complexes out for initial design work.[105]

Table 4.1: Projected Electricity Generation, 2001–2011

Capacity (MW)	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
SEN	38,519	41,095	44,918	46,002	46,877	49,463	51,865	53,109	56,311	59,915	63,214
Other	3,892	4,687	5,256	5,256	5,256	5,919	5,839	5,839	5,799	5,799	5,799
Total Capacity	42,411	45,782	50,174	51,258	52,133	55,382	57,704	58,948	62,110	65,714	69,013
Generation (GWh)											
SEN	197,106	201,821	211,658	220,400	232,345	245,305	259,929	275,872	293,459	311,964	331,218
Other	12,520	14,212	19,937	22,666	23,798	28,340	29,249	29,265	29,377	29,426	29,403
Total Generation	209,626	216,033	231,595	243,066	256,143	273,645	289,178	305,137	322,836	341,390	360,621

4.12 Figure 4.1, below, shows supply from major sources for 2001–2011, according to the SENER *Prospectiva,* while Figure 4.2 shows projected consumption by major category.

[105] Mexico has announced plans for four LNG terminals, two on the Pacific coast and two on the Gulf. Two of the terminals will be built very close to the U.S. border in order to facilitate the sale of natural gas to the U.S. (California and Texas, respectively). Large electric power complexes will be constructed near the regasification facilities.

Figure 4.1: Mexico's Power Generation, 2001–2011

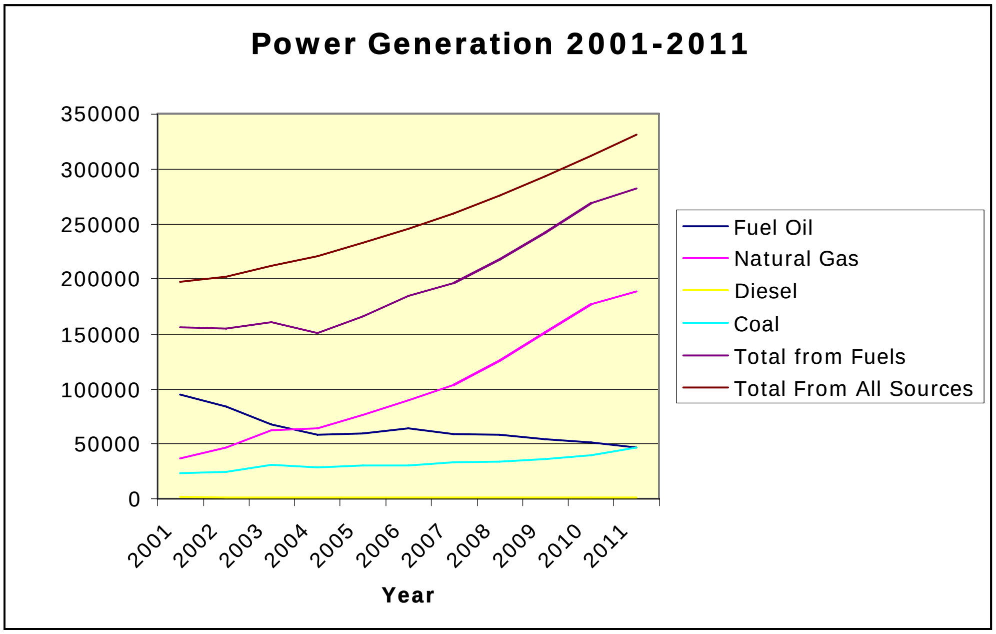
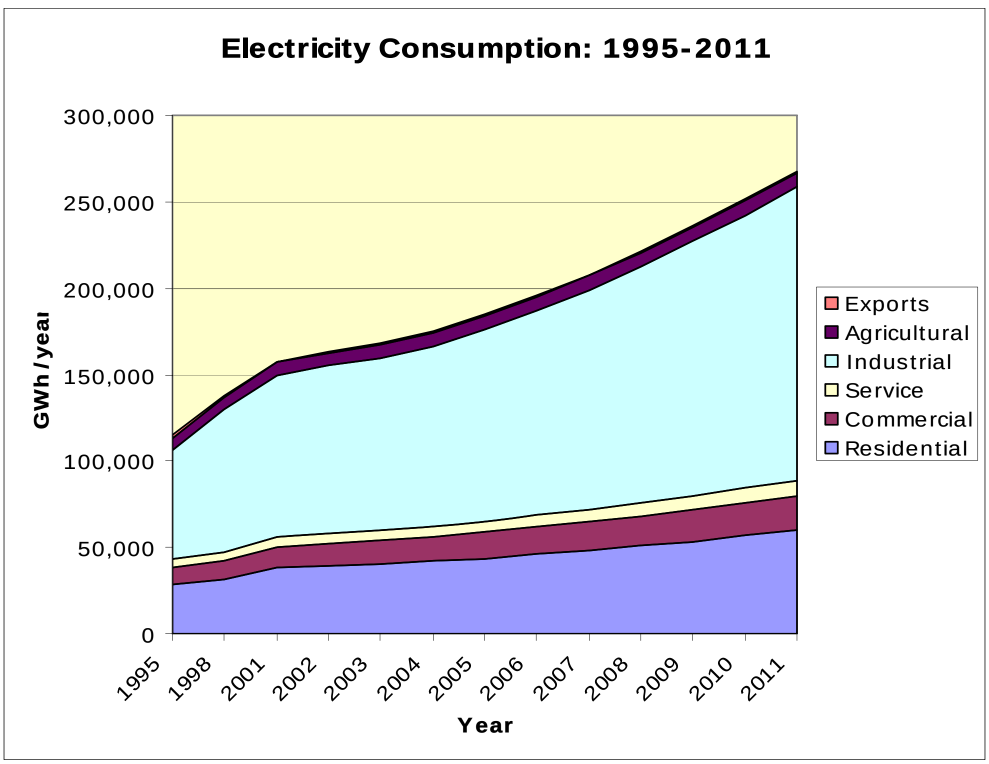


