Sergio Romero-Hernández *Omar Romero-Hernández* *Duncan Wood*
Editors

Renewable Energy in Mexico:
Policy and Technologies for a Sustainable Future

USAID
DEL PUEBLO DE LOS ESTADOS UNIDOS DE AMÉRICA
Wilson Center
MEXICO INSTITUTE
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1.
Overall Panorama

Dr. Duncan Wood

1.1
Introduction: the post hydro-carbon nation

Mexico is a nation that is defined by the use of hydrocarbon energy. The economy, government finances, politics, its traditions and large segments of the population recognize oil as a fundamental base, and the influence of the oil and gas industry is noticeable in all spheres. Mexico, as a country, has obtained great wealth from oil but unfortunately this wealth has not been effectively used due to corruption and poor planning: two curses that prevail in the Mexican system. Although oil production is currently declining, it's probable that oil as well as gas will continue to dominate the hydro-carbon industry during the following decades, either through the state-owned monopoly or eventually, with the opening to the private sector.

However, Mexico also needs to seen as a country that has great potential in renewable energy sources. While during the last years regional and international attention has rightly focused on Brazil as an emerging super power in terms of renewable energy, Mexico has been seen (again correctly) as a country that has not done enough to promote the development of the renewable energy sector. The energy debate in Mexico has been dominated by the economic and political problems in the hydrocarbon sector, while the media, the people responsible for formulating policy and many academics have practically ignored the energy sector.

Notwithstanding, civil society as well as private industry have been active looking for opportunities and niches in the internal and border renewable energy markets. The government has approved new reforms which are important to the investigation and the development in the sector, and the governments and the foreign companies as well as international organizations have invested in energy projects in Mexico.

In summary, the renewable energy sector in Mexico as will be shown in the rest of the book, is alive and well, prosperous and with great potential. It is necessary that Mexico sees itself as a country that as an energy future beyond Cantarell, beyond PEMEX, beyond oil. The future of renewable energy in Mexico offers great hope for the country and the region and the time is right for a concerted government, industry and social surge to push forward the development of this sector.

This introductory chapter offers and overall panorama of the renewable energy sector in the global and national context and briefly explains why renewable energy has acquired such relevance in recent years. In this chapter we will see the growing demand for alternatives to hydrocarbon sources and other fossil fuels and we will examine what is taking place in Mexico in order to prepare the way for this change.

1.1.1 The global challenge

Today it is common knowledge that the world is facing a climate change crisis caused by the effects of industrialization and by the use of fossil fuels. A significant increase in global temperature combined with extreme climatic conditions, flooding and more frequent droughts has brought with it of shift in the paradigm over how we view ourselves in relation to the planet. For the first time in 150 years, we are considering the possibility of reducing our dependence on fossil fuels and look for alternatives that can be more costly in the short and medium term but more sustainable in the long run.

Two other related events have taken place in conjunction with the above. The first is that the world population has reached new maximums and that for the decade 2040-2050, there will be a total of 9,000 million people. The second is that the experts predict that 85% of the world population will be concentrated in the developing countries, which means that there will be a rapid increase in the demand for goods and energy (U.N., 2005). Both factors imply the need to increase energy efficiency and to find new energy sources.

This demographic growth will coincide not only with the climate change but also, with conditions for the exploration and production of hydrocarbons that will be increasingly more difficult. In lieu of the fact that most of the world´s “easy oil” has been found, the oil companies and the nations have turned to alternatives such as the non-conventional oil reserves (pitch sands and complex camps) or to reserves which in the past would have been considered unrecoverable such as the existing reserves in the depths of the ocean. In addition, the political conditions in many of the oil-rich regions are uncertain, unstable and frequently hostile to the private oil companies and western nations.

1.1.2 Climate change and natural disasters

The urgency to find alternatives to fossil fuels has been confirmed during the last few years, due to increasing scientific evidence that we are suffering a noticeable anthropogenic shift in world climate and temperature. There are not only indicators that show that the planet is warming but that the loosening of the polar ice cap, the melting of the glaciers and more importantly in the short term the extreme climate conditions and an increase in the incidence of natural disasters has brought to the forefront the consequences of maintaining the *status quo* in our energy consumption patterns and industrial development.

It is estimated that global temperatures rose one degree centigrade in the last 100 years and that at the end of this century world temperatures will have risen in seven or eight degrees. Notwithstanding the reductions in green-house effect gases that are contemplated as the most ambitious reduction strategy, world temperatures can rise up to 6%. This would have a dramatic and disastrous impact on the developed as well as developing nations and would threaten the existence of the human race as well as animal and plant life.

Although industry and government have denied for many years that a relation exists between the green-house effect gases produced by man and global warming, at present, it is accepted that something must be done to reduce the amount of green-house gas emissions into the atmosphere. Given that 86% of global energy comes from fossil fuels (IEA, 2008) and that these produce annually 27 billion tons of CO_2 emissions, finding alternative energy sources is a critical component in the strategy to reduce the effect of climate change.

1.1.3 The increase in the world population

Although the increase in global population has been a constant during the last 2,000 years, the total number of people that inhabit the Earth had not been a topic of debate until just a few years ago. With a world population expected to exceed 9 billion for the year 2040 and with an estimated global capacity (the total number of people that the planet can sustain given certain technological and social conditions) of approximately 10 billion, demography has once again become a central element of global politics.

The consideration of the size of the population is important not only for energy supplies but for climate change. As the world population increases so increases energy demand to produce consumer goods which means higher levels of energy consumption. In addition, as the total population becomes wealthier, the demand will rise. With a per capita income of 6,000 dollars, individuals and families will consider the purchase of such items as automobiles which will increase the demand for hydrocarbons and particularly gasoline (Dyer, 2009).

With this, the impact on climate change is clear. The increase in population also impacts climate in other ways: the increase in demand for land for agriculture for example, implies an increase in deforestation. Large-scale agriculture to produce sufficient food goods also implies the release of great amounts of green-house gases at the rice plantations and livestock farms. As a matter of fact, the methane released from these sources has a greater impact per ton than CO_2.

1.1.4 Energy pressure

At the same time that climate change has become a main topic on the international agenda, the decline in oil reserves around the world and the increasing demand for oil and gas (specially in Asia) have led to a higher energy market volatility during the last few years. This gives us an idea of the long term challenge that the supplying of energy for the global market represents. As the “easy oil” has been used, the oil companies have to look in places that are deeper, farther and in non-conventional sources in order to locate new reserves.

Consequently, not only the environmental problems caused by oil have worsened the situation in terms of atmospheric contamination but also contamination of the ocean –as in the case of the explosion of a BP Oil Company platform in the Gulf of Mexico in 2010–. In terms of natural gas, during the last two decades the markets have shrunk as demand has risen more rapidly than supply; however the discovery of non-conventional gas (*shale gas*) has revolutionized the international markets. Although there continues to exist an abundant supply of coal and uranium, its environmental impact is such that the majority of the countries avoid its use.

When we think that the economic development of the last 200 years has been based on an increasing use of energy, first coal and then oil, the consequent reduction of energy reserves appears obvious. Also inevitable is slower economic growth, a lower standard of living in the developed nations, an increase in international and local conflicts over the resources and the need for rapid and drastic technologic changes.

On the other hand, renewable sources offer an almost unlimited alternative. Although at present, they represent a small fraction of total worldwide energy use, their potential is so great that in the long term they could completely replace the non-renewable sources. What is interesting and particularly attractive about the renewable energy sources is that the necessary technology for their exploitation already exists in the developing countries as well as in the developed nations. This means that with adequate levels of investment, effective government policies and the necessary cultural and attitude changes in society, renewable energy can advance quickly and significantly en the following years.

