Renewable Energies for Sustainable Development in Mexico

2009

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Renewable Energies for Sustainable Development in Mexico 2009

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Abbreviations

ANES	Asociación Nacional de Energía Solar (National Association of Solar Energy)
BID	Banco Interamericano de Desarrollo (Inter-American Develoment Bank)
BM	Banco Mundial (World Bank)
CDI	Comisión Nacional para el Desarrollo de los Pueblos Indígenas (National Commission for the Development of Indigenous Peoples)
CEPAL	Comisión Económica para América Latina (Economic Commission for Latin America and the Caribbean)
CERTE	Centro Regional de Tecnología Eólica (Regional Center for Wind Energy Technology)
CFE	Comisión Federal de Electricidad (Federal Electricity Commission)
CMNUCC	Convención Marco de las Naciones Unidas sobre el Cambio Climático (United Nations Framework Convention on Climate Change)
CMR	Comisión Mundial de Represas (The World Commission on Dams)
CONABIO	Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (National Commission for the Knowledge and Use of Biodiversity)
CONAFOR	Comisión Nacional Forestal (National Forest Commission)
CONAE	Comisión Nacional para el Ahorro de Energía (ahora CONUEE) (National Commission for Energy Savings – now CONUEE)
CONOCER	Consejo Nacional de Normalización y Certificación de Competencia Laborales (National Council for Standardization and Certification of Labor Competences)
CONUEE	Comisión Nacional para el Uso Eficiente de la Energía (National Commission for Energy Efficiency)
CRE	Comisión Reguladora de Energía (Energy Regulatory Commission)
DAC	Doméstica de alto consumo (tarifa eléctrica) (Residential Electricity Tariff for High Consumption)
ENACC	Estrategia Nacional de Cambio Climático (National Strategy on Climate Change)
FAO	Organización de las Naciones Unidas para la Agricultura y la Alimentación (Food and Agriculture Organization of the United Nations)
FIRCO	Fideicomiso de Riesgo Compartido (Trust Fund for Shared Risk)
GEF	*Global Environment Facility*
GTZ	*Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH* (German Technical Cooperation)
GVEP	*Global Village Energy Partnership*
IEA	International Energy Agency
IIE	Instituto de Investigaciones Eléctricas (Electrical Research Institute)
IMP	Instituto Mexicano del Petróleo (Mexican Petroleum Institute)
INEGI	Instituto Nacional de Estadística y Geografía (National Institute of Statistics and Geography)

ISCCS	*Integrated solar-combined cycle system*
LAERFTE	Ley para el Aprovechamiento de Energías Renovables y el Financiamiento de la Transición Energética (Law for the Use of Renewable Energies and Financing of Energy Transition)
LASE	Ley para el Aprovechamiento Sustentable de la Energía (Law for the Sustainable Use of Energy)
LPDB	Ley de Promoción y Desarrollo de los Bioenergéticos (Law for the Promotion and Development of Bioenergy)
LyFC	Luz y Fuerza del Centro (Central Power and Light Company)
$MtCO_2e$	Million tonnes of carbon dioxide equivalent (including green house gases other than CO_2 and their CO_2 equivalent in regards to climate change impact)
NESO	Comité Técnico de Normalización Nacional para Energía Solar (National Committee for Standardization of Solar Energy)
NMX	Norma Mexicana (voluntaria) (Mexican Standard - voluntary)
NOM	Norma Oficial Mexicana (obligatoria) (Mexican Official Standard - mandatory)
PERGE	Proyecto de Energías Renovables a Gran Escala (Large-scale Renewable Energy Development Project)
PND	Plan Nacional de Desarrollo 2007-2012 (National Development Plan 2007-2012)
PNUD	Programa de las Naciones Unidas para el Desarrollo (United Nations Development Program)
PPSIBDCT	Programa de Producción Sustentable de Insumos para Bioenergéticos y de Desarrollo Científico y Tecnológico (Program for the Sustainable Production of Bioenergy Inputs and for Scientific and Technological Development)
PROCALSOL	Programa para la Promoción de Calentadores Solares de Agua en México (Program for the Promotion of Solar Water Heaters in Mexico)
SAGARPA	Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food)
SEMARNAT	Secretaría de Medio Ambiente y Recursos Naturales (Ministry of Environment and Natural Resources)
SEDESOL	Secretaría de Desarrollo Social (Ministry of Social Development)
SENER	Secretaría de Energía (Ministry of Energy)
SHCP	Secretaría de Hacienda y Crédito Público (Ministry of Finance and Public Credit)
SIEPCRM	Servicios Integrales de Energía para Pequeñas Comunidades Rurales en México (Integrated Energy Services for Small Rural Communities in Mexico)
SSA	Secretaría de Salud (Ministry of Health)
USAID	*United States Agency for International Development*

Foreword

Mexico needs to harness all of its available energy potential, whether it derives from wind, sun, water, or geothermal energy. Doing so creates a great opportunity to augment our energy security, while at the same time we are engaged in the worldwide effort to combat global warming.

The prospect humanity faces regarding this phenomenon is daunting indeed, and combating it has become this generation's greatest challenge. We cannot sit with folded arms while the planet's future is at stake. Addressing this problem is far more than simply "urgent." The future of the planet is at stake, and we are moving with absolute determination to overcome it.

We have a responsibility to present and future generations. We have a fundamental obligation to leave the world a better place than it was when we received it from our parents. We owe that to our children and grandchildren, that they should have better opportunities, cleaner air and water, safer energy...just as they, in turn will pass on a better, cleaner, safer world to *their* descendents.

The Ministry of Energy is committed to this goal, and therefore recognizes its obligation to incorporate sustainability in the design and implementation of all public policies. It is within this framework that we present this document to the public.

It is important to note that cooperation between countries is essential in our efforts to achieve a true energy transition. In this light, it is an encouraging sign that the governments of Mexico and Germany have worked in cooperation to produce this publication.

In the spirit of environmental stewardship, we have chosen to present this document solely in electronic format.

It is our hope that anyone interested in the topic or concept of renewable energy sources will find it useful. Working together we hope and believe that we can reach our goal, that we can find solutions that allow us to diversify the country's entire energy landscape. In doing so, we can build a future in which we all can share in a better life

Georgina Kessel Martínez
Minister of Energy

1 Introduction

The National Development Plan (PND by its acronym in Spanish) 2007-2012 establishes Sustainable Human Development as its ruling principle. NDP incorporates the postulates of the World Report on Human Development (1994) of the United Nations Development Program, according to which "the purpose of development consists in creating an atmosphere in which everybody can enhance their capacity and opportunities can be broadened for present and future generations"

.

One of the elements for the attainment of this ruling principle is the policy for energy sustainability, which seeks to increase energy efficiency and the use of renewable energies in Mexico with a long-term vision. This document is focused on the second of these two elements. Renewable energies have been included within the Mexican public policies in several ways for decades; however, it is the first time that they occupy an important place in the NDP, because they are explicitly included in six of its strategies, which correspond to two different objectives.

The Sectorial Program of Energy 2007-2012[1] incorporates the objectives and strategies of the NDP and proposes, within its nine objectives, three related to the promotion of renewable energies:

- The first one is to "balance the portfolio of primary energy sources", and it has as a quantitative indicator to increase, during the present public federal administration, the participation of renewable energies in the generation capacity from 23 to 26%, integrated as follows: large hydroelectric projects (above 70 MW) 17%; small hydroelectric projects 3% and other renewables 6%.

- The second objective is to "promote the use of renewable energy sources and biofuels in an economically, environmentally and socially acceptable feasible manner", and it is also based on the previous objective indicator.

- The third objective consists of "mitigating the increase of green house gas emissions", and aims to double the avoided emissions from 14 $MtCO_2e$ in 2006 to 28 $MtCO_2e$ in 2012.

Renewable energies are also an important part of the national climate change mitigation policy. At present, the preparation of the Special Program on Climate Change is in its final stages including, amongst its objectives and strategies, the development of renewable energies.

[1] PROSENER (tinyurl.com/prosener).

Finally, renewable energies do have, at present, a specific legal framework: the Law for the Use of Renewable Energies and Financing of Energy Transition, published in the Official Gazette of the Federation on November 28th, 2008, which sets out, amongst other provisions, the obligation of the Ministry of Energy to elaborate a Special Program for the Use of Renewable Energies, as well as a National Strategy for Energy Transition and Sustainable Use of Energy.

This document presents the current situation of renewable energy technologies with a special reference to the Mexican case (chapter 2); it identifies its benefits and particularities (chapter 3) and proposes strategies in order to maximize the benefits offered by such technologies in our country (chapter 4).

1.1 Definition of renewable energies

Renewable energies (see box below) are those energies whose source is found in natural phenomena, processes or materials, susceptible of being transformed into useful energy by mankind, and which continuously regenerate through natural processes, thus being available in a continues manner. Renewable energy sources will last for thousands of years, hence they are considered inexhaustible. Renewable energies can be classified in different ways: by their primary energy source, the stage of technological development, and by their applications.

Renewable energy sources or renewable energies? Energy, in any of its forms, can be neither created nor destroyed; it can only be changed from one form to another (first law of Thermodynamics). Even though energy cannot be lost, it can be degraded during each irreversible process (second law of Thermodynamics). Hence, strictly speaking, energy cannot be considered as *renewable*. What can be renewed is the source, for example the wind, or a waterfall. Nonetheless, the use of language has called r*enewable energy sources simply* "*renewable energies*"*. This document uses the term* "*renewable energies*" according to this commonly accepted meaning of the words.

Table 1. Classification of renewable energies

Renewable energy source	Primary energy source			Stage of technological development			Application		
	Sun[1]	Earth (heat in the earth's interior)	Moon (gravitational pull of the moon)	Traditional	New	In development process	Electricity	Heat [2]	Liquid fuels [2]
Wind									
Solar radiation									
Hydro									
Bioenergy					(3)				
Geothermal						(4)			
Waves									
Tides									
Ocean currents			(5)						
Other oceans energies[6]									

Notes:
[1] In an indirect manner, most of the energy sources come from the sun. For example, in the case of wind, sun radiation heats air masses, which in turn causes their movement.
[2] All renewable sources can be used to generate electricity, and from it produce heat or energy for transportation, but the information shown here only refer to those sources which may have these applications in a direct manner.
[3] Bioenergy has been traditionally used as fuel since thousands of years ago. Nevertheless, there are also technologies used for power generation and the production of biofuels, which are relatively new or in their development process.
[4] Geothermal is traditionally used in several ways, and there are also technologies under development such as hot dry rocks and submarine geothermal.
[5] Ocean currents are due to different factors: wind, temperature differences, salinity differences, earth rotation and tides.
[6] Other ocean energy sources include thermal ocean gradient and salt concentration gradient (in river mouths).

1.2 Historical Perspective

The use of naturally occurring energy forms, in a renewable manner, starts with the origin of the human being, when our ancestors learnt how to control fire, using the energy of biomass. Throughout the history of humankind, we have obtained energy from biomass, direct solar radiation, wind, hydro, and geothermal in different ways, and it was only until the industrial revolution that we started using, on a large scale, the enormous amount of energy contained in non-renewable resources: mainly coal, petroleum, natural gas and uranium.

Since the beginning of the XIX century, but mainly throughout the XX century, humanity exponentially increased the availability of energy thanks to the exploitation of these non-renewable resources, giving rise to our industrialized and urbanized society. At present, non-renewable energy sources provide 87% of the primary energy supply worldwide,[2] whilst in our country such percentage is 91%.[3]

During the last decades, the world has experienced a transition process towards a greater participation of renewable energies, fostered by a series of factors, among which are the following:

- concerns regarding the sovereignty and security of energy supply in energy importing countries, especially after oil crisis and the every time more increasing volatility of fuel prices; and
- concerns regarding environmental impacts of energy systems, in particular, acid rain and more recently climate change.