Figure 4.2: Projected Electricity Demand in Mexico by Sector



Oil

4.13 Mexico produces about 3.4 million barrels/day, mostly from fields in and around the Campeche Bay in the Gulf of Mexico.[106] Reserves, which once stood above 40 billion barrels, are now rated at 28–30 billion bbl (end 2002). In the twelve months between January 2001 and January 2002, reserves fell by 1.4 billion bbl.[107] Pemex, the national oil company, must produce virtually all of its output from existing reserves. Of the current production total, about 2 million b/d, or 55 percent of total output, is consumed domestically.

4.14 Exploration and production development activities must be authorized by the Mexican Congress. In recent years the Government has looked to Pemex as a source of funds, not a recipient. Without substantial investments annually, the country cannot replace reserves lost due to production, pressure drops and field maintenance problems. A recent burst of upstream activity, resulting in an additional 100,000–150,000 b/d of output in 2000, has run its course and additional investment will be needed just to maintain production at current levels. Current production is maintained increasingly by resort to enhanced recovery techniques, a useful stopgap until more reserves can be proven. However, the country is still far from a consensus on retaining Pemex as the sole entity for oil production versus greater reliance on private and foreign companies in the oil sector.

4.15 The lack of investment extends to the refining segment of the industry as well. The government-owned refineries have capacity to meet about 75 percent of refined oil product demand, and about one third of gasoline demand, with the remainder met through imports. A major refining technology program is planned, pending Government funding. One of the country's major refineries, at Cadereyta, has already been fully upgraded to properly handle the country's heavy crude oil slate. The Government plans to increase refining capacity in coming years, but the funding for such projects is not yet assured.

Gas

4.16 Mexico's current gas production of about 1.33 Tcf (37.8 bcm)[108] in 2003 is an increase of 33 percent in the decade since 1991. However, production plateaued in 1998 and actually declined a bit between 1999 production of 1.29 Tcf (36.5 bcm) and 2001 production of 1.25 Tcf (35.2 bcm). This level of activity puts Mexico in the same output tier as Venezuela, Australia, and Argentina, among others. As with crude oil, Pemex has the sole right to prospect for and produce gas.

4.17 Gas reserves currently stand at 15.0 Tcf, down from 17.27 Tcf in December 2000.[109] Pemex's budget problems in gas exploration are virtually identical to the oil

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106 Total liquids production of 3.8 million barrels/day includes about 0.4 million barrels/day of condensates and gas liquids.

107 The amount by which reserves fell is almost exactly the annual output volume of Pemex, indicating no net reserve increases in 2001. In 2002 reserves fell further.

108 Equivalent to 4.51 billion ft^3/d.

109 As with oil, there is significant uncertainly about the true level of reserves. The *Oil and Gas Journal* puts the reserve level at 29 Tcf, while different divisions of the U.S. Department of Energy put gas reserves at 30.1 (*Energy Overview of Mexico*) and 16.3 Tcf (*Mexico Country Analysis Brief*).

market situation. Simply put, gas reserves are being used up annually without significant replacement efforts. Unlike the oil sector, Mexico appears to making some real effort to bring additional resources into the upstream gas industry, particularly for nonassociated gas reserves. In addition, the Government has permitted private firms to enter the transmission and distribution segments of the gas industry.

4.18 These modest initiatives in the gas industry are not expected to yield dramatic short-term results and the country has seen a rapid rise in gas imports from the U.S., now running at more than 740 million ft^3/d, about 18 percent of total use in the country. Both the industry and power sectors are increasingly dependent on natural gas. By 2020 the IEA expects Mexico to increase gas use in the power sector seven-fold, to 44 percent of all generation.[110] This level of gas demand for electricity would be equivalent to the entire *current* gas production of the country.