1.2 Renewable energy as part of sustainable growth

The link of these three elements –climate change caused by economic activity, population growth and energy pressure– give credence to the importance of the concept of sustainable growth, a term that was coined at the end of the 80´s in the Brundtland report titled “Our Common Future” (WCED, 1987). This report established that sustainable growth is based on the notion that development today must not compromise the capacity of future generations to achieve their growth objectives. This means less emphasis on non-renewable sources and on the development policies that destroy or irrevocably damage the environment. Since published in the Brundtland report, sustainable growth has become a central theme in the policies of governments and international organizations.

Thus, all the areas of renewable energy generation in the planet have seen a considerable increase albeit from a small initial position. Although, some of these types of generation have existed for more than 100 years their application through new designs and technologies has brought a dramatic improvement in their efficiency and recognition of their potential.

The history of hydroelectric energy dates from the 19th century with the construction of the first plants in the 1970´s. In the middle of the 20th century, it flourished with massive investments and megaprojects in the industrialized nations and through financing from organizations such as the World Bank, in the developing nations. There are cases such as China which, thanks to the great investments carried out in recent years, generates 20% of the worldwide electrical energy capacity (Ren 21, 2006). Another case is Paraguay, a country that depends 100% on hydroelectric generation and managed to export hydroelectric energy to its neighbors like Brazil. Others such as Canada and Norway also depend crushingly on dams for the generation of their electrical energy.

Wind energy also has a long history with the use of wind mills in the past and the pumping of water in modern times. The generation of electricity using the wind dates from the end of the 19th century although its use was limited throughout the 20th century until at the end of the 1970´s in Denmark where new materials and designs were applied that later were used around the world. In the last few years, the rapid innovation in design and the light weight materials have made it possible to have giant turbines with the consequent growth of the generation capacity of this type of energy.

The communities have taken advantage of solar energy during thousands of years for drying, heating and lighting. In Chile, during the decade of the 70´s, to produce drinking water there existed distillation projects based on solar energy but the use of this energy to to generate electricity is relatively recent. Electricity can be generated using solar energy in two ways: using photovoltaic cells which generate electricity through the interaction of the sun´s radiation and the chemicals contained in the cell, and using thermal solar plants in which the heat from the sun is used to generate steam with which the turbines produce electricity.

During the last decade, the bio-fuels have received a great deal attention from the communication media, from the politicians and the academics while industry, government and different organizations have looked for ways to reduce their dependence on hydrocarbons based on liquid fuel. Ethanol is possibly the best known of these and it is important to recognize that in the 19th century it was regularly used as a source for heating. At the beginning of the 20th century, ethanol briefly challenged gasoline as a source of fuel for automobiles but the low cost of oil rapidly surpassed this potential. The massive production of ethanol in Brazil, United States of America and the European Union in recent years has renewed the prospective that ethanol has a central role in transportation although the relative cost continues to be a challenge and the question still remains unanswered regarding the production of grains for the production of ethanol which directly or indirectly impacts the Price of the foodstuffs.

However, ethanol is only one part of the bio-fuel panorama. The bio-diesel which is derived from diverse sources is emerging as an important complement to ordinary diesel and offers potentially great benefits to the poor countries. In the same way, the bio-gas projects (methane) are being promoted around the world, as the governments are looking to take advantage of the damaging emissions from agricultural, industrial and municipal sources in order to generate electricity.

1.3
The economic logic of renewable energy

Renewable energy offers a tremendous opportunity to satisfy energy needs in the future and it does in a way that does not compromise the possibilities of the future generations to reach their development objectives. As can be seen in Figure 1.1, the total amount of solar radiation that reaches the Earth each year is equivalent to more than 1,000 times the amount of energy required to maintain our lives. Although there is enough coal, uranium, oil and natural to maintain our economies for 100 years, its impact on the environment can no longer be ignored.

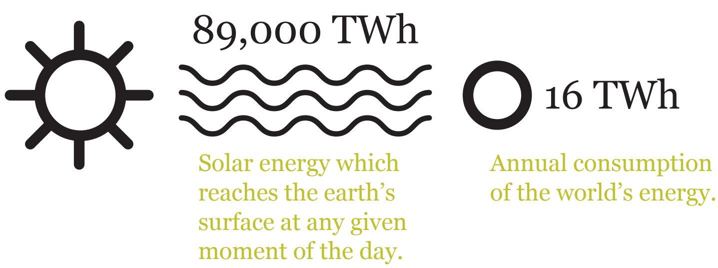

Figure 1.1
Annual use of the world's energy vs. solar potential

Source: Smil, Vaclav, General Energetics: Energy in the Biosphere and Civilization. New York: Wiley, 2001; International Energy Agency, www.iea.org.

Governments and private industries throughout the world have invested in new technologies and methods in order to produce energy with lower carbon emission levels. As a matter of fact, there are projects that are financed through organisms such as the World Environment Fund, and private organisms such as the Chicago Climate Exchange (CCX, its initials in English) and the European Climate Exchange (ECX, its initials in English). Energy efficiency has become a topic which gains importance in many countries as the governments and industries attempt to increase their production and at the same time reduce energy consumption.

However, a conjunction of investment, policies and social attitudes is still necessary to achieve a complete energy transition. And this is where the main problem resides. In the global scale, the investment in renewable energy experienced a dramatic stimulus during the first years of the 21st century thanks to the increase in the price of energy and afterwards, thanks to incentives from various developed countries in response to the worldwide economic recession. Unfortunately, this investment is still insufficient due in great part to the fact that there still exist lower cost alternatives.

The electrical plants that operate using coal, for example, offer cheaper energy although it is dirty and they also require less construction and start-up time. Added to this, the price factor in the case of oil collapsed in 2008 and the price of gas remained relatively low which resulted in a decline in the interest to invest in the production of bio-fuels. Up to now, the development policy has been disappointing in spite of the genuine and positive statements of several world governments.

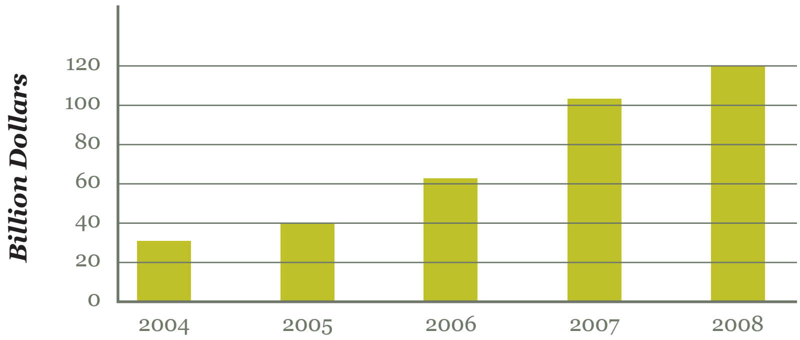

Figure 1.2
Global investments
in renewable energy projects.

Source: REN21.

As shown in Figure 1.2, the tendency for the investment in renewable energy is positive. Clearly, the initial levels of investment were very low in the first years of this decade and only reached 120 billion dollars in 2008. However, with the announcement by the governments of the United States of America and China at the end of 2009 regarding their firm commitment to reduce carbon emissions and with similar declarations from the principal developed and developing nations – we should expect new and significant policies and significantly higher levels of investment.

As mentioned, in the middle of this decade the renewable energy sector received an additional worldwide push from the high prices registered in the world oil market. In 2005, the prices of natural gas in North America reached a maximum of US$12/mmbtu, which increased the Price of electricity production and allowed the alternative energy sources such as wind to become more attractive. Due to this, large scale investments were made in wind power. In a similar manner, when oil reached $150 dollars per barrel, in the summer of 2008, many of the renewable energies which had been considered too costly became more accessible. Also large investments were carried out in bio-fuels especially in ethanol and, other renewable energies received greater stimulus as the population changed their vehicles to electric automobiles.