This transition process, driven by new technologies and lower prices as a result of the technological and industrial development, has been accelerated since the late nineties in several countries of the world, among which stand out Germany, Spain, Denmark, United States of America, Brazil, India and China.

Table 2. Worldwide development of renewable energies

Applications	Sources / technologies	Added Capacity in 2008[GW]	Existing Capacity at the end of 2008[GW]
Electricity	Wind power	27	121
	Solar photovoltaic in grid	5.4	13
	Concentrating solar power	0.06	0.5
	Large hydroelectrics	25-30	860
	Small hydroelectrics	6-8	85
	Bioenergy	2	52
	Geothermal power	0.4	10
Heat	Solar water heaters	19	145
	Bioenergy	n/d	~250
	Geothermal	n/d	~50
Liquid fuels	Bioethanol	17	67
	Biodiesel	3	12

Source: REN21, 2009 (tinyurl.com/gsr2009)

[2] Data corresponding to 2006 (IEA, 2008c). In developing countries more than 70% of primary renewable energy corresponds to the use of firewood and other biomass solid fuels for cooking and heating, under conditions that can be qualified as non sustainable, due to the impacts of indoor polution on the health of users, as well as, in certain cases, to deforestation.

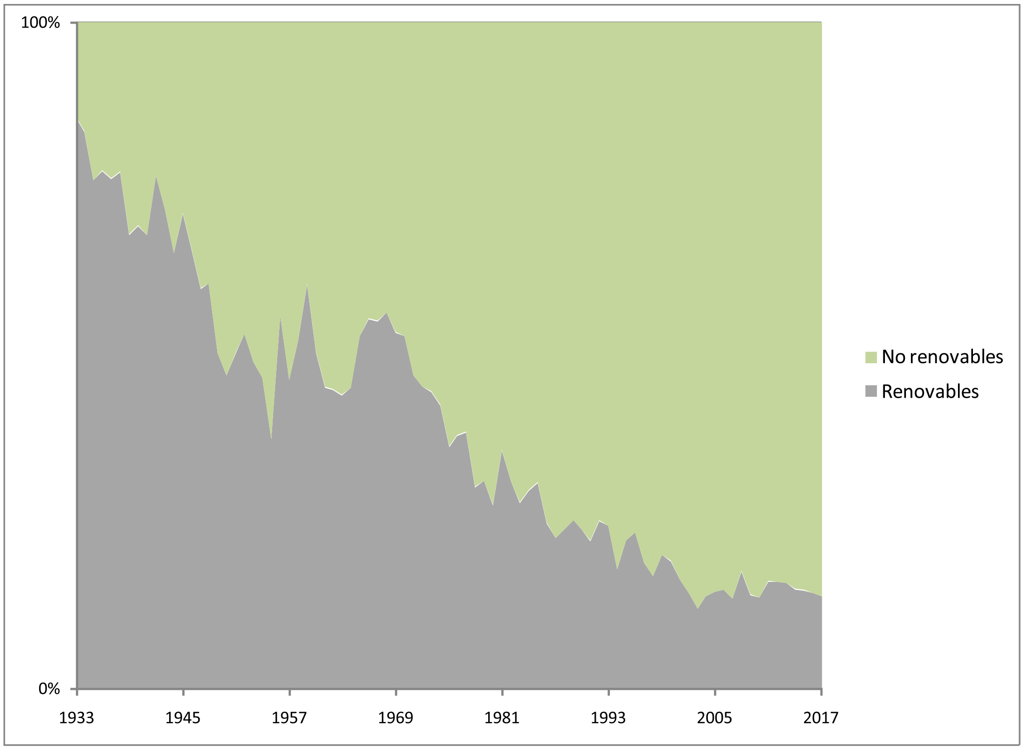
[3] National Energy Balance 2006. 36% of primary renewable energy corresponds to the use of firewood for cooking in non sustainable conditions.

Thanks to an annual investment of 40 thousand million USD in year 2005 and 71 thousand million in 2007, the installed capacity and energy production has soared during the last years (see table below). Wind capacity is a good indicator of such rapid growth. While in 1985, the world capacity was 1,020 MW (equivalent to less than half of the thermoelectric plant of Tuxpan)[4], it surpassed 120,000 MW (more than twice the total installed generating capacity in Mexico) in 2008.

1.3 The Mexican case

During the XIX century, hydraulic energy was the main engine for the industrialization of our country. Sugar mills as well as spinning and weaving mills, with hydraulic wheels, were installed in many regions of our country. During the last third of the century, wheels were substituted by hydraulic turbines, leading to

Illustration 1. Evolution of energy sources for power generation in Mexico, 1933-2017



Including generation for private and public service
Source: Elaboration from data and prospectives of the Ministry of Energy.

[4] Energy Watch Group, 2008 (tinyurl.com/EWGwind).

hydropower generation. Hydropower continued to play an important role in the internal supply of energy, but its participation diminished during the first half of the XX century due to the important growth in the use of fossil fuels, promoted, besides other factors, by the availability of oil-derived products and natural gas, which were cheap in those years.

In accordance with the Electricity Sector Outlook, the decreasing trend in the participation of renewable energies in the energy matrix of public services will continue during the coming years. However, if one takes into account the self-supply and cogeneration projects, the participation of renewable energies will increase in the next years, allowing the fulfillment of the goal established in the Sectorial Program of Energy 2007-2012 of reaching 26% of the installed capacity.

2 Technologies

Next, the main features of the different renewable energy technologies, their present situation, and their potential in Mexico will be briefly described. It does not include those in a development stage, such as the ocean technologies.[5]

2.1 Wind energy

2.1.1 Technologies

Wind turbines transform kinetic energy of the wind into mechanical energy either to move directly a machine, such as a water pump, or to drive an electric generator. Wind turbines come in many sizes, starting with 500 W and up to more than 7 MW. The largest ones are mainly for off-shore wind farms. During the last two decades, wind turbine technology has radically advanced, and its costs have been reduced to become competitive with conventional technologies in favorable geographic contexts (see illustration below).

Illustration 2. La Venta II wind farm

[5] For the potential of such technologies in Mexico, see Alcocer and Hiriart, 2008 (tinyurl.com/arpwdre). The Federal Electricity Commission is planning to install a pilot project to generate electricity from ocean waves in Rosarito, Baja California, with a capacity of 0.75 MW (El Universal, 2008; tinyurl.com/Rosarito).

2.1.2 Costs

Investment costs of wind turbines are approximately $1,700 USD per kW. Power generation costs depend upon wind velocity and resource availability throughout the year. Under optimal conditions, with costs of around 5 USD cents per kWh, such a technology is competitive with many of the conventional technologies for power generation.[6]

2.1.3 Status Quo

Wind energy has globally developed at quantum leaps during the last years. In 2008, the world installed capacity was 120,800 MW.[7] In Mexico there are currently 208 MW of wind capacity in operation,[8] which is distributed as follows:

- 85 MW in La Venta I and La Venta II projects, operated by CFE in the Tehuantepec Isthmus.
- 117 MW in the "Eurus" and "Ventosa" self-supply project, which entered into operation in January, 2009.
- 1 MW in a single turbine operated by CFE in Guerrero Negro, in South Baja California.
- 2 MW in small off-grid wind generators.
- 3 MW in small windpumps (wind turbines which drive a water pump).

Illustration 3. Wind farm

[6] For the case of off-shore wind farms, power generation costs increase between USD¢8 - 12/kWh. Average cost of turbines obtained from the World Bank, 2008 (tinyurl.com/draftdoc1). Generation costs: REN21, 2009 (tinyurl.com/gsr2008).
[7] As of year 2008 more than 27,000 MW of new wind capacity were installed (GWEC, 2009; tinyurl.com/GWEC090202).
[8] National Energy Balance 2007 (tinyurl.com/BNE2007) and Reforma, 2009 (tinyurl.com/NotaReforma).

Recently, CFE launched a tender for two other projects called La Venta III and Oaxaca I, each one with a capacity of 101.5 MW. These projects will be operated under the Independent Power Producer modality. During the next three years, CFE is planning to put into operation other three projects under the same modality, with a total capacity of 304 MW.

Large-scale Renewable Energy Development Project (PERGE) GEF-BM-SENER: This project has a 25 million USD grant from the Global Environment Facility (GEF) through the World Bank. Its objective is to promote grid-connected renewable energies in Mexico, thus contributing to mitigating green house gases and other pollutant emissions; to increase energy price stability; to contribute to the capacity of the National Electric Power System; and to meet the needs for energy diversification. PERGE will assign 20 million USD as incentives for La Venta III, a 101 MW wind project, which is currently under construction, and the remaining five will be for technical assistance to the Ministry of Energy (SENER), the Energy Regulatory Commission (CRE), and the Federal Electricity Commission (CFE). CFE will pay its avoided costs and PERGE will grant the incentive to the producers through a financial mechanism, a fix incentive per unit of generated energy during the first 5 years of project operation. (SENER, 2009; tinyurl.com/36733h; contact: jvalle@energia.gob.mx)

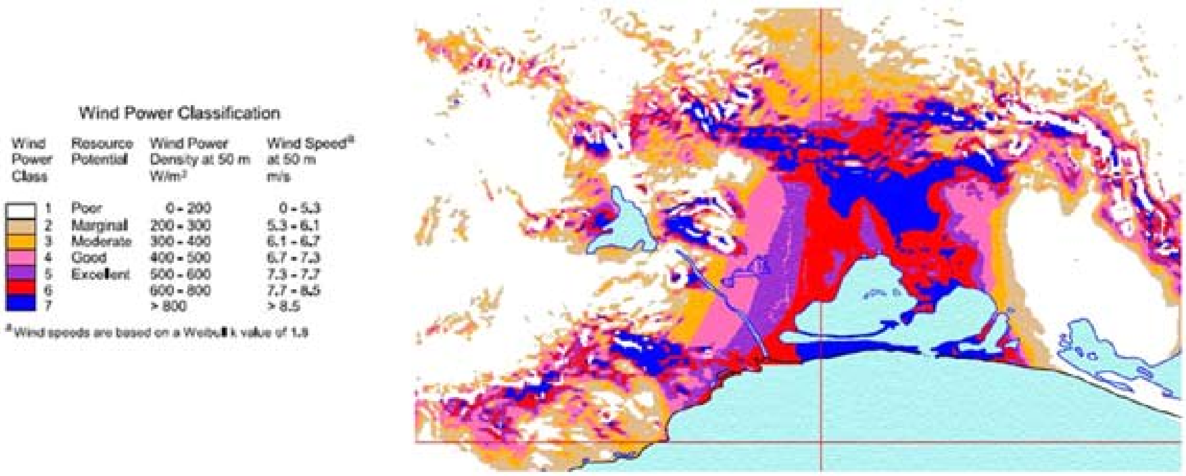
On the other hand, a large number of self-supply and export wind projects are under construction or planning, mainly located in the Tehuantepec Isthmus, as well as in La Rumorosa, in Baja California. These projects, with a total capacity of more than 2,000 MW, have been possible thanks to favorable regulatory instruments (see section 4.2.6).