4.19 To meet this burgeoning demand for gas in the face of stagnant reserves and production, the country is planning to turn to liquefied natural gas (LNG) to provide additional supplies. CFE, the electricity company, has announced two LNG regasification plant tenders, each of which will increase domestic supplies by 10 percent over current levels. Eventually, four of these plants are to be built, supplying at least 2 billion ft^3/d.

Coal

4.20 Coal currently provides almost 7 percent of electric power system capacity and about 12 percent of total generation. The plant capacity is located in the northeast portion of the country, which has some coal reserves. Current output of 10 million tonnes annually falls short of annual consumption, which now stands at 12 million tonnes. No new coal-fired power plants are currently shown as under development by CFE or private developers. However, the *Prospectiva* does show coal maintaining a 12–14 percent share of total generation through 2011. Generation from coal is shown to approximately double over the period 2001–2011, indicating that as much as 25 percent of the power plants shown as "other" in the CFE plan (>10 GW by 2011) are actually intended as coal units.

Other Energy Sources

4.21 The main source of renewable energy in Mexico today is hydroelectricity. Large hydro plants represent more than 25 percent of installed capacity and about 18 percent of total generation. The only other major nonconventional energy source is geothermal, with less than 5 percent of both capacity and generation. CFE plans to halve its oil use by the end of this decade, using large hydro in the short term and natural gas in the medium term. New hydro and geothermal plants are under construction and these sources could contribute as much as 30 percent of electricity supplies in 2004–2005. After that time, CFE projects that hydro and geothermal will gradually reduce their shares of generation to about 15 percent, with most hydro being used to meet peak demand, further replacing older combustion turbine units.

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110 The *Prospectiva* shows gas-fired generation already at 56 percent of total output by 2011.

GHG Emissions in Mexico's Power System

4.22 Current emissions of CO_2 in Mexico's electric power system amount to about 115 million tonnes/year (equivalent to 31 MT/y of carbon). With the *Prospectiva* projections of 149 MT in 2011, the carbon intensity of Mexico's power system will decline by more than 30 percent by 2011, from 74 g/kWh in 2001 to 53 g/kWh in 2011. Figure 4.3 shows projected GHG emissions from the power sector for the SENER planning period. With the least efficient fuel oil and middle distillate plants retiring, replaced by gas-fired CCGT and hydro, the overall CO_2 emissions of Mexico's power sector actually falls in the first three years by about 7 percent. After that CO_2 emissions continue their increase. In 2001, about 60 percent of total CO_2 emissions were due to fuel oil use. By 2011, fuel oil responsibility for emissions will fall sharply, though natural gas will take up all of the differential and more, with gas accounting for more than 40 percent of total GHG emissions in 2011.

4.23 As the figures below show, the increase in GHG is well below the increase in generation. The increasing efficiency of the power generation system is due largely to two factors, the replacement of intermediate oil steam facilities with gas-fired CCGTs and the increasing use of hydro to meet peak demand instead of combustion turbines. Figure 4.4 shows the changes in generation efficiency over the SENER planning period. Figure 4.5 shows how CO_2 emissions have changed by fuel over the period of SENER and CFE planning.