Without a doubt, the link with prices is a two-way street. With the fall of gas prices after 2006, the financing of renewable sources of electric generation had a negative impact much the same as the collapse of oil prices at the end of 2008 and in 2009 had and effect on bio-fuels. The volatility in the prices has appeared as a factor in the renewable energy market in which wind, solar and geothermal energy offer a more stable and predictable panorama in the long term. Notwithstanding, it is clear that the long term predictions point towards the fact that the majority of the hydrocarbons will have higher and not lower prices and that the global movement toward a reduction in the effects of climate change will continue to drive the investment in renewable energy.

A crucial element for the developing countries has been the belief in the positive link between the strategies for the reduction of the effects of climate control and social and economic development. The ability to convert municipal and agricultural waste into methane to be used as a source of energy for example, can dramatically alter the economic reality for the local authorities and the farmers. The use of photovoltaic cells to generate electricity in remote areas can offer new opportunities to the farmers and the small businessmen in terms of refrigeration, lighting and the capacity to pump water. Wind energy can rely on new strategies to obtain new electrical supplies in areas where there is no access to the national electrical grid. The investment in these installations would stimulate economic activity, jobs and offer a new source of income to the local landowners.

Another change which would represent important benefits for the developing countries would be a scheme of carbon compensations. The Mechanism for Clean Development (MCD, initials in English), created through the Kyoto Protocol, has influenced in this aspect. The MCD and other programs allow the organizations and corporations of the developed nations that cannot achieve the emissions quotas compensate their carbon emissions through the purchase of Emissions Reduction Certificates approved by the MCD. These funds are used for investments in carbon emissions reduction programs in developing countries. The income obtained from the compensation of carbon emissions becomes an additional capital flow, useful in the first phases of an energy project and an extra stimulus for investments. Another option are the Renewable Energy Credits (REC, initials in English), in which the energy produced from renewable energy sources replaces in the national energy grid, the electricity produced by conventional sources and in exchange, funds that compensate carbon emissions are received.

Renewable energy can also playa n important role in the capture and retention of carbon (CRC). The new technology of some of the American companies that can use algae to capture and retain CO_2, and later use the algae as raw material for the production of bio-fuels presents great potential particularly if it is used jointly with LED lighting generated using solar power. This technological innovation appears to be capable of absorbing the large amounts of CO_2 produced by the energy plants and the refineries, to later become a source of bio-fuels that can replace the traditional liquid fuels.

Of special interest to countries such as Mexico, that shares a border with developed nations or is located in geographic proximity to these, is the possibility of exporting renewable energy. As the demand of renewable energy from developing countries increases due to the new imposed standards, these countries can benefit exporting electricity derived from renewable sources or bio-fuels produced within their territory.

For countries experiencing great population growth, where the production of foodstuffs, industrial waste and landfills are increasing exponentially, methane gas is also a growing problem. The emissions of this element comes from an important variety of sources among which are found: rice crops, domestic livestock, landfills, coal mining and the extraction of oil and gas, all of which are associated with population growth. Methane gas has a greater impact on global warming when compared to CO_2 (approximately 23 times more than CO_2), and its worldwide impact is growing quickly.

Fortunately, some of these sources which generate methane gas are easier to contain tan others. The advantage is that when burned, the molecules are converted into CO_2 and the impact on global warming is reduced up to 96%. If methane is burned to produce electricity, then the positive impact on carbon emissions increases as it replaces conventional electricity generation sources (for example, natural gas or coal).

Renewable energy then presents a promising and challenging panorama for the governments, the companies and for society as a whole, around the world. With the combined pressure of climate change, population growth and a more complex extraction method of natural resources, renewable energy offers enormous opportunities many of which are just beginning to be explored.

1.4
Mexico and renewable energy

The commitment of Mexico to renewable energy is relatively recent. Although, hydroelectric energy was a great source for the production of electricity in the 40´s and 50´s, since then its importance has declined due to the increased use of other generation sources to cover the increasing national demand. At present, it is at 19% of its installed capacity (SENER, 2009). During the past decade, the idea of complementing the energy sources (hydrocarbon, coal, etc.) with renewable sources really took hold in the country. This thanks to diverse sources that drove this change.

In the first place, the impact in the decline of oil production should be recognized. As the production at the oil fields of Cantarell dropped precipitately in 2008 and 2009 and Mexico faced a future without oil exports, the need to think beyond hydrocarbons became clear (PEMEX, 2010). Consequently, energy efficiency became a central theme of the federal government and the energy saving programs multiplied. Likewise, the notion that one barrel of oil not used internally is an additional barrel for exporting became very attractive – more so as production and exports were declining-. Therefore, the need to provide alternative energy sources to replace the oil boom of the past four decades is now a real problem.

Another driver in Mexico is the growing attention that is dedicated to the air quality in the large cities and particularly in the Valley of Mexico. Having achieved important advances during the last years in terms of the reduction of automobile emissions, of the ozone at sea level and suspended particles in the air, the government as well as society as a whole, have searched for other ways to improve the local and national environment which has attracted not only international attention and praise, but has also generated confidence that Mexico could be a leader in environmental questions. Although, civil society is not as active as in other countries, it does play an important role as diverse environmental groups and universities Work on including local, state and federal governments.

International players also have an important role in promoting renewable energy. The government of the United States of America financed, during several years, projects related to renewable energy in Mexico through the United States Agency for International Development (USAID) with the objective of promoting the use of solar energy in the rural areas during the decade of the 90´s. Afterwards, they promoted the use of wind energy in Oaxaca during the first years of the 21st century by sponsoring a survey of the wind power resources in the state in 2002 (Mata & Feinstein, 2006). This iniciative laid the foundation for the development of the energy program at La Ventosa and was exhaustively used to attract investors to the project (USAID, 2009).

In 2008 and 2009, USAID had great influence on education programs centered on the financing for renewable energy projects and underlined the lessons that should be learned from the regulatory frameworks used in the United States of America for renewable energy. It should be pointed out that the neighboring country is not the only one involved in the renewable energy sector in Mexico. Public as well as private interests from Germany, Spain and the United Kingdom have been active in the construction and investment in this industry and of course, in taking advantage of business opportunities.

It is vital to recognize the internal political changes in the federal government as a first driver and a commitment towards renewable energy. The fact that President Felipe Calderon has been an active supporter of the policies to reduce the effects of climate change and, that the Energy Secretary, Georgina Kessel, recognized a commitment towards renewable energy has allowed for some of the policies in the federal government to be on the right path. It is also important to mention the contributions of certain states such as Oaxaca, Veracruz and Baja California; each one provided the ideal conditions for the development of the renewable energy sector.

Also, during the past few years, other initiatives have taken place in almost all green energy areas, whether it is investigation, design and development (RD&D) or in small projects that have concentrated on sources such as photovoltaics, wind and bio-gas. Other cases are the significant investments destined to projects for large scale energy such as the wind power developments in the states of Oaxaca, Baja California and Tamaulipas.

Although some of the government actions related to the promotion of renewable energy could be criticized, the truth is that it has achieved that the developing countries view Mexico as a regional and global leader en in this field. And even though it lacks the successes that countries such as Brazil have had in the development of bio-fuels, the Mexican government, notwithstanding, built a framework in which investment opportunities and the development of clean energy can be exploited.

The development package of 2008 which was approved by the Mexican Congress included the Law for the Better Use of Renewable Energy and the Financing of the Energy Transition (LAERFTE, initials in Spanish), which will be discussed at length in another chapter of this book. However, it is important to point out that the new law includes US $220 million dollars a year to fund during the next three years projects related with renewable energy. Significantly, the law requires that the SENER create new rules and offer new incentives for the renewable energy industry in Mexico. Although, it still remains to be seen how this law will be implemented, it remains as a great promise for this sector.