Wind Project GEF-PNUD-IIE: The "Action Plan for Removing Barriers to the Full-scale Implementation of Wind Power in Mexico" is a project carried out by the Ministry of Energy and the Electrical Research Institute, financed with a grant of the Global Environment Facility (GEF) through the United Nations Development Program. The Project pursues, amongst other objectives, to promote capacity development; to perform wind measurements and to create maps; to evaluate technologies; to adopt the international best practices; to revise the normative framework; and to promote small scale projects. As part of the project, the construction of the Regional Center for Wind Energy Technology (CERTE) is being planned in the Tehuantepec Isthmus, while a network of anemometers has been installed in the states of South Baja California, Chihuahua, Sinaloa, Zacatecas, Nuevo León, Tamaulipas, Veracruz, Hidalgo, Puebla, Oaxaca, Chiapas and Yucatán. The IIE has the measurements records performed in these sites during the last years. (IIE, 2009; tinyurl.com/planeol; contact: mabroja@iie.org.mx)

2.1.4 Potential

The wind potential of the country has not yet been evaluated in an exhaustive manner. Nevertheless, resource evaluation has been performed for specific regions. Especially, the National Renewable Energy Laboratory of the United States of America has coordinated the development of wind maps for Oaxaca (see illustration below), Southern Baja California, the coasts of Yucatán and Quintana Roo and the border areas of the States of Baja California, Sonora and Chihuahua.[9] These maps have been developed by integrating the information from meteorological stations by means of remote prospection techniques.

Illustration 4. Map extract for Oaxaca's wind potential



Source: Wind Energy Resource Atlas of Oaxaca, National Renewable Energy Laboratory (NREL)

As part of the project "Action Plan for Removing Barriers to the Full-scale Implementation of Wind Power in Mexico", the Electrical Research Institute (IIE) has installed anemometers in several points of the country and has found meaningful potentials in several of them. Likewise, and as part of the activities of PERGE, the Federal Electricity Commission will perform an evaluation during the next years, which, together with information available from other sources, will allow the creation of a national wind map.
The possibilities for the development of wind energy in Mexico in the short to medium term depend, not only on the availability of the resource, but also on the industrial capacity and the capacity of the electric power system to receive the generated electricity without risking the security and stability of the system. The economic feasibility of these projects will depend on the regulatory mechanisms and on the access to international instruments related to the climate change mitigation.

There is also a technical and economic potential for the development of wind systems in off-grid applications, such as power generation and water pumping by means of windpumps.

[9] See NREL, 2009 (tinyurl.com/NRELmaps) and Sandia National Laboratories, 2009 (tinyurl.com/SandiaMaps).

2.2 Solar radiation for power generation

2.2.1 Technologies

There are two technologies for the generation of electricity from solar radiation: photovoltaic and concentrating solar power.[10] Photovoltaic cells convert energy from the sun directly into electricity by means of a physical phenomenon called photovoltaic effect. Solar cells may be used in grid connected applications or in isolated sites by means of systems which include batteries.

At solar thermal power plants, the solar radiation heats a fluid, which in turn drives a thermal machine and an electric generator. The heating of the fluid is generally achieved by optic devices which concentrate the solar radiation, reaching high temperatures, the same way one can burn a piece of paper with a magnifying glass. One version of such a technology consists of mirrored parabolic troughs, which concentrate solar radiation onto a collector tube in which a fluid circulates (see illustration below), while in other approach to solar thermal power, a field of individually tracking mirrors concentrates radiation onto the top of the tower called "solar tower".
Solar thermal power plants have the additional advantage that may allow thermal energy storage, i.e. heat, through additional investments, Thus, power generation is possible even when solar radiation is not available. During the last years, both technologies, photovoltaic and concentrating solar power, have had an accelerated development, reaching efficiencies of more than 15%.

Illustration 5. Parabolic trough power plant Kramer Junction, California

[10] Other technologies using indirect solar radiation, such as the one of the energy tower, are still in their conceptual development stage. See JIQ, 2009 (www.jiqweb.org/jiq0408.pdf).

2.2.2 Costs

Amongst the different technologies available for electricity generation from solar radiation, concentrating solar power requires the least investment costs, approximately $2,200USD/kW.[11] Grid connected photovoltaic systems cost US$8,000/kW, whereas off-grid systems cost twice as much as grid connected systems.[12] Power generation costs are still very high in order to be competitive with other technologies: between 12 and 18 US¢/kWh for concentrating solar power, between 0.26US¢/kWh (Mx$2.85) and 0.36 US¢/kWh (Mx$3.94) for photovoltaic systems —connected to the Mexican electric grid and assuming an investment cost of US$7,490.90/kW (Mx$82,400)—, and between 40 and 60 US¢/kWh for rural photovoltaic systems. However, it is expected that such costs can be reduced significantly in the following years.

2.2.3 Status Quo

Worldwide, there is a photovoltaic installed capacity of 13 GW in grid connected applications and approximately 2.7 GW in off-grid applications.[13] On the other hand, concentrating solar power capacity reaches 0.5 GW.

In Mexico, almost all of the photovoltaic systems are located in rural communities, isolated from the electrical grid, and many of them were installed through government programs for rural electrification. The total capacity of such installations is estimated in 18.5 MW, which generates an average of 0.032 TJ/year.[14]

Thanks to the new regulations, which make possible photovoltaic installations connected to the electrical grid (see section 4.2.6), some projects of this type already exist in Mexico (see illustration below), and there is interest from various stakeholders in developing more projects, especially in Baja California. Nonetheless, the economic feasibility strongly depends on the investment costs and on the competing electricity tariff of the system.[15]

[11] Projection for year 2010 proposed by the World Bank, 2006 (tinyurl.com/wb2006).
[12] Average figures proposed by the World Bank, 2008 (tinyurl.com/draftdoc1). See also CONUEE/ GTZ, 2009.
[13] REN21, 2009 (tinyurl.com/gsr2009). 2008 Figures.
[14] National Energy Balance 2007 (tinyurl.com/BNE2007).

Integrated Energy Services for Small Rural Communities in the Southeast of Mexico: The Ministry of Energy, through the Integrated Energy Services Project, will provide electricity to 50,000 households —approximately 250,000 inhabitants, most of them indigenous populations and among the municipalities with lowest human development index in the States of Chiapas, Guerrero, Oaxaca and Veracruz— for domestic consumption and the detonation of productive activities related to the natural vocations of the communities. This will be achieved by using the most appropriate and cost benefit renewable energy technologies, which ensure project sustainability during a 5 year execution period. The project requires the participation of different bodies of the federal (SEDESOL, CDI, FIRCO, IIE, CFE, NAFIN), state and municipal governments. Besides, it considers the direct participation of the beneficiary population, non-governmental organizations, universities, the private sector and enterprises developing renewable energies projects. The resources for its development will consist of $100 million USD, including a World Bank loan of $15 million USD, a Global Environment Facility (GEF-World Bank) grant of $15 million USD, a contribution of $30 million USD by the participating States, a contribution of $30 million USD by the beneficiary municipalities, and $10 million USD from other sources, (SENER, 2009; tinyurl.com/SIE; virastorza@energia.gob.mx)

2.2.4 Potential

The average solar insolation in Mexico is 5 kWh/day/m², but in certain regions of the country, it reaches values of 6 kWh/day/m².[16] Assuming an efficiency of 15%, a square of 25 km in Chihuahua or in the Sonora desert would be sufficient to supply all of the electricity required by the country nowadays. Thus,

Illustration 6. Grid-connected photovoltaic system

[15] CONUEE/ GTZ, 2009 (tinyurl.com/NichosFV).

Regarding to concentrating solar power, Mexico plans to build such a facility in Agua Prieta, Sonora. The facility would operate in combination with a natural gas combined cycle plant.

Solar Thermal Project Agua Prieta II: This project will contribute to the reduction of green house gas emissions through the installation of an integrated combined cycle solar system (ISCCS) using solar parabolic trough technology. The net capacity is 10 MWth when the solar field is fully integrated to the combined cycle. The project, known as Agua Prieta II, is planned to be located in the State of Sonora and will consist in a GEF grant of 49.35 million USD through the World Bank of. (World Bank, 2009) tinyurl.com/AguaPrieta; contact: jvalle@energia.gob.mx)

the technical potential could be considered as practically infinite.

However, the economic and financial potential is limited to specific niches due to the high costs of technologies. For communities, isolated from the electrical grid, the high cost for the extension of the grid implies that photovoltaic technology would be, in most of the cases, the most economic source for energy applications of a high value and low energy consumptions, such as lighting and electronic devices.

Regarding to grid connected applications, there are some market niches of at least 700 MW[17], which are financially feasible for residential consumers.

2.3 Solar radiation for thermal applications

Solar radiation has been traditionally used for a wide variety of thermal applications, such as passive solar heating and cooling of buildings, salt production or clothes, grain, wood, fish and meat drying; this in magnitudes which have never been quantified. At the same time, there are several commercial technologies for heating —water or other fluids— or cooling. Solar cooling technologies are not included here due to the fact that they have not yet reached the stage of commercial deployment.

2.3.1 Technology

The main technology for solar thermal applications is the solar water heater. Solar heaters are mainly divided into two types: flat-plate evacuated tube collectors. The first one frequently use a metallic plate for the reception of radiation, and is welded to the pipes through which water circulates; everything is placed

[16] Mulás *et al.*, 2005 (tinyurl.com/psuerm).
[17] CONUEE/ GTZ, 2009. This potential was assessed for 28 cities, not including Mexico City, and is based on investment costs of 7,490 USD$/kWp.

within a box having the upper part made of glass or any other transparent material. Low cost collectors, having plastic pipes are also provided. They are used in lower temperature applications, such as in the case of water heaters for swimming pools. Evacuated tubes are made of several metallic pipes located through the center of the glass tubes. To avoid heat losses, a vacuum is created in the space between them.

2.3.4 Potential

As for the case of solar power, the technical potential for solar thermal applications is practically unlimited. Thus, the potential for the development of this technology depends rather on the demand for low temperature fluids heating applications in residential, commercial, service, industrial and agricultural

Illustration 7. Solar water heaters

Most of solar heaters have an insulated tank in the upper part. Thanks to the thermo-siphon principle, water circulates between the heater and the tank without requiring any additional mechanism. Nonetheless, pumps are required for the circulation of the liquids, in certain applications. Efficiencies of solar heaters are typically of 50%, even though there are technologies with higher efficiencies.

2.3.2 Costs

At present, a standard solar water heater with a 150 liters storage tank and an efficiency of 50% costs around US$1,050.[18] Energy costs depend upon the size of the system and they vary between 1 and 20 US¢/kWh.[19]

Program for the Promotion of Solar Water Heaters in Mexico: The National Commission for Energy Efficiency (CONUEE), in collaboration with GTZ and the National Association of Solar Energy (ANES), have adopted the initiative of designing and implementing the Program for the Promotion of Solar Water Heaters in Mexico (PROCALSOL) with the purpose of supporting and complementing actions —which are being considered and developed in Mexico— so that the market for solar water heaters in the residential, commercial, industrial and agri-business in Mexico significantly grows during the term of the present federal administration. Likewise, PROCALSOL seeks to ensure the quality of products and offered services; to promote the national industry and technologies developed by the national research centers. The goal of the program is to have one million eight hundred thousand square meters of newly installed solar collectors by means of four Lines of Action: Regulation, Financing and Economic Incentives, Information and Management. (CONUEE, 2007; tinyurl.com/Procalsol; www.procalsol.gob.mx; contact: jbrash@conuee.gob.mx)

2.3.3 Status Quo

At the end of 2007, the world had an installed surface of approximately 208 million square meters of solar water heaters, of which Mexico had one million m^2.[20] With an annual heat generation of 41 MJ per capita, our country is lagging behind others such as Brazil (with 380 MJ), China (with 1,600 MJ) or Israel (with 17,000 MJ) per capita per year.[21]

[18] Johnson, T.; C. Alatorre, Z. Romo and F. Liu, et al., 2009, Mexico: Low-Carbon Country Case Study (MEDEC), World Bank. (in press)
[19] REN21, 2008 (tinyurl.com/gsr2007). 2007 Figures.
[20] Weiss *et al.*, 2009. Data for Mexico based on the National Energy Balance 2007 (tinyurl.com/BNE2007).
[21] Calculations based on REN21, 2008 (tinyurl.com/gsr2007) and IEA, 2008c (tinyurl.com/kwes08). Figures for these three countries exclude heating systems, which do not have glass covers and are mainly used in swimming pools.

sectors, which has been estimated in 230 PJ/year. Assuming that half of this demand could be met with solar water heaters, the potential for solar collectors would be 35 million m², providing 115 PJ/year,[22] equivalent to 2.5% of the final energy consumption in Mexico. All of this potential is economically feasible.