Figure 4.3: Total CO_2 Emissions by Source

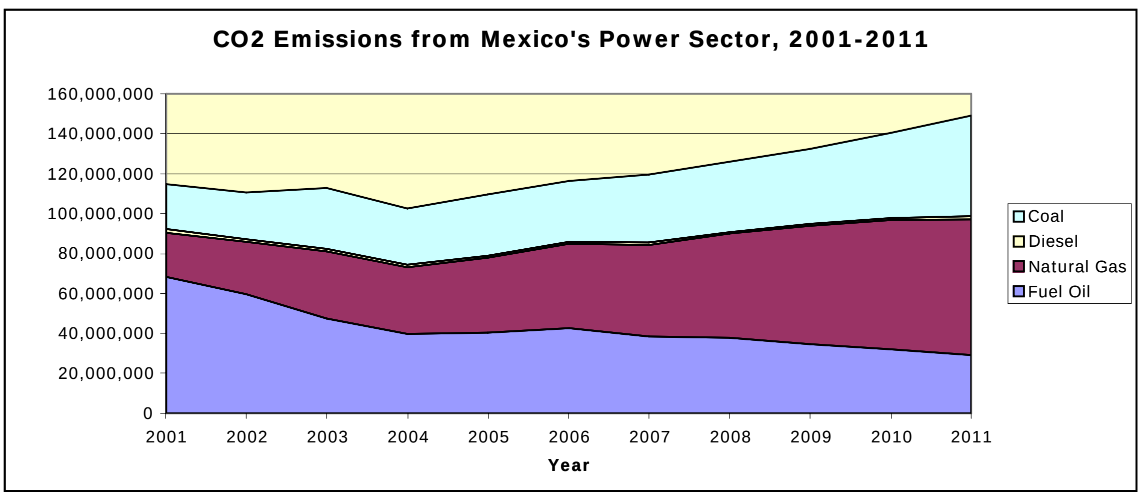


Figure 4.4: Efficiency Changes in Mexico's Power Sector

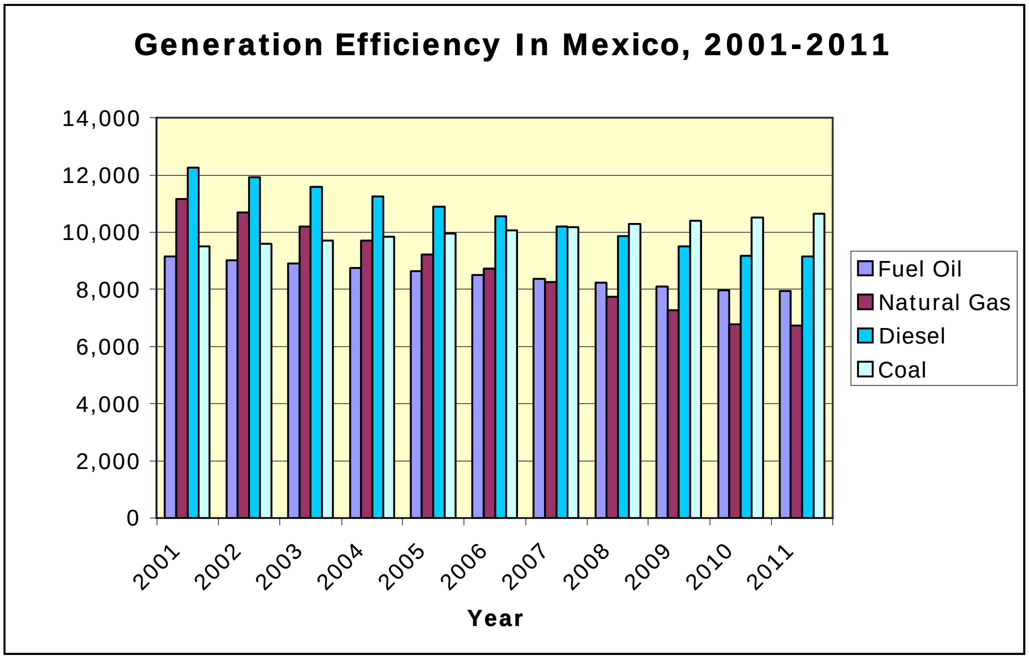
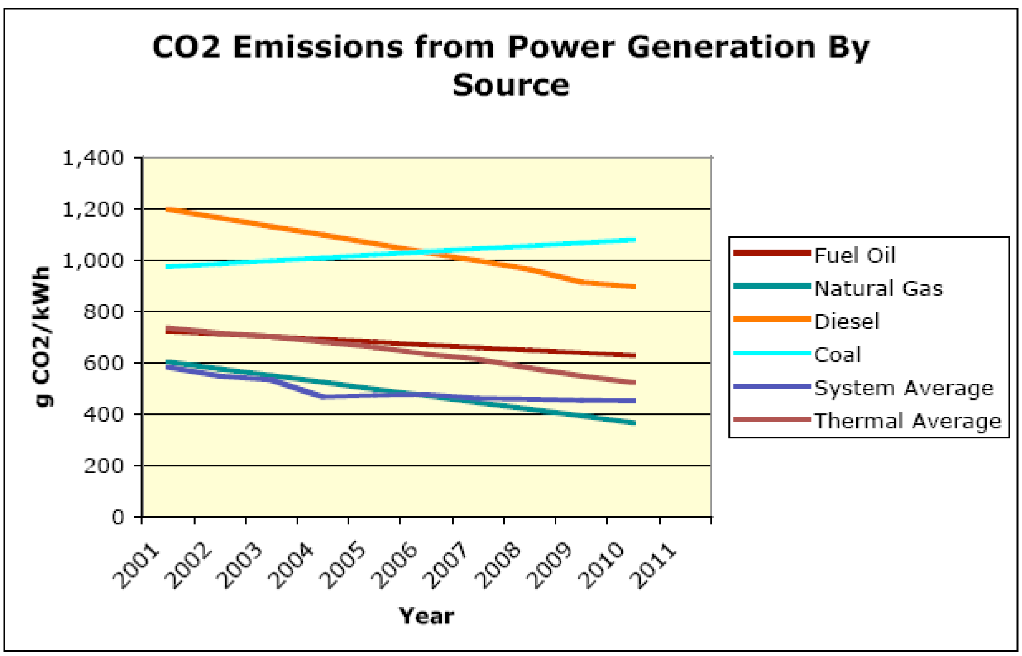


Figure 4.5: CO_2 from Mexico's Power Sector: g per kWh



Impact of 100 MW of Wind Capacity on Power Generation in Mexico

4.24 Basic cost and output data on the proposed investments in wind were analyzed using a simulation model of Mexico's power system. This model calculates the cost of meeting electricity energy and capacity demand under a wide variety of assumptions regarding Mexico's economy, oil sector, gas supply and power technology.