Important obstacles exist in the country related to the generation and the distribution of energy from renewable and clean sources. The legal framework is unclear and there is uncertainty in the public as well as the private sector regarding the legal implications and the difficulties related to the participation of the private sector in the Generation of electricity from renewable sources. Another topic is, without a doubt, the one related to the price of the electricity and the bio-fuels with respect to the conventional sources and their subsidies.

In the same manner social and cultural barriers are present in some areas. The difficulties experienced by Mexican and foreign companies that operate in the wind generation fields of Oaxaca as they face local communities will probably be repeated in other projects such as solar and the production of bio-fuels. These challenges are surmountable. How? Simple: with cultural sensitivity and the will to insure that all the participants benefit and feel that they are justly compensated.

Perhaps the most complex is the political question. Although the government of President Calderón has taken concrete steps towards the reduction of CO_2 emissions –through the LAERFTE, providing the provisions for the country´s renewable energy– there is little enthusiasm among the rest of the political elite. For example, the Institutional Revolutionary Party (PRI, initials in Spanish) and the Democratic Revolution Party (PRD, initials in Spanish) have shown, up to now, little initiative regarding the topic of climate change or of renewable energy, concentrating their efforts on the protection of the country´s hydrocarbon reserves against foreign intervention. The legislative elections of 2009 showed a shift of political power toward the PRI, as there exists now a real possibility of a PRI presidential victory in 2012, it is necessary that the party change its position in order to concentrate its efforts more intensely in this area..

On the international front, Mexico and President Felipe Calderon have positioned themselves as leaders in the campaign against climate change. In May, 2008, the Mexican government announced its proposal for the creation of a global “Green Fund” Or “World Fund for Climate Change”. This fund contemplated that developed countries as well as developing countries would participate and the monies would be used to finance activities for the reduction of the effects of climate change. In December of that year, the declaration of the Mexico plan to reduce carbon emissions in 50% by 2050, based on the levels of 2002, achieved worldwide acceptance. However, the details of the plan still need to be defined. The country received a “medium” note from Climate Action Tracker (climateactionttracker.org) as it still needs to detail its long term commitments.

On the road towards the Climate Summit in Copenhagen in December 2009, the Calderon government received enthusiastic approval from some members of the Iberoamerican Summit regarding the Green Fund idea. Similarly, the President announced that he would present 144 carbon emissions reduction projects in the next Summit, which reinforced the role of the country as a regional leader. Still to be seen is the level of international consensus reached regarding the strategies of climate control which will arise as a result of the summit in Copenhagen and of the follow-up meetings; notwithstanding, the position of Mexico as a leader among developing countries will be strengthen.

1.5
The objectives of this book

Besides being opportune, this book attempts to inform an ever-growing public of the real potential that exists in Mexico for the renewable energy sector and in this way, inspire greater social and economic investment in the sector. Its chapters are focused on the economic, social, development and environmental benefits that will be obtained from a greater investment in renewable energy. On the other hand, it identifies the current obstacles to achieving a more productive development of renewable energy in Mexico. In that sense, this publication is directed towards the formulators of public policy and the governmental administrators in an effort to highlight the ways that policy can be designed to promote the sector in a more holistic manner.

The chapter that precedes this presentation, the second, examines the national panorama for renewable energy in Mexico. Also highlighted is the lack of conscience in Mexico regarding climate change together with the enormous potential for renewable energy. This potential is explained in terms of the contributions made towards a national energy supply, access to electricity in rural areas and in terms of its contribution to agricultural productivity.

The third chapter analyzes the regulatory and legal framework for the development of renewable energy in Mexico. Although the package of energy reforms of 2009 included the LAERFTE much more work is needed on the part of the regulatory authorities in order to provide certainty to private investors. Upon examining the LAERFTE, the chapter invites the Energy Regulatory Commission (CRE, initials in Spanish) to accept the challenge and define contracts and set prices in the models in order to inspire future investment in the generation of renewable energy.

Chapter 4 examines the hydroelectric sector in Mexico; an area of renewable energy that many consider has been exploited to its maximum potential. This chapter argues the opposite showing that the potential for large and small scale hydroelectric generation is very promising, in terms of the net contribution to the generation of electricity in Mexico as well as in terms of the reduction in carbon emissions.

Chapter 5 examines bio-mass and bio-gas and their potential contribution to the generation of energy, employment, local development and a higher income for the rural population. The focus in chapter 6 centers on the fact that although the first generation of bio-fuels was somewhat successful, there exists the need to accelerate the transition to the second generation of bio-fuels in order to stimulate production and avoid the controversy that arises concerning the interchange of bio-fuels and food sources.

Wind energy in Mexico is perhaps the best known renewable energy sector. The importance of the project in La Ventosa and the possibility of future developments in other areas of Mexico has allowed for wind energy in Mexico to garner considerable international attention. Chapter 7 offers a profound discussion about the wind energy sector in Mexico, analyzes the economic and environmental impact of the projects and identifies opportunities for developments in the near future.

Chapter 8 examines one of the best developed areas of renewable energy Generation in Mexico, geothermal energy. This sector has contributed significantly to the Mexican supply of electrical energy since the decade of the 70´s and continues to be an important source in the north of the country. Geothermal energy is also very interesting as it constitutes a renewable energy source which has been exported to the United States of America and provides an important model for potentially lucrative sales in the future.

Chapters 9 and 10 deals with solar energy in its photovoltaic and thermal-solar forms and contemplates the regulatory and financial incentives as well as the barriers to future development. It is clear that solar energy is terribly under exploited in Mexico and offers an enormous potential for large scale generation as well as for off-grid access by the rural communities.

The topic to improve Access to electricity as a means to accelerate the development of the rural areas is looked at again in chapter 11, which studies small-scale generation. Achieving the production of electrical energy using this model would bring not only a considerable reduction in carbon emissions but would also improve conditions of small businesses and agricultural producers.

1.6 Conclusions

For all the reasons previously outlined, it is now opportune and imperative that Mexico develop its own renewable energy sector. The country has a real opportunity to become a great producer of renewable energy and also to export this energy to its neighbor to the north, the United States of America. In a time when oil income is declining, the political circles should examine this very closely.

It's a fact: the world spins towards a post-hydrocarbon future in which, although it is true that oil, gas and coal continue to play an important role, it is also true that they are being substituted, with greater frequency, by cleaner alternatives. In that sense, Mexico has an opportunity to become a leader. This would help improve not only Mexico´s international position but also increase its competitiveness.

The following chapters analyze the different renewable energy production areas in Mexico and contemplate the potential for their development as well as the economic, political and social problems that will be encountered. The authors that have contributed their ideas to this book come from different academic, political, industrial and social settings. This provides and holistic vision of what exists, what is required and the direction the exploration of renewable energy will take us.

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2.
Rewenable energy and sustainable economic development

Prof. Francisco Torres,
Dr. Omar Romero-Hernández
Dr. Sergio Romero-Hernández

At present, the world faces great challenges: how to guarantee sustainable economic growth, improve social conditions for the population and, at the same time, protect the natural resources and improve the environment. Unfortunately, the scientific evidence indicates that we are not doing enough and the adverse effects derived from such phenomenon as global warming will shortly represent a higher cost than the action required to avoid them.

During the last decades, the world´s economic development has been linked to the progress in several sectors among which the energy sector stands out. Traditionally, the fossil fuels have been the principal source of energy which can be explained basically by the oil wealth of various regions and by the wide spectrum of needs that this can cover. In this manner, we moved from a time of abundant energy during the 70´s to a period of international crisis in crude prices. As a result, the consumer nations, faced with the high cost of oil and an almost total dependency on this energy source changed their habits and looked for options in order to reduce their dependency on non-renewable sources.