2.4 Hydropower

2.4.1 Technology

Standards for solar water heaters: The development of different standards is an important ingredient for the development of a market for solar water heaters. The National Technical Committee for Standardization of Solar Energy, "NESO 13", has been elaborating several voluntary standards for labeling and test methods, as well as for minimum installation requirements. On the other hand, the National Council for Standardization and Certification of Labor Competences developed a technical standard for the recognition of competences of solar water heater installers, which was published in the Official Gazette of the Federation on February 5th, 2009 (tinyurl.com/nusim005). The Mexican Federal District issued in 2006 a standard (tinyurl.com/nadf008), which mandates the installation of solar water heaters in medium (51 to 100 employees) and large-sized (more than 100 employees) establishments, as well as in those facilities with hot water requirements and performing a total refurbishment. The Solar water heater has to supply at least 30% of the annual energy consumption of each establishment. Similar standards are being considered in Guadalajara and Monterey. At present, the Mexican Official Standards for Solar Energy are: NMX-ES-001-NORMEX-2005-Solar Energy-Thermal Performance and functionality of solar collectors for water heating-Labeling and Test Methods; NMX-ES-002-NORMEX-2007-Solar Energy-Definitions and Terminology; NMX-ES-003-NORMEX-2007- Solar Energy-Minimum Requirements for the installation of solar water heaters. Furthermore, there is a draft standard PROY-NMX-ES-004-NORMEX-2009-Solar Energy-Thermal performance evaluation of solar water heaters-Test method (contact for NMX: comer@normex.com.mx). Besides, there is a technical specification to evaluate whether the systems meet with a minimum monthly saving of 13.5

[22] PROCALSOL, 2007 (tinyurl.com/Procalsol).

kg of LP-gas, which is required within the framework of the Green Mortgage of Infonavit. (http://www.conae.gob.mx/work/sites/CONAE/resources/LocalContent/6534/3/Alcance_DITfeb08.pdf; contact: Franco Buzio: onencce@mail.onncce.org.mx)

At present, the most frequently used technology to harness energy from moving water is the hydraulic turbine. There are different types of turbines, and depending on the characteristics of the site (for example, sites having a high head and low flow, or low head and a high flow), it is selected the most appropriate type. Hydraulic turbines are generally used for power generation, even though they can also be used to drive machinery directly. In addition to turbines, there are other technologies, such as hydraulic wheels and ram pumps, used in small scale applications such as water pumping.

Illustration 8. Las Trojes small hydro project (8 MW)

Small and large hydro projects: Usually, hydroelectric power stations have a dam for storing water from one season to the other. However, there are also small systems called "run-of-river", which do not require the construction of a dam, using the available water flow at any time. Large dams bring undoubted benefits for electric power systems, besides other benefits such as irrigation and flood control. However, they can also produce several environmental and social impacts. The World Commission on Dams was created in 1998 with the aim of maximizing these benefits and minimizing such impacts. It published in its 2000 final report a series of recommendations. (WCD, 2000; www.dams.org)

2.4.2 Costs

Hydroelectric power stations have relative low costs and can favorably compete with nonrenewable energy technologies. Although investment costs vary greatly from one site to another, on average, investment costs are USD$2,100/kW,[23] while power generation costs are typically between 3 and 4 USD¢/kWh.[24]

2.4.3 Status Quo

The hydroelectric installed capacity worldwide is 860GW[25]. In Mexico, the hydroelectric installed capacity is 11.4 GW, of which approximately 300 MW corresponds to small hydro projects owned by the utilities, and 90 MW of self-supply private projects. Gross generation is 27,300 GWh/year.[26] The Electricity Sector Outlook considers the construction of new hydroelectric power stations for a new added capacity of 1,224 MW over the next 10 years.

[23] In average, and according to the World Bank, 2006, the cost of small hydroelectric power stations is USD$2,300/kW, (tinyurl.com/wb2006).

[24] Electricity generation costs of small power stations are between USD¢4 and 7/kWh, according to REN21, 2008 (tinyurl.com/gsr2007), 2007 figures.

[25] REN21, 2009 (tinyurl.com/gsr2009).

[26] Data for 2007 obtained from the Electricity Sector Outlook 2008-2017 (tinyurl.com/PSE2017) and from the Energy Regulatory Commission. Neither the few hydroelectric power stations of rural communities, isolated from the electrical grid, nor the facilities for applications different to power generation are included.

2.4.4 Potential

The Federal Electricity Commission (CFE) has identified the hydroelectric potential of the country in those sites with an average capacity of more than 5 MW. Excluding projects already in operation, or in their planning stage, the identified potential is 39 GW.[27] This is a purely illustrative estimate of the potential, since the technical, economic, environmental and social feasibility has not yet been defined for many of these projects. However, one can assume that at least 25% of this potential is feasible.

There is also an important potential in smaller hydro projects, but with the exception of a study carried out in a region of the States of Puebla and Veracruz,[28] such a potential has not been evaluated. A preliminary estimation of the national potential for small hydro projects indicates a potential of around 3 GW.[29] As the different benefits of the small hydropower are acknowledged, including their impact on climate change mitigation, their potential will be economic and financially feasible.

There is also a non-identified potential in the construction of micro hydro projects for the supply of electricity in isolated communities, as well as in other energy services such as water pumping by means of ram pumps.

2.5 Bioenergy

2.5.1 Technology

Bioenergy, in all of its different forms, can be used in thermal applications, for power generation or the production of liquid biofuels for transportation.

In regards to thermal applications, the most used technologies in Mexico are the traditional firewood stoves, used for cooking and heating of rural households and small cities. Likewise, firewood is used in micro and small industries for the production of ceramics, bricks, bread and other products. During the last decades, different models of firewood furnace and stoves have been developed and improved with the aim of reducing health impacts of smoke produced by traditional firewood stoves, as well as for the reduction of wood consumption.

[27] Calculations based on CFE, 2000.
[28] CONAE, 1995.
[29] Mulás *et al*., 2005 (tinyurl.com/psuerm)

Open for Ecological Stoves Substitution Program: As part of the Program for the Development of Priority Zones, the Ministry of Social Development, through the Micro-regions Unit and in coordination with CONAFOR and CDI, is substituting open stoves by improved firewood stoves in rural communities across the country, with emphasis on the municipalities of the 100 x100 Strategy. The project is trying to reduce indoor air pollution due to excessive smoke; to protect the environment by reducing the use of biomass as an energy source; to generate mechanisms for energy saving that can be translated into benefits to the family economy; and to reduce polluting emissions. In the mean time, mass communication strategies are being generated to make the population aware of the problems related to the use of firewood and its adverse impacts on health, the environment and the quality of life. (SEMARNAT, 2008; tinyurl.com/trdsapf8; www.microrregiones.gob.mx/pdzp.html; contact: ramon.medina@sedesol.gob.mx)

Illustration 9. "Onil" Improved firewood stove in Zinacantán, Chiapas

Biomass is also used in several industrial applications: energy contained in biomass products and its derivatives such as sugar cane bagasse, black liquor, biogas and several agricultural and agro-industrial residues, which are used for industrial applications in boilers and other technologies for heat production and, in certain cases, power generation.

Finally, biomass is used for the production of biofuels in several countries, led by Brazil, United States and Germany. The main biofuels are bioethanol (ethylic alcohol) and biodiesel. Both can be blended with gasoline and diesel in small proportions (less than 10%), respectively, without the need of adapting the engines of modern vehicles. Bioethanol can be produced from sugar crops (such as sugar cane, sugar beet and sweet sorghum), starchy crops (such as maize and yucca) and cellulose materials. On the other hand, biodiesel is elaborated with different oil seeds such as palm oil, pine nut (jatropha) or colza.[30]

Biofuel Programs: With the goal of promoting the production and use of biofuels in Mexico, the Federal Government has been working on the elaboration of an Inter-secretarial Strategy on Bioenergy (2008), and will be complemented with two sectorial programs: the Program for the Sustainable Production of Bioenergy Inputs and for the Scientific and Technological Development (2008), led by SAGARPA, and the Program for the Introduction of Bioenergy (2008), led by the Ministry of Energy. With the Strategy and the Programs "the basis for the integration of the agricultural sector to the energy activity will be established, contributing to energy diversification and sustainable development, without jeopardizing food safety. Furthermore, they will contribute to the reactivation of the rural sector and the improvement in the quality of life of the population, in particular those with high and very high marginality," setting a 2012 goal of 300 thousand hectares dedicated to biofuel input crops, especially bioethanol and biodiesel. (SENER/ SAGARPA/ SEMARNAT; tinyurl.com/eibioen; tinyurl.com/ppsibio; tinyurl.com/; contact: SENER, garboleya@energia.gob.mx; SAGARPA, miguel.cervantes@sagarpa.gob.mx; SEMARNAT, jlestrade@semarnat.gob.mx)

2.5.2 Costs

The Investment costs for electricity and/or heat generation from biomass technologies, at an industrial scale, are approximately USD$1,500/kW. The corresponding generation costs are between 5 and 12 USD¢/kWh for power generation, and between 1 and 5 USD¢/kWh for heat.[31]

Improved firewood stoves cost roughly USD$150, including training and follow up costs.

[30] FAO, 2008 (tinyurl.com/sofaesp).

[31] Figures for wood pellets technology. Projection of investment costs for electricity generation from the World Bank, 2006 (tinyurl.com/wb2006), and costs of thermal applications proposed by Masera *et al.*, 2006b (tinyurl.com/biocds). Energy costs based on REN21, 2008 (tinyurl.com/gsr2007).

Finally, bioethanol and biodiesel production plants require investments of USD$390 and $330/(m³-yr) of capacity. Production costs vary according to local conditions, but international references suggest values between 25 and 30 USD¢/liter for bioethanol, and between 40 and 80 USD¢/liter for biodiesel. [32]

Sustainable Rural Development Project for the Promotion of Alternative Energy Sources in Agri-business: The Trust Fund for Shared Risk of the Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food, is implementing a renewable energy project, within its support program for agri-business. The project consists of several financing sources, including a grant from the Global Environment Facility (GEF), as well as credits via a mechanism for investment reimbursement during a 5-years scenario The project supports solar energy installations, wind energy and bio-digestors in several productive applications, as well as energy efficiency improvements. (tinyurl.com/fae2009, tinyurl.com/fircoper; contact: omontufar@firco.gob.mx)

2.5.3 Status Quo

Modern biomass energy technologies supply 4% of the global demand for primary energy in the form of heat, electricity and liquid fuels,[33] mainly in developed countries. In Mexico, sugar cane bagasse is, after firewood, the main source of bioenergy in sugar cane mills, and it is used to cover their own needs of heat and power. It is estimated an annual bagasse consumption of 100 PJ, equivalent to 1.2% of Mexico's total primary energy supply.[34]

On the other hand, traditional biomass technologies supply 6% of world primary energy demand. The traditional use of firewood contributes with 3% of energy supply and 28% of energy consumption in the residential sector in Mexico. It is estimated that around one fourth of the population uses this type of fuel in traditional stoves.