4.25 For the purposes of this project, the base case was taken as the Sener/CFE expansion plan, including demand forecasts, economic growth forecasts and technology expectations. The only change vis-à-vis the SENER *Prospectiva* is that this analysis covers a period of 20 years subsequent to the commissioning of the proposed wind investments, unlike the 10-year horizon of the SENER *Prospectiva*.

4.26 A wind investment resulting in an additional 100 MW of power generation capacity represents about 0.33 percent of proposed CFE additions aver the period of the *Prospectiva*. Moreover, with the 40 percent plant factor, one that is lower than normal intermediate service plants, the proportion of system energy generated by the wind facility will be in the range of 0.3 percent of *additional* output, and less than 0.01 percent of *total* output during the period in question.

CFE Baseline

4.27 The Ministry of Energy in Mexico, through SENER and CFE, has plans to construct 50 MW of wind energy plants over the period of the current SENER plan (through 2011). The proposed CFE plant will be commissioned in 2006. No other wind plants are envisioned through the end of the current SENER planning horizon. The output from that investment, about 175 GWh annually, will provide approximately 0.15% of additional output in the SEN through 2011.

4.28 CFE, through its Renewable Energy Directorate, is conducting studies to assess the effects of wind energy on the CFE system and to find ways to enhance the value of that energy once it enters the national transmission system. These studies, now ongoing, are intended to provide a better understanding of the system and power plant management efforts that are required to give wind energy the ability to contribute some degree of firm capacity to the Mexican power system. At the current state of understanding of these issues it is difficult to attribute firm power capacity to wind energy, given its highly predictable, though intermittent, nature. Thus the output from the planned CFE wind plant will be given an energy-only value, with a present value of $20.06 million for the period 2006 through 2011. Since the present value of project costs is approximately $62 million, the project is not expected to return net benefits to the owners of the plant, CFE, in the short run. Table 4.2 shows the economic analysis of the CFE wind energy baseline over a 20 year *economic* lifetime.

Table 4.2: CFE Baseline Wind Energy Activities, 2002–2011

Item	Unit	Baseline Value
Annual Generation	GWh	175.2
Leveled Economic Generation Cost	$/MWh	48.01
Value of Energy Displaced	$/MWh	34.20
Value of Capacity Displaced	$/MWh	0.00
Present Value of Project Costs	$M	62.44
Present Value of Project Benefits	$M	48.48
Internal Rate of Return	%	6.77
CO_2 Displacement (2006-2011)	Tonnes	480,682
Source: SENER Prospectiva and CogenPro Simulation Model		

Impacts of the Model Wind Energy Plant

4.29 As a general rule, a single 100 MW power plant will not have a significant impact on a system the size of the CFE SEN. In planning terms, a plant can be considered a part of the least-cost plan if that plant can contribute capacity to the SEN. On its own, the proposed wind facility cannot contribute capacity to the SEN. Almost by definition, the plant generates electricity on a generally predictable, but not firm or dispatchable, basis. Without a firm power rating, CFE cannot delay the construction and commissioning of some other firm power facility due to the commissioning of this wind plant. Therefore, most of the economic impacts of the wind facility discussed below will come in terms of displaced energy.

4.30 The issue of the precise value to the SEN of wind energy is still open. However, there are three distinct types of values that can be placed on wind energy output. These are:

1. Wind energy is worth the system marginal energy cost (MEC) at any given time less the cost of providing spinning reserve for that capacity;[111]
2. Wind energy is valued at exactly its energy replacement figure on the assumptions that (i) wind capacity is too small to affect the overall system output, and (ii) wind energy can be replaced almost immediately by some other generator if the wind speed falls; and
3. Wind energy is valued at its energy replacement value plus a capacity value that represents the ability to back up wind output to some, or possibly full, extent.

4.31 The primary locale for wind energy development in Mexico is the Oaxaca province, one that is blessed with abundant and relatively predictable wind resources. Given the relatively high plant factor and good predictability of power generation, the

[111] This method is the basis of the current CFE buyback approach to renewable energy generators.

first valuation option seems overly restrictive. Perhaps if wind were a significant proportion of total output in the Mexican system, if the Mexican wind resources were of a lower quality, and if there were little ability to quickly replace the wind output by some other generator, then this approach might have some validity.[112]

4.32 For the purposes of analyzing the value of output for incremental cost analysis, the base cases for wind energy value were the following:

- Wind energy valued at its periodic MEC for the times that the unit generates energy;
- Wind energy valued at the MEC plus full capacity value for the times the unit generates energy;
- Wind energy valued at the MEC plus a partial capacity value for the times that the unit generates energy.