Notwithstanding the changes in their habits regarding their energy consumption and the worldwide economic crisis, the appetite for energy continues; for the year 2050, world energy demand will double compared to current demand. By that year, the world population will have increased from 6.5 Billion to 9.0 billion inhabitants. Moreover, countries such as Mexico, China, India and Brazil will integrate millions of inhabitants into a modern economy with a lifestyle that will demand more energy per capita.

The studies regarding energy prospectus carried out by international organisms such as the International Energy Agency (IEA) and the United Nations Environmental Program among others shows that, in the following decades, fossil fuels will continue to be the dominant source of energy. However, each day that passes, the easily-accessible and financially viable sources are being depleted.

Adding to the above, the energy sector has a far-reaching impact on the environment. This sector represents an important source of emissions of green house effect gases which means an increase in their atmospheric concentration and the consequent effect on one of the principal environmental problems of the planet: climate change. The role of this sector in Mexico is very similar with what is happening on the international stage as close to 60% of the sources of greenhouse effect gas emissions are related to the generation and use of energy (Figure 2.1).

- *28% Energy generator (196.53)*
- *33% Energy use (233.5)*
- *18% Agriculture, woodlands and other land uses (131.56)*
- *14% Waste (100.42)*
- *07% Industrial processes (53.29)*

Figure 2.1
Principal sources of greenhouse effect gas emissions reported for 2006 in MICO2e. Prepared with preliminary data from the INEGI.

Source: Special Program for Climate Change 2009-2012.

The topic of climate change, its effects and consequences, is part of the international agenda, backed up by hundreds of studies prepared by the United Nations (Intergovernmental Panel for Climate Change), governments, non-governmental organizations (NGO), private industry and universities among others. The evidence is overwhelming as climate change is a serious global menace and requires a global answer.

Just to mention some of the anthropogenic climate change effects it is possible to cite extreme meteorological phenomena such as droughts or torrential rains. The result: a reduction of food production, dangerous flooding, a drop in the productivity of agricultural activities, a greater incidence of forest fires and serious damage to coastal infrastructure such as ports and bays, due to an unusual rise in the level of the oceans. In terms of the economic and social environment, the result has been a serious impact on trade and tourism and grave health problems as a result of the “heat spikes” as well as due to the spreading of diseases by vectors (Galindo, 2008).

The conclusions drawn up by the economic models prepared under the auspices of the government of the United Kingdom show that if we do not act, the costs and the risks of climate change will be equal to the loss of 5% of the Gross National Product each year. Moreover, if a wider range of risks and impacts is considered, this could go up to 20% of the world´s Gross National Product (Stein, 2007). On the other hand, the price of action -the reduction of the emission of greenhouse effect gas in order to avoid the worst impacts of climate change – could represent 1% of the annual Gross National Product. The investment carried out during the next 10 to 20 years will have a profound effect on the climate of the second half of our century and the century to come.

In the case of Mexico, the results are similar to the ones found in the international studies. The government recognized that one of the principal conclusions is very uplifting and encloses a very profound lesson about public policy. And this is that the costs related to an effective and efficient action to combat climate change are lower than the economic impacts that could be avoided and that the opportunities for growth and development that can be achieved are infinite.

Definitely, to act in a decisive and timely manner is wise public policy. Fortunately, the range of possibilities available to contribute to economic growth and reduce greenhouse gas emissions is very broad.

In this chapter, we will concentrate our efforts on understanding the national and international panorama regarding projects for energy production from renewable sources as well as the projects leading to energy efficiency.

2.1
International panorama

The IEA is one of the principal international venues with regards to energy cooperation and a reliable source of statistical information regarding the energy sector. This agency informed that in 2007, the total primary energy supply (TPES) was 12,026 Mtoe (Figure 2.2) of which, 12.4% - 1,492 Mtoe was produced from renewable energy sources. Figure 2.2 also shows that fossil fuels continue to be the main source of energy with more than 80% of the total. Finally, nuclear energy represents 5.9% of the world´s total (IEA, 2009).

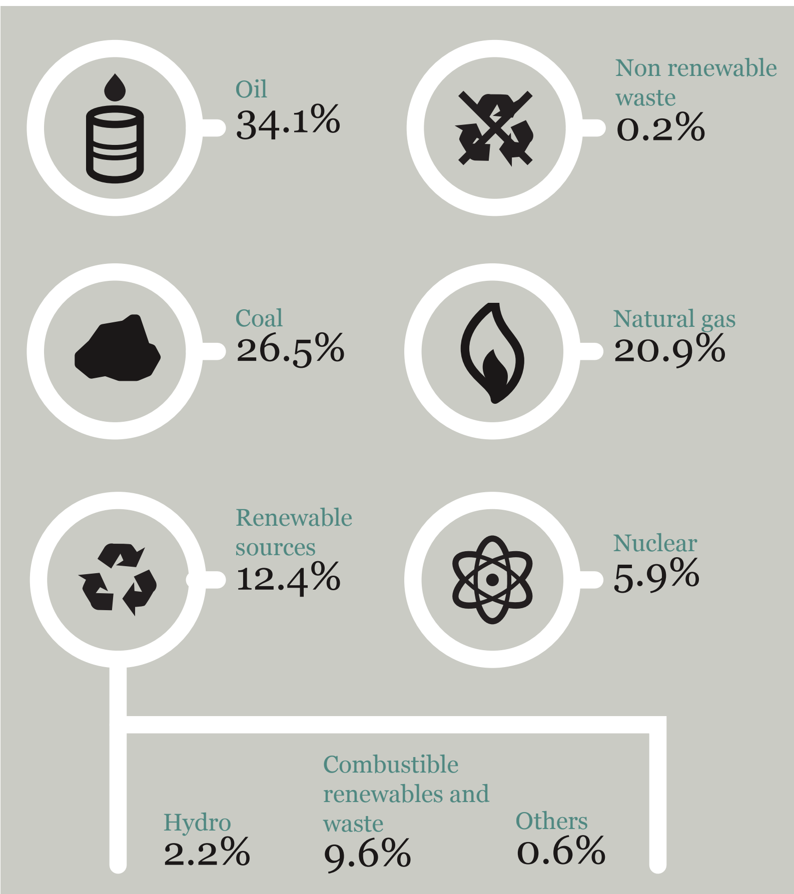


Figure 2.2
Distribution of World´s Total Primary Energy for 2007 – Different Energy Sources

Source: IEA, 2009. The partial percentages have been rounded. others, geothermal, solar, wind, marine.*
Toe: is defined as tone of oil equivalent). This unit is equivalent to 107 kcal (41.868 GJ).

The REN21 report, prepared by a committee of international experts with the collaboration of several investigators in different countries, is one of the international key references regarding the state of renewable energy in the world. The main conclusions of this study indicate that, regardless of the important decrease in worldwide economic activity, the investment in renewable energy has increased (Figure 2.3).

In response to the economic crisis, some nations have provided incentives for the creation of "green jobs" that derives from the requirement that jobs originate from the generation of energy from renewable sources. The principal incentive is the one given by the government of the Unites States of America which earmarked $150 billion dollars over the next 10 years. Private industry has played a prominent role: by August 2008, at least 160 public companies related to renewable energy had a market value equal to or greater than $100 million dollars.