[32] Investment costs, Johnson et al., 2009 (in press). Fuel costs based on REN21, 2008 (tinyurl.com/gsr2007). Fuel costs are referred to liters of gasoline and diesel equivalent, according to the heat capacity of fuels. Bioethanol data refer to sugar cane-based bioethanol.
[33] IEA, 2008d (www.worldenergyoutlook.org).
[34] National Energy Balance 2007 (tinyurl.com/BNE2007).

2.5.4 Potencial

The potential of bioenergy in Mexico goes far beyond than the limited use it has at present. The potential is estimated between 3,000 and 4,500 PJ/year,[35] and is divided into wood fuels (from natural forests or plantations, forestry and wood industry byproducts), agro-fuels and biogas from landfills. This potential would be enough, in a sustainable manner:

- To meet energy needs of the population for cooking and heating through improved stoves, instead of using firewood.
- To produce charcoal for domestic use, small business and the substitution of coke in the steel industry.
- To generate approximately 50,000 GWh of electricity per year in small wood-fired power plants (i.e. 20% of the national consumption of electricity).
- To produce bioethanol and biodiesel, meeting up to 10% and 5% of gasoline and diesel demand, respectively.[36]

With the exception of the production of biofuels, all these options are, at present, economically feasible, as long as their advantages are evaluated regarding the reduction of health impacts due to the use of traditional stoves, and the reduction of deforestation due to a sustainable forestry management.

2.6 Geothermal

2.6.1 Technology

Geothermal, or the heat of the earth's interior, can be used either for power generation or thermal applications, such as indoors heating, spa bathing and industrial or agro-industrial processes. There are five types of geothermal resources and each one is associated to specific technologies: (a) hydrothermal systems, (b) hot dry rock (c) geopressure, (d) submarine, and (e) magmatic.[37] The first are those currently exploited in Mexico, as in other countries, while the other four are still in their research and development stages.

[35] Between 35% and 55% of nation's gross energy supply. Masera *et al.*, 2006b (tinyurl.com/biocds). See also Masera, 2006 (tinyurl.com/pvubbtm).
[36] Masera, 2006 (tinyurl.com/pvubbtm).
[37] Mulás *et al.*, 2005 (tinyurl.com/psuerm).

Illustration 10. Geothermal power plant in Los Azufres, Michoacan

At the same time, hydrothermal systems are divided into high and low enthalpy resources. The first one can be used for power generation, while the latter are normally used only for thermal applications.

2.6.2 Costs

Geothermal power requires high investment costs in exploration, drilling and in the construction of the power plant. Investment costs are approximately USD$3,800/kW, and power generation costs are between 4 and 7 USD¢/kWh. Regarding thermal applications of geothermal resources, their costs are lower between 0.5 and 2 USD¢/kWh.[38] Such costs are competitive with other options.

2.6.3 Status Quo

Worldwide geothermal power capacity is slightly above 10 GW.[39] Our country has, more or less, the tenth part of such capacity -960 MW, occupying the third place worldwide. The Electricity Sector Outlook considers the addition of 233 MW during the next ten years.[40] At present, and regarding thermal applications, these are mainly geothermal spa waters, even though few cases are reported of its use in building heating, wood drying, green houses and mushroom crops.[41]

[38] Figures refer to binary technology. Cost projections for technology up to year 2010, according to the World Bank, 2006 (tinyurl.com/wb2006). Energy costs, REN21, 2008 (tinyurl.com/gsr2007).
[39] REN21, 2008 (tinyurl.com/gsr2007).
[40] Electricity Sector Outlook 2008-2017 (tinyurl.com/PSE2017).
[41] Mulás *et al*., 2005 (tinyurl.com/psuerm).

2.6.4 Potential

Due to the high cost for geothermal exploration, a detailed evaluation of the geothermal potential in our country has not yet been carried out. Nonetheless, some estimates have been done. Regarding to high temperature reserves (suited for power generation), a potential of around 12 GWel has been estimated.[42] Low temperature reserves are much higher than the first one (for example, a study suggests a figure of 45 GWel[43] by summing up the potential of two regions of the central and Northern part of the country), which implies that it would be possible to use this practically unlimited potential for industrial and residential applications in these regions. In summary, the technical and economic potential of electrical and thermal applications has not yet been evaluated.

[42] Mercado (1976) proposes a potential of 13 GW, while Alonso (1985) suggests a figure of 12 GW, divided as follows: proven reserves 1.3 GW, probable 4.6 GW, and possible 6 GW.
[43] Mercado *et al*., 1985.

3 Benefits and particularities

3.1 Benefits of renewable energies

International experience shows that renewable energies produce several types of benefits to energy systems and to countries as a whole. These benefits are economic as well as social and environmental. Next, we will revise such benefits in regards to the Mexican case.

3.1.1 Economic benefits

Energy costs and economic risks reduction

Many renewable energy technologies, such as solar water heaters or rural electrification systems for isolated communities, are the most economic options for their users. Thus, their use brings them important savings in a direct manner. Other renewable energy technologies, such as wind power, seem to be more costly than conventional technologies when evaluated without carrying out a detailed analysis. Nevertheless, when analyzing the energy system as a whole and taking into account not only energy costs, but also the risks related to the variability of such costs, it can be observed that renewable energies thanks to their low/ no risk level, indeed in many cases, may lead to cost reductions.

Portfolio-based Planning for Electricity Generation in Mexico: Low risks of renewable energies are due to the fact that once the infrastructure investment has been made, operation costs are practically constant. Cost reduction due to the minor risks of renewable energies can be observed by using the modern techniques of risk analysis and risk management applied to energy systems. One of such techniques is the "modern portfolio theory", originally designed by the Nobel Laureate Harry Markowitz, which "proposes that the investor should approach a portfolio as a whole, studying the characteristics of global risk and return (or cost), instead of choosing individual securities because of the expected return of each security" (es.wikipedia.org: *portfolio theory*). When applying this theory to energy systems, it can be proved that the optimum solution is to have an adequate balance between high risk and low risk sources, even if these are more expensive when evaluated in an individual manner. (See also Cabraal *et al.*, 2007; Awerbuch, 2004; Bolinger *et al.*, 2003).
The Ministry of Energy is, at present, developing a planning model called "Optimization Model of Technology Portfolios for Electricity Generation in Mexico" (MOPTEG), in which risk factor is taken into account during planning. (www.awerbuch.com; tinyurl.com/4jy832; tinyurl.com/4fvldh; tinyurl.com/5yrf9c

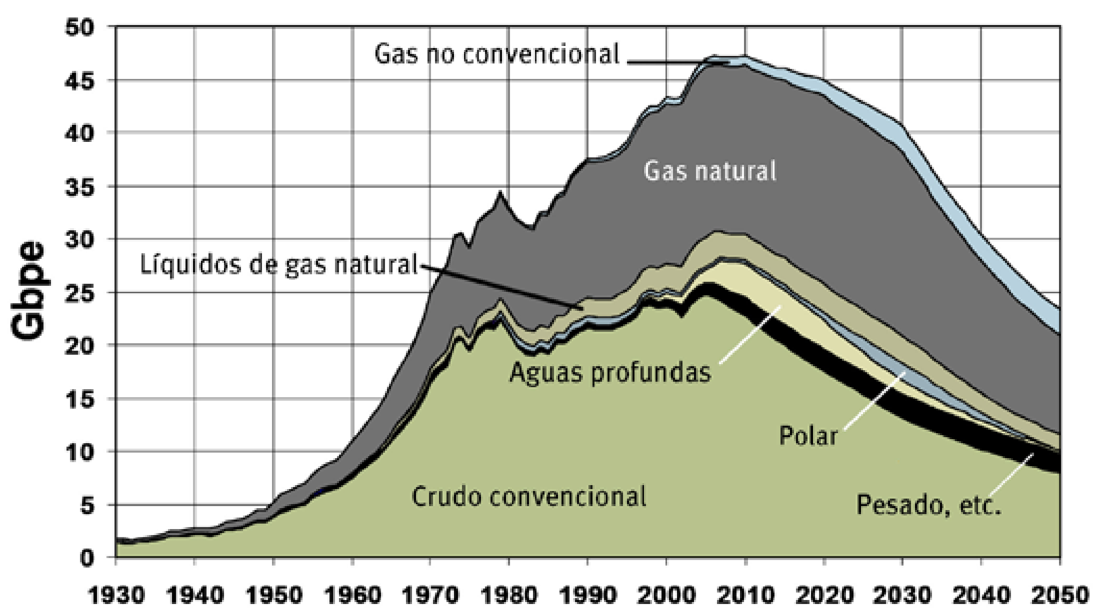
Contribution to energy sovereignty

Since the seventies, our country has been an important energy exporter, mainly crude oil. Nevertheless, at present, crude oil production has been reduced mainly due to the decline of Cantarell, the main oil field of the country, while the imports of natural gas, gasoline, coal and other oil-derived products have been increased. In 2007, the economic value of fossil fuel imports surpassed 40% of the exports value, and such a percentage is still increasing. Participation of renewable energies would allow us to preserve our non-renewable resources; hence, postponing the possible moment in which the country would become a net energy importer. Thus, they will contribute to further energy sovereignty; i.e. less dependency on other countries regarding energy.

Increased security of energy supply

The future supply of fossil fuels worldwide is an issue that concerns more and more stakeholders. According to the International Energy Agency (IEA), world oil production will increase from 82 to 104 million barrels per day between 2007 and 2030.[44] In contrast, some analysts of the world industry of hydrocarbons claim that we are already at the peak of the curve of the global hydrocarbon production (see illustration below).

Illustration 11. Scenario evolution of worlwide hydrocarbons production



Source: ASPO, 2008.
Gbpe: Thousands million barrels of oil equivalent per year.

[44] IEA, 2008d (www.worldenergyoutlook.org).

Ilustración 12. Solar water heaters in household applications

Within this context, it is necessary to seriously consider the possible scenarios, and to take into account that there are restriction risks of energy supply in the medium and long term. In any scenario, renewable energies play an important role in increasing security of energy supply.

3.1.2 Social benefits: Rural and industrial development

Increased access to sustainable energy services in rural areas

Energy stock is one of the main engines for rural development, and quite frequently, renewable energies are the best option for supplying energy services to rural communities. Particularly, rural electrification with renewable energies is, in many cases, a more profitable option than grid extensions for 2.5% of the households of the country with no access to electricity.[45] In the rural environment, there are also other thermal and mechanical applications of renewable energies, such as efficient firewood stoves, bio-digestors, wind and ram pumps, which are relevant for domestic, as well as for productive applications.

[45] INEGI, 2008 (tinyurl.com/cpv2005).

Fostering industrial and rural development

Renewable energy technologies are more labor intensive than conventional energy technologies. International experience shows that their manufacturing and operation leads to the creation of a local value chain with the creation of small enterprises and employment. It is estimated that, at present, 2.3 million people work in the industry of renewable energies.[46] According to this data, it is estimated that the accelerated development of renewable energies in Mexico, together with mechanisms of industrial policy, could create at least 100,000 employments.