4.33 The third case, valuing wind at energy + partial capacity value, will indicate the potential returns to the country if CFE and CENACE understanding and management of wind energy's interface with the SEN are improved over the next several years.

Methodology

4.34 A simulation model ("CogenPro") was used to calculate the impacts of the proposed wind energy investments. This model is able to reproduce most of the simulation results of the WASP III or Wasp IV models as they pertain to Mexico's system expansion. Although the model works at a lower level of resolution than does WASP III, it contains several additional features that are useful for the analysis of projects. The user inputs a variety of economic and technical parameters regarding the power system and the host country's economy, as well as important technical parameters on fuel prices, operational efficiency, GHG emissions, system operation and fuel supply. In addition, the model embeds a proposed power plant investment in the system simulation and then produces key economic and financial measures of merit for that plant under a variety of assumptions.

4.35 The table in Annex describes briefly the operation of the key elements of the simulation model used in this analysis.

4.36 At the time of this writing other analytical efforts are under way and the results of these activities will be used to further refine and validate the current analysis. In particular, there are current simulation efforts at CFE and USAID that seek to provide additional light on questions of the capacity value of wind energy and the economic/GHG-reduction value of wind energy when operated in a large system with a variety of resources. Current results will be further discussed with SENER, CFE and CENACE to arrive at an appropriate validation of the suggested approach to valuing wind energy.

[112] If this approach were to be accepted, then the value of wind energy would be approximately 85 percent of the periodic Marginal Energy Cost. All measures of merit, NPV, and ERR would fall into the unacceptable range.

Results to Be Reported

4.37 The key outputs of interest concern the incremental costs and benefits of the proposed wind investments. Using the three general cases for establishing the value of the output, the following results will be reported below for each case:

- Generation cost of wind project
- System avoided generation cost, with specified levels of capacity value
- Economic rate of return
- Present value of benefits (as noted above)
- Net present value of project
- CO_2 displacement

4.38 In each case, the outputs will be provided for a base case and for three other cases—slow economic growth and power system investment, high economic growth and power system investment, and enhanced investments in LNG and coal-fired power plants on the base economic forecast—and two crude oil (WTI) prices will be used: $24 and $28/bbl.[113]

Discussion of Results

4.39 **Generation Cost of Wind Project**: The model wind project will entail a present value of investment and operation of approximately $120 million, the overwhelming proportion of which is the initial investment cost.[114] The generation cost from the proposed wind facility varies from $45.46–53.19/MWh, depending on assumptions regarding dispatch hours, and operational costs.

4.40 **System Avoided Cost and Present Value of Benefits**: An avoided cost is calculated for the prospective power generation system independently of any proposed investment contained in this analysis. That avoided cost represents the value of additional system investments and the marginal energy cost by season (dry or wet) and time of day (base, intermediate, or peak) for each combination of oil price, economic scenario and investment scenario. For the base case, that is, the SENER/CFE expansion plan and economic growth forecasts, the system avoided cost of new generation falls into the range of $41–63/MWh, as crude oil ranges from $18–34/bbl. This discussion will focus on the $24–28/barrel cases.

4.41 The benefits that are calculated for *each case* represent the value of the energy displaced during the proposed plant's hours of operation plus the value, if any, of capacity displacement attributed to the plant. The energy figure depends largely on three elements: (i) hours of operation, including time of day, (ii) plants displaced, and (iii) fuel prices for displaced plants. For example, if the wind plant were to operate during a period in which the marginal plant on the system was a gas-fired CCGT (dry season), and

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[113] Cases using both $18 and $34/bbl were also examined.

[114] The PVC is calculated based on a project start date in 2004, with commissioning in 2006. If the project were to get under way immediately, then the PVC would rise to about $115 million.

a combination of CCGT and hydro (wet season), and assuming that the oil price was $28/bbl, then the value of the energy displaced by the wind plant would be that marginal energy cost, or $47.70/MWh[115] during dry season, and $41.40/MWh during the wet season. The value of capacity during this intermediate period is about $17.10/MWh.[116] if the plant gets full attribution of capacity displacement value, then the value of benefits attributable to the wind plant is $64.80/MWh in the dry season and $58.50/MWh in the wet season.

4.42 The present value of benefits (PVB) is simply the value of displaced energy and capacity that can be attributed to the plant's output over the simulation period expressed in present value terms. For energy displacement only, the PVB is the value of fuel not burned and ranges from $84–98 million. A full attribution of capacity displacement value to the plant is worth about $80 million in present value terms, bringing the PVB to $165–179 million.