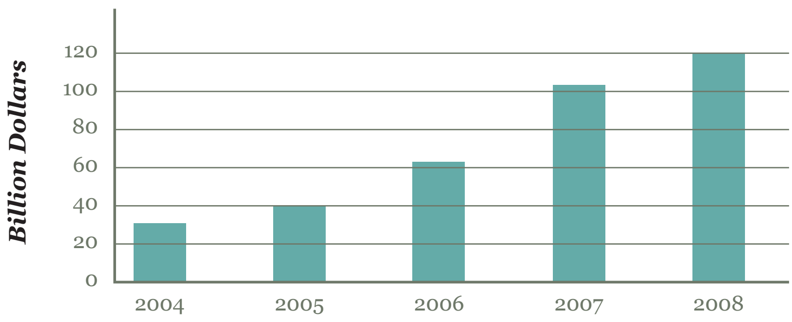


Figure 2.3
Worldwide investments in renewable energy projects. Based on information from REN21, 2009.

Worldwide energy generation capacity from renewable sources (except hydraulic) was 280,000 MW in 2008, 16% higher than the 240,000 MW reported in 2007. This increase in generation capacity is due, in great measure, to two reasons: climate change and energy security.

The legislatures have also shown interest in many countries. For the first quarter of 2009, a large number of governments approved laws in this area promising to reach specific levels of emissions and they initiated specific action in order to achieve these levels. Specifically, 64 countries now have defined policies to promote the use of renewable energy sources.

Chart 2.1 is a summary of the performance in recent years of some of the indicators relating to renewable energy sources.

Investment indicators in renewable energy projects.

Indicator	2006	2007	2008	
Global investment in renewable energy (RE)	63	104	120	Billions USD
RE generation capacity (except hydraulic)	207	240	280	GW
RE generation capacity (includes hydraulic)	1020	1070	1140	GW
Wind power generation capacity	74	94	121	GW
Solar energy FV in grid generation capacity	5.1	7.5	13	GW
Thermal solar energy generation capacity	105	126	145	GWth
Ethanol production (year)	39	50	67	Billions liters
Biodiesel production (year)	6	9	12	Billions liters

Chart 2.1
Investment indicators in renewable energy projects.

Source: REN21, 2009.

Figure 2.4 shows that the contribution of the renewable energy sources that more frequently appear in the news (solar, wind and marine) are marginal. These only represent 0.02% of the total primary energy supply (approximately 24 Mtoe), equivalent to 1.6% of the total of renewable energy sources. The two main sources of renewable energy in the world are hydraulic (17.7%) and the renewable residuals and fuels which total 77.4% of the total renewable sources (residuals, biomass and biogas).

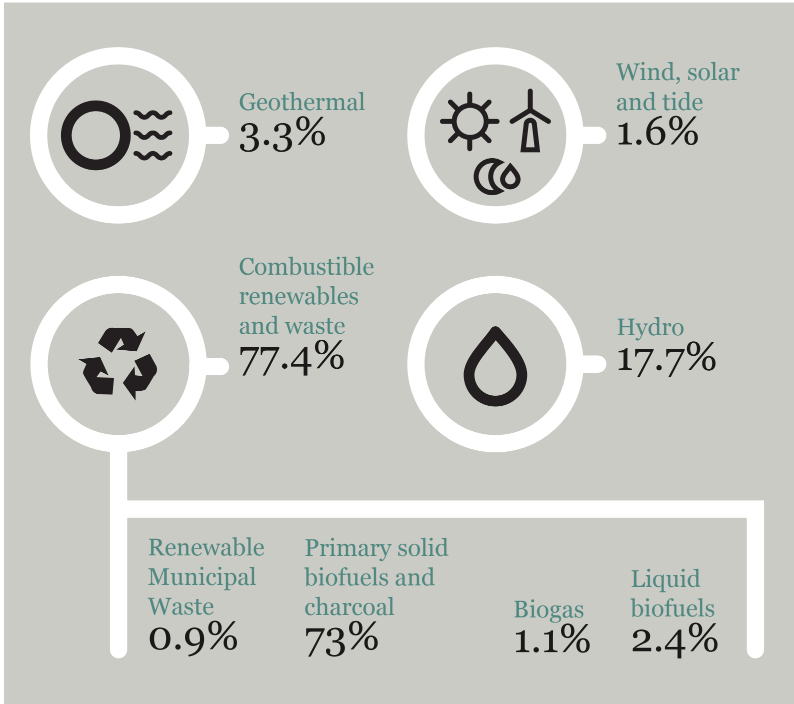


Figure 2.4
Distribution of the global primary energy supply from renewable energy sources in 2007.
(Total 1,492 Mtoe)

Source: IEA, 2009. Partial % have been rounded.

The annual growth rate for the energy supply from renewable sources for the period 1990-2007 was 1.7%; which is encouraging, although it is lower than the rate of the global primary energy supply for the same period (1.9%).

The countries in the Organization for Cooperation and Economic Development (OCED) represent the majority of the production and growth in systems that use solar and wind energy. The increase in the production of energy from renewable sources has been especially high for wind energy with an average annual rate of 25%. The second highest growth rate was in the use of renewable municipal waste, biogas and liquid biomass. This combined sector grew an average of 10.4% per year during the period 1990-2007. The use of solar energy with photovoltaic and solar thermal systems saw an annual growth rate of 9.8% during the same period. Finally, the annual growth rate in the use of hydroelectric systems was 0.4% in the OCED countries and 3.7% in the other countries.

Average annual growth (1990-2007) for renewable sources

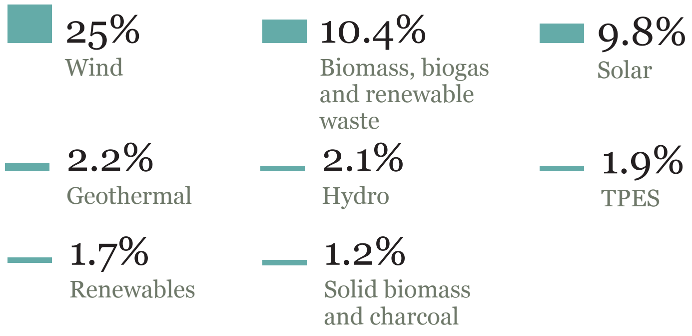


Figure 2.5
Average annual growth rate for some renewable energy sources during the period 1990-2007.

Source: IEA, 2009.

The role played in developing nations by the renewable energy sources should be noted. In the non-OCED nations, the non-commercial use of biomass together with the use of other renewable sources makes this block of nations responsible for 76% of the total supply of energy from renewable sources. On the other hand, the countries in the OCED supply the remaining 24% even though at the same time, they are responsible for 45.7% of the TPES (total primary energy supply).

Figure 2.6 shows that the OCED countries supply 6.5% of their primary energy from renewable sources. On the other hand, the average for the Latin American countries is 30.5% although, once again, the greater part of this average is biomass and hydroelectric. The role of the "new" sources of renewable energy such as solar, wind and marine is still low in the countries that are not in the OCED while in the developed nations it is as high as 68.8%.

Average annual growth (1990-2007) for renewable sources

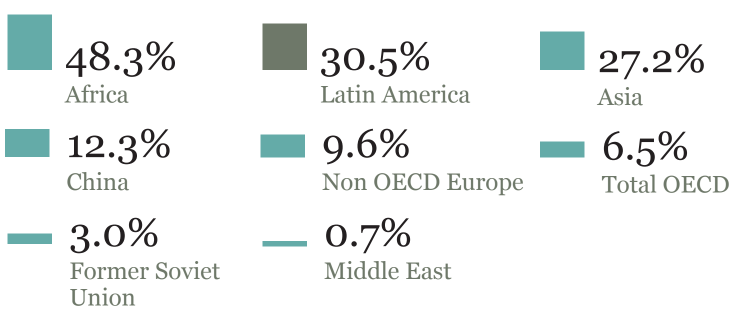


Figure 2.6
Average annual growth rate during the period 1990-2007 for selected renewable energy sources

Source: IEA, 2009.