In addition, international experience shows that many of the projects for renewable energies are located in rural areas and do have positive impacts on rural development.[47] Such impacts are translated into further income for the inhabitants (through leasing contracts, local employment, or through the participation of the inhabitants as project partners). There may also be other types of impacts, for example, in education, job training, entrepreneurial capacity development, etc. As it happens with any other project for rural development, the positive impact of renewable energy projects depend upon the measure in which adequate mechanisms are generated for the flow of information, the distribution of benefits, the strengthened of social capital, and the development of long term social projects.

3.1.3 Global and local environmental benefits

Mitigation of climate change

In Mexico, the energy sector contributes with 61% of the emissions of greenhouse gases, and the country occupies the 13th place worldwide regarding this type of emissions.[48] The use of renewable energies, when displacing the consumption of fossil fuels, constitutes one of the main strategies for the mitigation of the climate change worldwide. Due to its high vulnerability to climate change, and to preach by example to the international community, our country has a special interest in promoting global mitigation mechanisms. Besides, the development of renewable energy projects represents an important opportunity for capturing international resources in the carbon bonds markets (the Clean Development Mechanism of the Kyoto Protocol and others such as the voluntary markets).

[46] Worldwatch, 2008 (tinyurl.com/3snlfr). The tenth part of this figure is concentrated in Germany.
[47] See REN21, 2005 (tinyurl.com/retsmdg).
[48] ENACC, 2007 (tinyurl.com/3nkhly).

Impact reduction of the energy sector on health and environment

The energy sector produces emissions of other gases and particle pollutants, which have direct or indirect local effects on health of the human population, the conservation of biodiversity, and the preservation of historic monuments. Especially, the case of sulphur dioxide (SO_2), which reacts with the atmosphere to form sulphuric acid, causes acid rain as well as suspended particles, resulting in damage to health. Renewable energies allow the displacement of the consumption of fossil fuels, thus reducing such impacts.[49]

Renewable energies may contribute to the protection of forests and jungles

The use of renewable energies may, in certain cases, increase the economic value of jungles and other biodiversity rich zones, and thus increasing not only the interest of local populations, owners and forest tenure holders in their conservation, but also the generation of local employment and the forest income. This especially happens in the case of two technologies: hydroelectric power (whose proper functioning is necessary to ensure the conservation of vegetation and soils in the basins) and bioenergy. There are several positive experiences in the world of how energy systems can contribute to the preservation of relevant areas because of their environmental value.

3.2 Particularities of renewable energies

Besides the aforementioned benefits, renewable energy sources and their associated technologies have some particularities, which make them intrinsically different to conventional energy sources and technologies.

3.2.1 Small scale and territorial dispersion

With the exception of technologies, such as the hydropower and geothermal, which can obtain in one place significant amounts of energy, renewable energies are generally dispersed throughout the territory. This means that there is a need for a larger territory in order to obtain a given amount of energy in comparison with conventional technologies. Hence, renewable energy projects are usually of a smaller scale than those of conventional energy. When the operating rules of energy systems have been conceived for large scale technologies, the above feature of renewable energy projects turns into an obstacle for their development.

[49] According to a study (ECLA and SEMARNAT, 2004; tinyurl.com/MEXL644), health impacts of the main thermoelectrics in Mexico are equivalent to 465 million USD per year. See also, Bickel and Friedrich, 2005 (tinyurl.com/ExternE).

[50] See in CMR, 2000 (tinyurl.com/wcdesp) examples of how hydroelectric power stations can be planned, constructed, and operated, while reducing negative environmental impacts and maximizing positive impacts. Regarding an example of positive impacts of a bioenergy system, based on sustainable forest production, see Peryn et al., 2008.

3.2.2 Time variability

Many of the renewable energy technologies depend upon variable natural processes which turns their availability into non-predictable or controllable result. This particularity of renewable energies is especially relevant for power generation. Indeed, in the case of electrical power systems, it is required that the power supply meets the demand at any time (this is due, in part, to the fact that batteries and other technologies for the storage of electricity are still too expensive for their application on a large scale). Presently, many of the conventional technologies for electricity generation, which can be started and stopped when required, allow electrical power systems to bring the required capacity and meet the demand, mainly during peak hours. On the other hand, many of the technologies based on renewable energies (especially wind and solar) depend upon the availability of an uncontrollable energy source.

This *non-controllable* feature of these energy sources has been one of the obstacles for a greater participation in electricity generation. It has been sometimes argued that a power plant, which relies on an "intermittent" source, can substitute the use of fuels, but cannot contribute to the capacity of the electric power system. This means that there is the need of having a conventional station ready to enter into operation whenever the intermittent resource is not available. However, during recent years, new criteria for the planning and operation of electric power systems have been developed. Such criteria show that intermittent or variable technologies can contribute to the generating capacity of the electric power systems.

The maximum percentage of participation of variable sources in an electric system depends on its flexibility, and there are several mechanisms to increase it, such as: (i) stronger interconnections with neighboring electrical systems; (ii) additional biomass and hydropower capacity so as to increase the flexibility of the system; (iii) new generation and grid control technologies, and (iv) demand side management (for example interruptible contracts or real time tariffs).[51]

3.2.3 Higher Initial Investment

Investment costs per MW of renewable energies are higher than those of conventional technologies; while their operation costs are lower (see typical costs of the main renewable energy technologies as well as other data shown in the table below). This particularity turns into another barrier for the development of renewable energies, especially within the context of a lack of finance for investments.

[51] The German project Kombikraftwerk evaluates the feasibility of a 100% electricity supply in that country through renewable energies. Kombikraftwerk, 2009 (www.kombikraftwerk.de), IEA, 2008b (tinyurl.com/VarRen).

Table 3. Status Quo, potential, and costs for renewable and non-renewable energies

Applications	Sources/technologies	Status in Mexico		Referencia internacional	
		Energy production in Mexico [GW average][1]	Technical-economic-potencial [GW average][1]	Energy cost [US$/GJ]	Investment cost [US$/kW]
Electricity	Natural Gas	13.9[2]	-	$7.0-19.4[3]	$898[3,5]
	Coal	4.0[2,6]	-	$6.5-7.3[3]	$2,069[3,7]
	Diesel and fuel oil	5.8[2]	-	$11.3-15.6[3]	•$2,483[3,8]
	On-shore wind power	0.066[2,9]	3[10]	$15-20[11]	$1,700[4]
	Off-shore wind power	0	-[12]	$20-35[11]	$2,700[13]
	Off-grid solar photovoltaic	0.000001[14]	0.02[15]	$110-170[11]	$16,000[16]
	Grid connected solar photovoltaic	≈0	0.09[17]	$80-140 [11]	$8,000[4]
	Concentring solar power	0	-[12]	$30-50[11]	$2,200[18]
	Large hydropowe (>10 MW)	3.0[2]	39[19]	$8-11[11]	$2,100[18]
	Small hydropowe (<10 MW)	0.16[2]	3[20]	$10-20[11]	$2,300[18]
	Bioenergy	0.09[2,21]	10[22]	$15-30[11,23]	$1,550[18,23]
	Geothemal power	0.85[2]	10[24]	$10-20[11]	$3,800[18,25]
Heat	Industrial Boiler	9.4[14,26]	-	$8.5[27]	$140[27]
	Water heater	3.9[14,28,29]	-	$24[29,30]	$10[31]
	Modern bioenergy	0.14[14]	3.2[32]	$3-50[11]	$630[33]
	Bioenergía moderna	-[34]	4.7[35]	$2-7[27]	$530[27]
	Geothemal	-[36]	-[37]	$1.5-5[11]	$200[38]
Liquid fuels for transportation	Gasoline	44[14,39]	-	$17[30]	-[40]
	Diesel	18[14,39]	-	$14[30]	-[40]
	Bioethanol	-	3[42]	$7.5-9[11,43]	$580[33]
	Biodiesel	0.005[44]	0.7[42]	$11-22[11]	$300[33]

Notes:

[1] Annual energy production is expressed in terms of "*average GW* ". In the case of electrical and thermal applications, each unit is equivalent to 8760 GWh or 31.5 PJ per year; in the case of bioethanol and biodiesel each unit is equivalent to 1.49 million of m³ per year and 0.90 millions of m³ per year, respectively.

[2] Estimated values from the Electricity Sector Outlook and the Energy Regulatory Commission.

[3] Royal Academy of Engineering, 2004

[4] World Bank, 2008 (tinyurl.com/draftdoc1), average figures.

[5] Combined cycle.

[6] Including coke.

[7] Supercritical technology.

[8] Diesel and internal combustion.

[9] It includes new wind farms inaugurated in January 2009.

[10] Based on the assumption of a potential of 10,000 MW and an average load factor of 30%.

[11] REN21, 2008 (tinyurl.com/gsr2007).

[12] Technologies with still very high costs, to be financially viable.

[13] Approximation based on REN21, 2008, and World Bank, 2008.

[14] National Energy Balance 2007 (tinyurl.com/BNE2007).

[15] Assuming 3% of the population with no access to electricity, 5 people per household; 80% of the demand is covered by photovoltaic

systems (the remaining 20% by other technologies); 120 W peak systems; 7 hours per day.
[16] Assuming USD$2,000 for the system described in the previous note.
[17] Assuming an average load factor of 12.5% and a potential of 700 MW; CONUEE/ GTZ, 2009 (tinyurl.com/NichosFV)
[18] World Bank, 2006 (tinyurl.com/wb2006), 2010 figures.
[19] Studies carried out by CFE.
[20] Mulás *et al*., 2005 (tinyurl.com/psuerm).
[21] Includes biogas (Monterrey), sugar cane mills, and black liquor from the paper industry.
[22] Islas et al., 2007 (tinyurl.com/apsobuim).
[23] Pellet technology and steam turbines.
[24] Alonso (1985).
[25] Binary technology.
[26] Assuming that 70% of fuel consumption in industry (excluding self-supply and co-generation) is used in boilers with an efficiency of 80%.
[27] RETScreen International, 2006 (tinyurl.com/APCbiomass).
[28] Assuming that 50% of fuel consumption in the residential, commercial and service sectors is used by water heaters.
[29] Assuming water heaters with an efficiency of 60%.
[30] Considering the cost of fuels at present prices in Mexico in April, 2009.
[31] Assuming a USD$90 heater, which allows an outlet temperature up to 25°C and a heating capacity of 5 liters of water per minute.
[32] Assuming that half of the energy demand for low temperature needs is met by solar heating.
[33] Johnson et al., 2009 (in press)
[34] There is no information.
[35] Assuming that 50% of the industrial boilers could be fired with biomass; according to Masera et al., 2006b, the existing dendro energy potential can meet such a need. (tinyurl.com/biocds).
[36] The use of geothermal heat in applications such as spa bathing, building heating, wood drying, green houses and mushroom crops has not been quantified.
[37] Geothermal could meet a significatant part of industrial thermal needs in specific regions of the country, but this potential has not yet been evaluated.
[38] IEA, 2007 (tinyurl.com/IEArhc).
[39] Data for gasoline and diesel correspond to the national consumption for transportation.
[40] The investment costs, required to increase oil production and the refining capacity, are not included.
[41] At present, Mexico produces bioethanol, but not as a fuel.
[42] Masera *et al*., 2006 (tinyurl.com/pvubbtm).
[43] Costs for sugar cane based bioethanol.
[44] Masera *et al*., 2006b (tinyurl.com/biocds).

4 Strategies for promotion and development

4.1 Policies for renewable energies around the world

4.1.1 The triple objective of policies

The purpose of policies for the promotion of renewable energies around the world is threefold. First, they seek to recognize and value the benefits of renewable energies. Many of these benefits have not been evaluated at present, and in this sense, they can be considered as *externalities*, which should be *internalized*.[52]

Second, to adapt systems and energy markets to the particularities of renewable energies. Current energy systems and markets were designed for non renewable energies; and require specific public policy instruments in order to suit the features of renewable energies.