4.43 The base case for this analysis uses a partial capacity payment, representing 50 percent of the value of capacity in the system while the plant is operating. This figure is used with the idea that better management of overall CFE generation and system resources can permit a *predictable* energy source, such as the Oaxaca wind, to displace at least *some* firm capacity in the system some of the time. Throughout the economic life of the plant, this partial capacity payment would be worth approximately $39.6 million.[117]

4.44 **Economic Rate of Return**: The ERR is the rate at which the project returns value to the investors and society, based on the real cost to Mexico of the resources used in the project and opportunity cost of the displaced energy and capacity that is attributable to the project. The results for this proposed project are uniformly negative for all cases and all oil prices if no capacity benefit is attributable to the project. If the project can displace some capacity (50 percent of its rated output in this case), then the ERR results indicate that oil prices above $24/bbl may allow the plant to break even and generate some returns for the society and investors.[118] If the wind facility can be operated in such a manner that the CFE can attribute full capacity credit to the wind output, perhaps by some combination of wind and hydro twinning, then it is possible for the plant to show positive returns unless oil prices fall below $18/bbl. For a plausible range of oil prices, $24–28/bbl, a twinned wind/hydro facility can generate economic returns ranging from 10.52-12.05 percent.

4.45 **Net Present Value of Project**: Based on the project's present value of costs of $120 million and the Pubs, which range from $97–179 million, the NPV will be positive or negative as appropriate. In general, project returns are only positive when capacity displacement value attributable to the project is greater than 50%, or when oil prices are very high.

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115 This figure includes both Pemex gas and LNG imported at the Gulf of Mexico regasification stations.

116 This figure averages $20.70/MWh for the operational hours of the proposed wind plant.

117 It is expected that the outcome of the technical assistance component of the project will provide system management and valuation methods that can enable CFE to continue to provide a capacity payment to the wind plant.

118 A capacity attribution above 80% is required for the project to break even at oil prices of $20/bbl.

4.46 The Base Case results shown in Table 4.3 below correspond to the SENER/CFE reported expansion plan as contained in the *Prospectiva*.

Table 4.3: Summary of Model Wind Project Key Economic Results

	Project NPV (millions)	Project ERR	Value of Output ($/MWh)	Present Value of Benefits (millions)
Base (SENER/CFE) Case - Crude oil Price ($/bbl WTI)	**Energy Value Only**			
24	($36.12)	5.53%	29.62	$83.81
28	($22.15)	7.35%	34.19	$97.78
	Partial (50%) Capacity + Energy Value			
24	$4.51	10.52%	39.96	$124.44
28	$18.48	12.03%	44.53	$138.41
	Full Capacity + Energy Value			
24	$45.45	14.79%	50.30	$165.08
28	$59.12	16.14%	54.87	$179.05
NB: the present value of costs is $119.93 million.				

4.47 **CO_2 Displacement**: The project can displace as much as 230,000 Tonnes of CO_2 annually under current the system configuration or 1.4 million Tonnes over the SENER planning period. Table 4.4, below, shows the CO_2 reduction attributable to the wind project. If all of the output of the wind project can be attributed to fossil plants only, then the pattern of output of the wind project can reduce CO2 emissions from Mexico's power system by 231,194 tonnes in the first year of full operation, 2005. That value drops over the SENER planning period as new power plants replace older, less efficient units (see Figures 4.3 and 4.4). If management of system resources does not permit CENACE and CFE to distinguish among fossil and other system resources, then the effective CO_2 displacement would be lower, starting at 165,065 tonnes in 2005, falling slightly to 157,656 tonnes in 2011. The displaced CO_2 represents 0.15–0.21% of year 2005 expected CO_2 emissions from power generation. The figure falls to 0.11–0.12% by 2011.

4.48 The actual displacement figure will probably depend on the ability of CENACE and CFE to upgrade their analysis and system management tools so that the maximum value is obtained from the output of the wind unit.

Table 4.4: CO2 and Carbon Displacement from Wind Project

Year	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Average of All Plants							
Wind (CO2)	165,065	166,519	161,326	159,928	158,139	157,796	157,656
Wind (Carbon)	5,406	5,454	5,284	5,238	5,180	5,168	5,163
Fossil Plants Only							
Wind (CO2)	231,194	221,747	214,214	202,667	191,790	182,941	184,934
Wind (Carbon)	62,950	60,379	58,326	55,183	52,220	49,810	50,350

4.49 **Summary:** The tables above indicate the nature of the incremental cost results for the model project.