The use of the supply of primary energy has different profiles when comparing members of the OCED with the other countries. The main use of primary energy in the OCED members is to generate electricity. The developing countries use a significant portion of the primary energy to cover directly their demand without the need to transform it into electrical energy. This is the result of the widespread use that the biomass has in the homes in the developing nations. In fact, only 24.4% of the renewable energy supplied in the world is used to produce electricity while 52.3% is used for residential, commercial and public sector consumption.

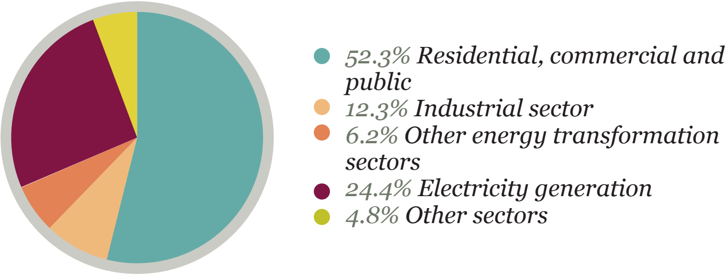


Figure 2.7

In total, the renewable energy sources represented the third main contributor to the production of electricity in the world (Figure 2.8). Its participation totaled 17.9% of the global generation of electricity in 2007 after coal (41.6%) and biogas (20.9%).

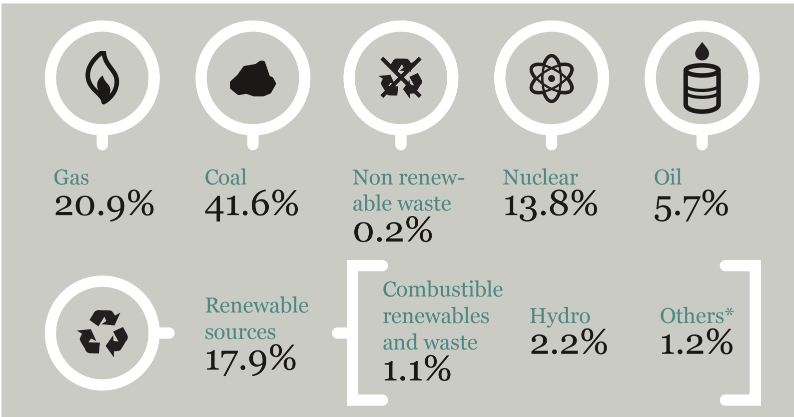


Figure 2.8
Participation of diverse fuels used for the generation of electricity in the world.

Source: IEA, 2009
Others: solar, geothermal and wind.*

The generation of electricity from renewable energy sources had an average annual growth rate of 2.6% for the period 1990-2007- significantly lower than the average growth rate for the worldwide generation of electricity during the same period (3.1%).

2.2 National panorama

The energy sector is one of the most important economic activities in Mexico representing 3% of the Gross National Product (GNP). The proven oil reserves place Mexico in the ninth position worldwide and in the fourth position in terms of natural gas. The two principal state-run energy companies occupy similar positions as PEMEX is in the seventh position worldwide in terms of crude oil production and the National Electricity Commission (CFE – name in Spanish) occupies the sixth position among the largest electrical energy producers in the world.

The energy sector has been one of the principal contributors to the emission of greenhouse effect gases because it depends on fossil fuels (oil, coal and natural gas). The following is a brief panorama of the Mexican energy sector. This will allow us to better understand and put into context the initiatives adopted to make use of renewable energy sources and of the programs that have been implemented to increase energy efficiency and decrease the intensity of the use of energy sources with a high content of carbon-based fuels.

2.2.1 The Mexican electrical system

The Mexican electrical system operated by presidential decree of the 10th of October of 2009 by CFE provides service to approximately 97.3% of the total population (CFE, 2009). The cycle that gives life to the national electric system consists of: the generation of electricity, transformation in substations that increase the voltage, transmission by high-voltage lines (161 to 400 kV), a reduction transformation in order to continue to distribute electricity by way of lines that operate at lower voltage (69 to 138 kV), transformation in order to reduce the voltage to distribution levels (2.4 to 35 kV) and lastly, the distribution in the secondary grid to industrial clients that have their own substations and to the transformers that feed the residential sector. This cycle is shown in figure 2.9.