Finally, to promote the flow of information. The lack of information regarding potentials, characteristics of the technologies, costs and benefits to the society, etc., increase perceived risks; hence, the costs of renewable energies. Further access to information allows for risk and costs reduction.

4.1.2 Characteristics of effective policies

The three purposes mentioned above lead to the following features that policies should have for the promotion of renewable energies:

- Policies should allow the participation of small-scale stakeholders in energy markets. Due to the geographic dispersion of energy sources, renewable energy projects are, in most of the cases, of a minor scale than projects based on conventional technologies.
- Based on the above mentioned feature and the high investment requirements, the participation of private stakeholders (individuals and companies) is needed during the financing, execution, and operation of renewable energy projects. Similarly, many of these projects are linked to other productive processes and uses of the territory; thus, policies should allow the participation of the involved stakeholders.

[52] Externalities are positive or negative impacts on a third party that occur as a by-product during the provision of a good or a service. Externalities occur when private costs or benefits, in which producers or buyers incurred in the provision of any good or service, are different to the total social costs or benefits involved during their production and consumption.

- Due to the high investment requirements, it is of special importance that policies should offer a long term certainty; and they should guarantee simple and transparent administrative procedures so as to reduce risks (hence costs) in the project development process.
- On the other hand, the territorial dimension of renewable energy projects implies the need for administrative simplification, and certainty in the political instruments associated with territory planning at federal, state and municipal levels.
- Public policies should establish mechanisms, which may allow the assessment of the different benefits of renewable energies. To this end, international experience shows the need for establishing financial incentive mechanisms. Amongst the several mechanisms used in the world, the most effective systems have been pre-defined prices per kWh due to the fact that they create certainty, which allows reduction of project risks to a minimum, especially in small scale projects.[53]
- In the case of electric power systems, policies should establish procedures for the adjustment of the planning and operation stages of such systems to new and more distributed generation schemes, as well as variable generation technologies.

4.2.4 Mexican legal, regulatory and normative framework

4.2.1 Constitution

The use of renewable energies is rooted in several constitutional articles[54], amongst which the following should be emphasized:

- **Article 4**, establishes the right to an adequate environment.
- **Article 25** establishes that the State is responsible for leading the development of the nation, which will be integral and sustainable, while strengthening the sovereignty of the nation.
- **Article 27**, in paragraph three, grants the Nation right of regulating the exploitation of natural resources, which are susceptible of appropriation — including non renewable energy sources —, with the purpose of achieving not only an even distribution of public wealth, but also a balanced development across the country, including improved living conditions of both, rural and urban populations."
- **Article 28** establishes the need of assuring the effectiveness of the rendering of services and the social use of such goods.

[53] Systems of pre-defined tariffs are known as *feed-in tariff systems*. See International Feed-in Cooperation, 2009 (www.feed-in-cooperation.org); Bode and Groscurth, 2008 (tinyurl.com/5jye5u); REN21, 2008 (tinyurl.com/gsr2007); IEA, 2008a (tinyurl.com/acq8ok).
[54] Political Constitution of the Mexican United States (Constitución Política de los Estados Unidos Mexicanos) (tinyurl.com/cpdleum).

4.2.2 International Agreements

Our country is a signatory of the United Nations Framework Convention on Climate Change. Even though it is a country that has no emission reduction obligations, it should "formulate, apply, publish, and regularly update national and, where appropriate, regional programs for climate change mitigation measures[...]".[55]

4.2.3 Law for the Use of Renewable Energies and Financing of Energy Transition (LAERFTE)

On November 28th, 2008, the Official Gazette of the Federation published the Law for the Use of Renewable Energies and Financing of Energy Transition.[56] The law seeks to regulate the use of renewable energies for electricity generation "in different purposes than those of public service"; it sets out the following:

- The Ministry of Energy (SENER) will elaborate a Special Program for the Use of Renewable Energies —published in the Official Gazette of the Federation on August 6th, 2009— to evaluate the net economic benefits of renewable power generation (article 12). Such benefits will be considered in the economic evaluation of renewable energy projects carried out by the state-owned electric power utilities (article 13).
- SENER will elaborate a National Inventory of Renewable Energies (article 6°, fraction VI).
- SENER, considering the opinions of SHCP, SEMARNAT and SSA, will elaborate a methodology to evaluate the externalities associated to renewable power generation (article 10).
- The Energy Regulatory Commission (CRE) will issue norms, guidelines, methodologies and other administrative provisions, which will regulate the electricity generated with renewable energies (article 7°, fraction I).
- CRE will define the rates that power utilities should pay for to private generators, including coordination with SHCP and SENER (article 7°, fraction II).
- CRE will issue the methodologies to determine the capacity contribution of renewable energy technologies (article 7°, fraction V).
- The above mentioned rates for power generation must include both, capacity and energy payments, depending on the technology and geographic location of the projects (article 14).

[55] CMNUCC, 1992 (tinyurl.com/cmnucc). Article 4°, fraction I, clause "b".
[56] LAERFTE, 2008 (tinyurl.com/laerfte).

4.2.4 Law for the Promotion and Development of Bioenergy

This law,[57] published in the Official Gazette of the Federation on February 1st, 2008, considers, among other issues, the following:

- The creation of an Inter-secretarial Commission on Bioenergy, integrated by representatives of SENER, SAGARPA, SEMARNAT, SE and SHCP.
- The implementation of a Program for the Sustainable Production of Bioenergy Inputs and for Scientific and Technological Development by SAGARPA, with the aim of creating adequate conditions for the production of bioenergy in Mexico (mainly bioethanol and biodiesel).
- The implementation of a Program for the Introduction of Bioenergy, with the aim of creating the necessary changes in the energy sector for the incorporation of biofuels in the fossil fuel mix.

4.2.5 The Law for the Sustainable Use of Energy (LASE)

The Law for the Sustainable Use of Energy[58] transforms CONAE into CONUEE (National Commission for Energy Efficiency), and establishes the implementation of a National Program for the Sustainable Use of Energy. LASE mainly addresses energy efficiency, but it includes the use of renewable energies for thermal applications.

4.2.6 Regulatory Instruments for the electric power sector

The Energy Regulatory Commission has issued three resolutions related to electricity generation from renewable energies.

Interconnection contract for intermittent renewable energies (CIEI)

This contract[59] is applicable to self-supply remote projects using intermittent renewable energy sources, i.e. wind, solar or hydropower (the latter refers to those cases where the water flow cannot be controlled). Remote projects are those in which the power plant and the end users are not located at the same site; hence, it is necessary to use the transmission grid in order to transport energy between different sites. In general terms, the contract establishes the following:

[57] LPDB, 2008 (tinyurl.com/ldpyddlb). The corresponding ordinance was published on June 18th, 2009: RLPDB, 2009 (tinyurl.com/rldpyddlb).
[58] LASE, 2008 (tinyurl.com/LApSuEn).
[59] Interconnection Contract for intermittent renewable energies, 2007 (tinyurl.com/res140).

- Payments for transmission services will be according to the actual transmitted capacity and energy, instead of the reserved power.
- The electric power system will play the role of a power pool, and will compensate, within the same or different load intervals, either the surplus or the non-delivered energy. Surplus power, available at any given load interval, can be used to compensate the non-delivered at other times, according to the corresponding electricity tariffs.
- In order to estimate the charge for billable demand to the end users, the monthly average supplied energy - during the hour of maximum demand for all the working days of the month - is acknowledged as the capacity contribution to the system.
- At present, and thanks to this favorable contract for self-supply projects, several wind and hydroelectric projects are in their design or construction processes.

Interconnection contract for small scale solar energy sources

This contract[60] allows households and small businesses, connected to the electrical grid, to generate their own electricity using solar energy under the modality of *net metering*. In case of electricity surplus, the private generator may exchange energy with the electric power utility, which can be compensated with the consumption at other times.

Contract Model for the Sale and Purchase of Electricity under the Modality of Small Power Producer

This contract[61] is applicable to any small scale project (capacity under 30 MW for the sole purpose of selling generated electricity to the electric power utilities); it offers a preferential condition to those projects using renewable energies.[62]

4.2.7 Standards and technical specifications

Official (NOM) and voluntary (NMX) standards are a fundamental ingredient to facilitate the development of renewable energies, since they facilitate decision making for consumers, producers and different levels of government. At present, there are, or are in process of elaboration, the following norms related to renewable energies:

[60] Interconnection contract for small scale solar energy sources, 2007 (tinyurl.com/solarpeq).
[61] Contract Model for the Sale and Purchase of Electricity under the Modality of Small Power Producer, 2008 (tinyurl.com/ContPeq).
[62] Electricity is normally purchased at 85% of the short term total cost when there is no previous notification or at 95% when there is a previous notification. In the case of renewable energies, such percentage is increased to 95% and 98%, respectively.

- The Mexican Official Standard for the construction, operation and abandonment of wind facilities in agricultural, livestock and wastelands, which is being developed by SEMARNAT (see chapter 2).
- Voluntary standards for labeling and test methods, and minimum installation requirements for solar water heaters, amongst others, developed by the National Technical Committee for Standardization of Solar Energy, "NESO 13" (see chapter 2).
- The Technical Standard for the Recognition of Competences of Solar Water Heater Installers, developed by the National Council for Standardization and Certification of Labor Competences (see chapter 2).
- Mexican Federal District's environmental standard for technical specifications related to solar swimming pool heating and other applications (see chapter 2).

Technical specifications for the interconnection to the electrical grid

Requirements for the interconnection of wind generation (Grid Code): This document establishes the terms and conditions for the interconnection of wind generators to the National Electric Power System (in force since the July 1st, 2008), as well as the requirements for facilities connected to 115 kV and higher voltage systems. (contact: Ing. Eduardo Meraz: eduardo.meraz@cfe.gob.mx)

Technical interconnection requirements to the low-voltage grid for photovoltaic systems up to 30 kW (G0 100-04): This specification has the objective of defining the requirements for the design, installation, inspection, authorization and use of photovoltaic systems connected to the electrical grid; and to guarantee the energy quality in the grid and the physical and operational integrity of both, CFE staff and the end users. Its scope of application includes the interconnection of photovoltaic systems with a capacity of up to 30kWp to the low voltage grid, which can be installed in individual households, commercial facilities, schools and public buildings, including only those systems based on solid-state-static inverters for the conversion of direct to alternate current. (contact: those interested should contact the closest costumers service office of CFE; http://201.144.12.130/norms/qbe_norms.asp)

4.2.8 Project implementation procedures

The implementation of renewable energy projects requires different administrative procedures before the municipal, state and federal authorities. Such a process is much more complex in the case of electricity generation. With the aim of providing guidance to project developers, the former CONAE, in collaboration with the IIE and the PNUD, elaborated a *Guide to the Implementation of Renewable Energy Projects for Electricity Generation in Mexico*.[63] The guide is also available on line "www.layerlin.com". In spite of the fact that the guide has not been updated, most of its content is still in force.

[63] CONAE, 2006 (tinyurl.com/GuiaER).

4.3 Instruments of public policy

The following describes the main policy instruments for the promotion of renewable energies in Mexico (see Annex for a description of the institutional stakeholders).

4.3.1 The National Development Plan and the Sectorial Program of Energy

The National Development Plan (PND) 2007-2012[64] sets Sustainable Human Development as it guiding principle. The NDP incorporates the postulates of the 1994 World Report on Human Development of the United Nations Development Program, according to which "the purpose of development consists in creating an atmosphere in which everybody can enhance their capacity and opportunities can be broadened for present and future generation". Reference to renewable energies is made in two of the axis of the NDP, i.e. Axis 2 "competitive and employment generation economy", and in axis 4 "environmental sustainability". Such a duplicity reflects the fact that strategies for the use of these sources allow the achievement of both objectives.