- Project costs range from $120–125 million for a 100 MW project and the incremental benefits represent at a minimum the value of displaced energy;
- Improved CENACE system management and dispatch will permit CFE to pay a partial capacity credit to the project, equivalent to 50 percent of the capacity value in effect when the plant is generating;
- The value that can be assigned to displaced energy will vary with the price of oil, and ranges from $84–98 million over the life of the project;
- The only other major measurable incremental benefit is capacity displacement, whose value is entirely dependent on whether other firm capacity can be attributed to a project of this nature;
- With improved management of generation and other system resources, it may be possible to attribute a capacity price of 50% of the relevant value. This fractional capacity is worth about $10 MWh, with a present value of just over $40 million over the life of the project;[119]
- Technical assistance is required to improve the tools available to CFE and CENACE to undertake the types of activities necessary to better manage both intermittent and firm system resources, thereby adding value to both.

4.50 The net result of this scenario would be positive returns for a 50 percent capacity credit at oil prices above $22/bbl, and with a capacity credit of 80 percent the project could generate positive returns at oil prices as low as $19/bbl.

4.51 On the down side, an inability on the part of the project developers or CFE to effectively twin the project with a firm capacity supplier would make it difficult or impossible for the project to contribute net value to Mexico at most conceivable oil prices and output situations.

4.52 Both the positive and negative possibilities should be further investigated to assess the operational, institutional and financial implications of effective capacity provision by an intermittent energy resource. In some countries projects of this sort can provide effective capacity by operating within the same firm as a firm capacity supplier so that the obligation to provide firm capacity is with the generation company. In other systems an independent generator can purchase reserves on the market, making possible the “conversion” of intermittent energy to firm capacity for the customers of that intermittent supplier.

[119] The actual value of the plant’s capacity displacement, if any, will depend critically on management of the power system, and coordination of the wind facility with its backup plant. In general, it is only feasible for an intermittent energy resource to claim capacity displacement if it can be operated in tandem with another, firm, power source, or with management of overall system resources acting as the “firming” power source for the wind energy plant.

Annex to Chapter 4

Description of the CogenPro Simulation Modeling System

Module	Description	Analytical Output
System Expansion	Future expansion of the power system can be simulated in two ways: (i) a least cost expansion plan is generated consisted with a given (or generated) demand forecast, fuel prices, operational parameters, or (ii) a least cost expansion plan is adapted from the host country and used as a basis for further analysis and discussion.	Plant capacity by type and year of commissioning, investment costs, plant output, variable and fuel costs, average and marginal costs of output, plant retirements
Dispatch	The existing, new and retiring plants in the system are dispatched on the basis of economic merit for each daily time period and season. Changes in the least cost plan will be reflected in dispatch results as will changes in fuel prices. This module also contains a subroutine for specifying economic and system operation conditions to produce different scenarios for comparison with a base case.	Plant dispatch merit order, MEC by time period, season and year, MEC by plant type, various weighted average MECs and energy generation values. In addition, this module produces a summary by scenario of different operating and economic conditions.
Investment	A proposed power plant investment can be included in the LCP and dispatch models. The user can specify very detailed assumptions regarding the operational, financial and economic characteristics of the proposed plant. This power plant will than be subject to economic dispatch as appropriate and a variety of economic and financial measures of merit will be produced. Comparisons of PPAs and pool payment schemes can be made.	All of the usual economic and financial measure of merit are produced, including 7 different rate of return calculations, present values of all cost and revenue streams, fuel values (netbacks), returns for different payment schemes (PPA, pool, partial capacity, etc.)
Fuel Prices	A simulation of oil and refined product markets, including interaction with LNG, pipeline gas, and alternative hydrocarbon fuels, provides the fuel prices for the various power plants in the system. The model works from a specified forecast of a marker crude oil price, or a forecast can be produced by the model, with full stochastic variation of key price factors. This module is liked to a gas production module for pipeline gas supply and to a gas processing module for LNG and LPG supply or export comparison.	Annual prices of crude oil and major refined products (naphtha, mogas, diesel, jet, kerosene, IFO, HFO, LNG, pipeline gas, methanol, LPG), prices in all common units (T, bbl, mmbtu)
Gas Production	This module calculates the cost of gas supply (if appropriate) by pipeline, provides comparisons of	Gas supply investments, pipeline investment and tariffs,

and Supply	export v. domestic supply options and pricing options for different pipeline and supply modes.	returns to upstream investors, alternative investment and legal regimes.
Gas Processing	This module simulates the construction and operation of a gas processing complex, with options to produce LNG, LPGs, methanol and ammonia. It is used if LNG is a significant consideration for fuel supply for the power system and can be used on its own to evaluate investments in gas processing for export.	All of the normal economic and financial results are produced, along with alternative fiscal regimes for the government's take from proposed gas system investments. Upstream and gas transportation are internal, or the user can specify an interface with the external gas supply model.

Operation of the model uses a combination of spreadsheet (Excel), Visual Basic program routines, and optimization programs to calculate results. User-definable parameters exceed 1,000 and data needs are consistent with a simulation model of this scope.

Joint UNDP/World Bank
ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME (ESMAP)

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