Renewable energies in the National Development Plan 2007-2012
<u>Axis 2: Competitive and employment generation economy.</u>
Objective 15. To ensure energy supply quality and reliability of energy inputs demanded by the consumers at competitive prices.

- Strategy 15.11. To broaden electricity coverage in remote communities through renewable energies in those cases where the connection to the electrical grid is neither technically nor economically feasible.
- Strategy 15.12. To diversify primary power generation sources.
- Strategy 15.14. To foster the use of biofuels and renewable energy sources by setting up a legal framework that defines the State's capabilities and promotes investments to enhance the utilization of the country's resource potential.
- Strategy 15.16. To use research activities in the energy sector by strengthening support for research institutes, and to design their programs, amongst others, towards the development of renewable energy projects and energy efficiency measures.
- Strategy 15.17. To strengthen the attributions of the regulatory bodies.

[64] National Development Plan 2007-2012 (pnd.presidencia.gob.mx).

Axis 4. Environmental Sustainability.
Objective 10. To reduce Greenhouse Gas Emissions (GEI).

- Strategy 10.1. To foster efficiency and clean technologies (including renewable energies) for electricity generation.

In line with these objectives and strategies, embodied in the National Development Plan 2007-2012, the Sectorial Program of Energy 2007-2012[65] states, within its nine objectives, the following three:

- Objective II.2. To balance the portfolio of primary energy sources.
- Objective III.2. To promote the use of renewable energy sources and biofuels which are technically, economically, environmentally, and socially feasible.
- Objective IV.1. To mitigate the increase of Greenhouse Gas Emissions.

4.3.2 Economic and financial instruments

Within the set of existing policy instruments for the promotion of renewable energies in Mexico, there is one of a financial nature: the accelerated depreciation for investments in renewable energies, established in 2005, which allows a depreciation of 100% of the investments "in machinery and equipment for energy generation coming from renewable sources".[66] Depreciation can only be applied when there is an income tax charge. That is to say, if the depreciation deduction is greater than the tax depreciation, the tax payer will continue depreciating the investment in the following years. With the purpose of preventing that this mechanism could favor investments in low quality technologies, it is established that "what is provided in this fraction will be applicable as long as the machinery and the equipment are in operation during a minimum period of 5 years following the tax deduction declaration".

4.3.3 Support instruments for research and technology development

The Sectorial Fund CONACYT-Ministry of Energy-Energy Sustainability has as its main objective to "promote scientific research and applied technology, as well as adoption, innovation, assimilation and technology development in renewable energy sources, energy efficiency, use of clean technologies, and

[65] PROSENER (tinyurl.com/prosener).
[66] Income tax law, article 40, fraction XII (LISR, 2008; tinyurl.com/LISR2008).

diversification of primary energy sources". Resources for this Fund will come from a fee equivalent to 0.13% of the value of crude oil and natural gas extracted by PEMEX.[67]

4.3.4 International cooperation programs

International cooperation is one of the elements of Federal Government's policies regarding the promotion of renewable energies. Within this ambit, it is important to mention:

- Mexico's ratification of the United Nations Framework Convention on Climate Change and the Kyoto Protocol.
- Mexico's participation in international conferences on renewable energies: Berlin 2004, Beijing 2006, and Washington 2008.
- Cooperation with multilateral financial institutions: The World Bank and the Inter-American Development Bank.
- Cooperation with bilateral agencies; particularly the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH (German Technical Cooperation) and the British Embassy.

The German Technical Cooperation Program for Sustainable Energy in Mexico: Since 2005, the GTZ (German Technical Cooperation) has been implementing technical cooperation activities in the Mexican energy sector. At present, the Program for Sustainable Energy in Mexico is being implemented by GTZ on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ). The program aims to help improve the framework conditions in order to increase energy efficiency and the use of renewable energy sources in Mexico. To achieve this goal, there is a close cooperation between GTZ and key players, both the public sector (mainly SENER, CRE, CONUEE, and CFE) and the private sector. The Program is mainly focused on three lines of action:

- Assistance to improve the regulatory and normative framework
- Assistance for the design and implementation of promotion and dissemination programs
- Training and organizational development in public and private sectors

(www.tinyurl.com/PES-GTZ-eng; contact: andre.eckermann@gtz.de)

[67] Federal Fees Law, article 254 bis, fraction IV (LFD, 2008; tinyurl.com/LFD2008).See also CONACYT, 2009 (tinyurl.com/FSCSESE).

4.3.5 Summary of policies, programs and projects

The next table summarizes the different policies, programs and projects related to renewable energies, which are implemented by the Federal Government.

Policy/ program/ project	Institutions	Technologies	Link
Sectorial Program of Energy	SENER	All	tinyurl.com/prosener
Action Plan for Removing Barriers to the Full-scale Implementation of Wind Power in Mexico	SENER, IIE, GEF, PNUD	Wind	tinyurl.com/planeol
Large Scale Renewable Energy Development Project	SENER, GEF, BM,	Wind	tinyurl.com/36733h
Integrated Energy Services for Small Rural Communities in the Southeast of Mexico	SENER, GEF, BM	Solar, hydro, wind, bioenergy	tinyurl.com/SIE
Solar thermal project Agua Prieta II	SENER, GEF, BM	Concentrating solar power	tinyurl.com/AguaPrieta
Program for Sustainable Energy in Mexico	SENER, CONUEE, CRE, CFE, GTZ	All	tinyurl.com/PES-GTZ-eng
Program for the Promotion of SolarWater Heaters in Mexico	CONUEE, GTZ, ANES	Solar water heating	www.procalsol.gob.mx
Draft Program for the Sustainable Production of Bioenergy Inputs and for the Scientific and Technological Development	SAGARPA	Biofuels	tinyurl.com/ppsibio
Draft Program for the Introduction of Bioenergy	SENER	Biofuels	tinyurl.com/pibioen
Program for the Substitution of Open Stoves by Ecological Stoves	SEDESOL	Firewood stoves	tinyurl.com/pdzprior
Sustainable Rural Development Project for the Promotion of Alternate Energy Sources in Agri-business, promoting energy efficiency in the Agricultural Sector	FIRCO	Solar photovoltaic, solar heating, wind, bio-digestors	tinyurl.com/fae2009
Accelerated Depreciation	SHCP	All	tinyurl.com/LISR2008
Sectorial Fund CONACYT-Ministry of Energy-Energy Sustainability	CONACYT, SENER	All	tinyurl.com/FSCSESE

4.4 Future scenarios

Several studies have been carried out in order to propose different long term possible scenarios for the development of renewable energies in Mexico. Amongst them, it is worth to mention the following:

- The study entitled "Prospective on the Utilization of Renewable Energies in Mexico. A Vision to the Year 2030", coordinated by Dr. Pablo Mulás and elaborated by the Ministry of Energy in year 2005.[68]
- The document "Mexico: Low-Carbon Country Case Study", elaborated by the World Bank, in coordination with the Federal Government. The objective of this study is to evaluate the potential for reducing greenhouse gas emissions in Mexico over the next decades. Interventions in different sectors were evaluated, including the use of renewable energies, using a common methodology, and based on these interventions, a scenario of low carbon was developed for year 2030.[69]
- The study "Low-Carbon Growth. A Potential Path for Mexico" elaborated by the consulting firm McKinsey, in collaboration with the Mario Molina Center for Strategic Studies on Energy and Environment, A.C. [70]
- The document "Energy Revolution: A Sustainable Energy Outlook for Mexico", conducted by Greenpeace, proposes a scenario in which domestic CO2 emissions are stabilized by the year 2030, and subsequently reduced by 60% in year 2050 through the use of renewable energies and energy efficiency.[71]

[68] Mulás *et al.*, 2005 (tinyurl.com/psuerm).
[69] Johnson et al., 2009 (in print).
[70] McKinsey y CMM, 2009.
[71] Greenpeace, 2008 (tinyurl.com/GPrevene).

5 Conclusions

At present, our country has a much more favorable normative, institutional and programmatic context than several years ago. This allows us to use the multiple economic, social and environmental benefits of renewable energies. Particularly, we have the Law for the Use of Renewable Energies and Financing of Energy Transition, which clearly establishes the obligation of the Ministry of Energy regarding the assessment of net economic benefits attributed to the use of these energy sources. Furthermore, renewable energies play a very important role within the National Development Plan.

Without any doubt, electricity generation is the renewable energy application with the greater potential for Mexico. At present, a large number of these kind projects are being developed in the modality of self-supply. The challenge is to find mechanisms that replicate these experiences, but in projects for the supply of electricity to the state-owned utilities. In such a way, the public service of electricity may receive the benefits of renewable energies, mainly in terms of economic risks reduction.

To this end, it is necessary to design public policy mechanisms that allow the true fulfillment of the triple objective; i.e. to acknowledge and evaluate benefits; to adapt systems and energy markets; and to foster the flow of information. In a very special manner, it is necessary that benefits assessment can be translated into financial instruments.

Due to the lack of accurate information regarding the potential of renewable energies, their costs and direct or indirect benefits, public policy should also consider the elaboration of future studies with the aim of covering such gaps.

Mexico is facing the challenge of designing new political instruments that promote the development of renewable energies, especially those cases in which costs are lower than the long term net benefits to the country. Thus, the construction of such a system will require the participation of the Executive and Legislative branches, as well as the collaboration of different levels of government, the private sector, and the general population.

ANNEX: LIST OF CONTACTS

Federal Executive Power

Ministry of Energy (SENER)
(Conducts energy policy, including renewable energies)
Ing. Julio Alberto Valle Pereña
Director General de Investigación, Desarrollo Tecnológico y Medio Ambiente
(55) 5000 6047
jvalle@energia.gob.mx
www.sener.gob.mx

Energy Regulatory Commission (CRE)
(Regulates the electric industry, including permits, model contracts, and methodlogies used to calculate the corresponding payments to private-owned generation plants)
Dr. Alejandro Peraza García
Director General de Electricidad
(55) 5283 1520
aperaza@cre.gob.mx
www.cre.gob.mx

National Commission for Energy Efficiency (CONUEE)
(Promotes energy efficiency measures and the utilization of renewable energies)
Dr. Gaudencio Ramos Niembro
Coordinador de Oferta Eléctrica, Procesos Térmicos y Transporte
(55) 3000 1000, ext. 1234
gframos@conuee.gob.mx
www.conuee.gob.mx

Federal Electricity Commission (CFE)
(State-owned electric power company, holds 65% of the total installed capacity, and serves 82% of the end users)
Ing. Raúl Maya González
Subgerente de Proyectos en la Gerencia de Encargado de la Gerencia de Proyectos Geotermoeléctricos
(443) 322 7002
raul.maya@cfe.gob.mx
www.cfe.gob.mx

Central Power and Light Company (LyFC)
(State-owned electric power utility, holds 2% of the total installed capacity, and serves 18% of the end users)
Lic. Jorge García Cantú
Secretario Particular de la Dirección General
(55)5140 0411
jorge.garcia@lfc.gob.mx
www.lfc.gob.mx

Ministry of Environment and Natural Resources (SEMARNAT)
(Sets up national policies on climate change mitigation)
Dr. Juan Cristóbal Mata Sandoval
Director General de Políticas para el Cambio Climático
(55) 5490 2127
juan.mata@semarnat.gob.mx
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Ministry of Social Development (SEDESOL)
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