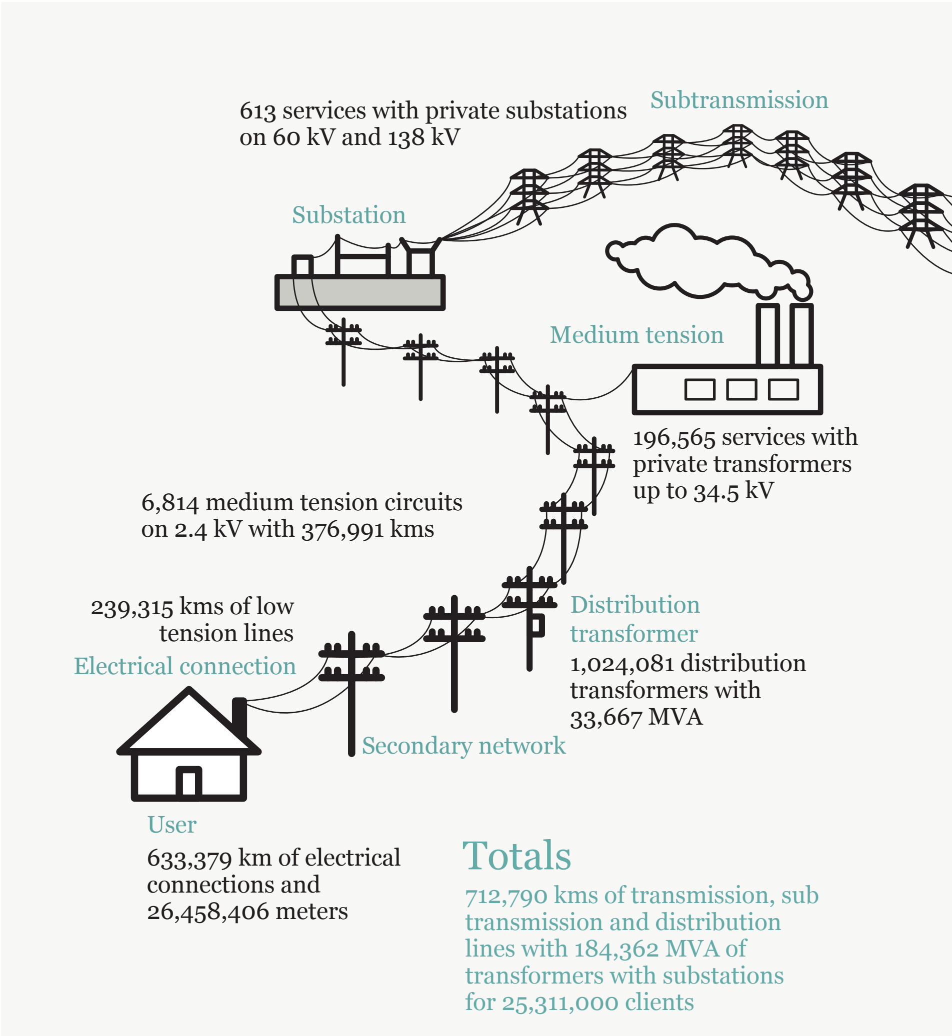
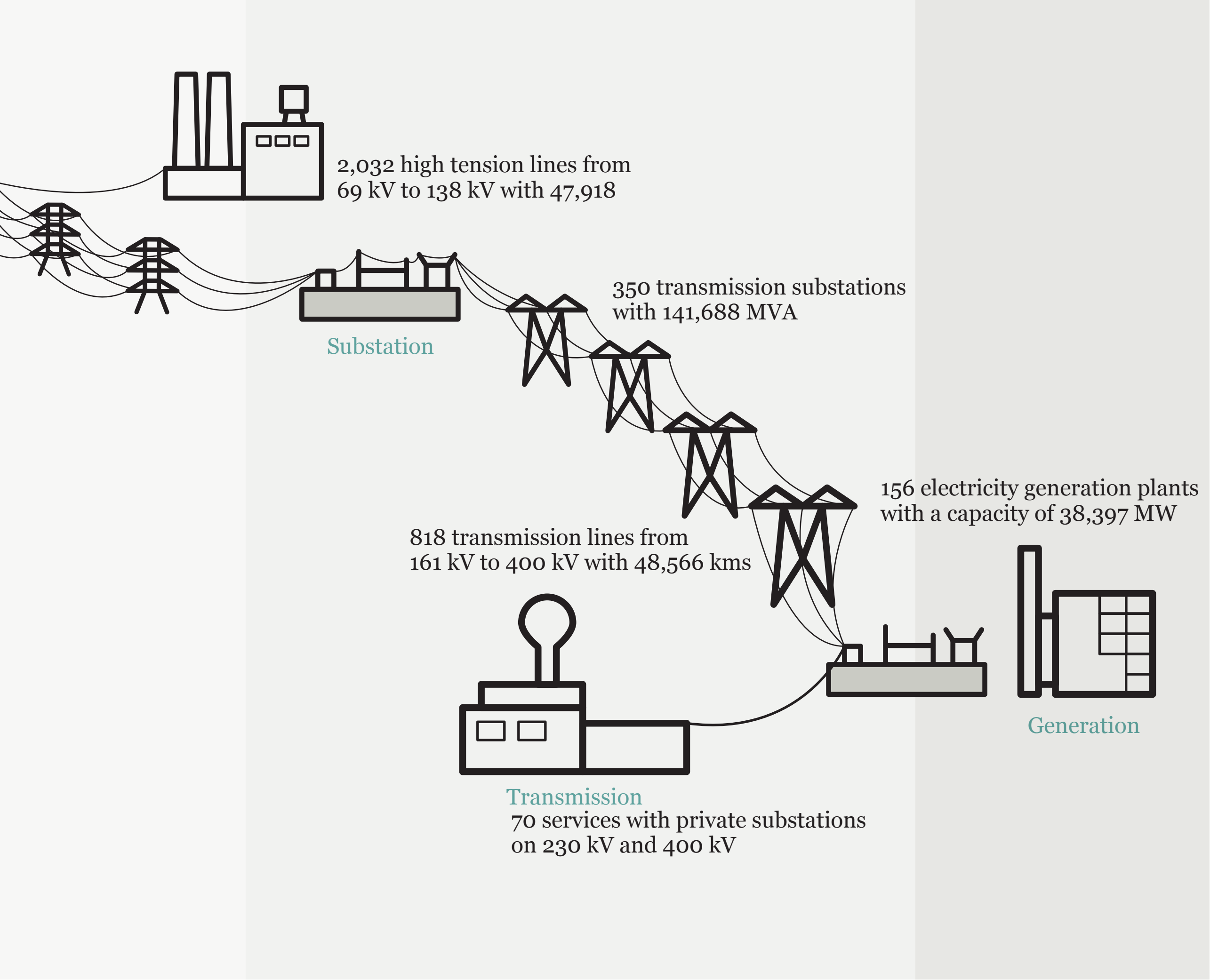


Figure 2.9
National Electrical System.

Source: CFE, 2009.

There exists at least four voltage transformation phases which begs the question: Why is each phase required? Simple: because it is necessary to deliver the electricity to the entire country. The transmission-distribution grid can be explained using the analogy of the human circulatory system; better said, large arteries are required in order to transport substantial amounts of blood to the body which culminates in the small capillaries. In this same manner, the transmission lines distribute substantial amounts of high-voltage electricity forming a grid which covers the whole country.



In figure 2.10, it is easy to appreciate that there exist extensive areas between the transmission lines. The sub-transmission and distribution grids supply electricity to all the country. It is important to note that the civil infrastructure relating to the transmission-distribution lines is less complex when the voltage that is transmitted is lower. At the close of 2007, the CFE grid had close to 720,000 kilometers comprised of different voltage lines.

Regions

Northwest

1. Hermosillo
2. Nacozari
3. Obregón
4. Los Mochis
5. Culiacán
6. Mazatlán

North

7. Juárez
8. Moctezuma
9. Chihuahua
10. Durango
11. Laguna

Northeast

12. Río Escondido
13. Nuevo Laredo
14. Reynosa
15. Matamoros
16. Monterrey
17. Saltillo
18. Valles
19. Huasteca
20. Tamazunchale

Western

21. Tepic
22. Guadalajara
23. Aguascalientes
24. San Luis Potosí
25. Salamanca
26. Manzanillo
27. Oarapan
28. Lázaro Cárdenas
29. Querétaro

Central

30. Central CFE

Eastern

31. Veracruz
32. Poza Rica
33. Puebla
34. Acapulco
35. Temascal
36. Coatzacoalcos
37. Tabasco
38. Grijalva

Peninsula

39. Lerma
40. Mérida
41. Cancún
42. Chetumal

Baja California

43. USA
44. Tijuana
45. Ensenada
46. Mexicali
47. San Luis Río Colorado

Baja California Sur

48. Villa Constitución
49. La Paz
50. Los Cabos

Figure 2.10
Transmission capacity between regions.

Source: CFE, 2009.

Another fundamental stage in the national electric scheme is the generation. By March 2009, a little more than 73% of the installed capacity of 51 MW depended on fossil fuels with plants working based on the combustion of petroleum or its derivatives including combustion or conventional thermal electric turbines. These represent approximately 26% of the installed capacity.

The plants working with natural gas represent close to 43% of the generation capacity which is close to 35% of the generation derived from other thermal electric plants. The hydroelectricgeneration represented 16% of the total energy supplied to the national electric system.

Chart 2.2 presents a summary which shows that the percentages of capacity and of generation are not directly related due to different factors such as availability, selection of the basket for base generation, among others. The independent producers normally use natural gas as the resource in their combined-cycle plants.

Capacity & generation per type of energy

	Capacity (MW)	Generation (GWh)
Hydroelectric	22.20%	15.94%
Thermoelectric	45.57%	35.12%
Independent Producers*	22.42%	33.94%
Carbon-electric	5.09%	9.16%
Nuclear Electric	2.67%	2.59%
Geothermal Electric	1.89%	3.13%
Wind-powered Electric	0.17%	0.12%
Total	51,105	236,951

Chart 2.2
Capacity & generation per type of energy.

Source: SENER, 2008.
**21 PIE, primary energy: natural gas.*

The above chart shows that more than 78% of the electrical energy was produced using fossil fuels. When the percentage of installed capacity is compared with the gross annual generation, we see that CFE´s generation strategy maximizes the utilization factor of the independent producers (with combined-cycle plants), of the two carbon electric and generation by geothermal electric sources. Likewise, we can see that the nuclear electric installation at Laguna Verde operated, on average, at 97% of its capacity during all of 2008.

Probably the most important development factor in the Mexican electric sector will be the change in the composition of the fuels mix which will translate into a greater dependency on natural gas and alternative sources for energy generation. This invites us to reflect on topics outside the scope of this chapter, but not for this less important: the electric macro-generation used by the thermonuclear plants has many operational advantages that have already been tried in the electrical energy sector.

In the above figure we can appreciate how the modification in the consumption patterns of fossil fuels for the electrical energy generation is based on the need to reduce greenhouse effect gases that result from

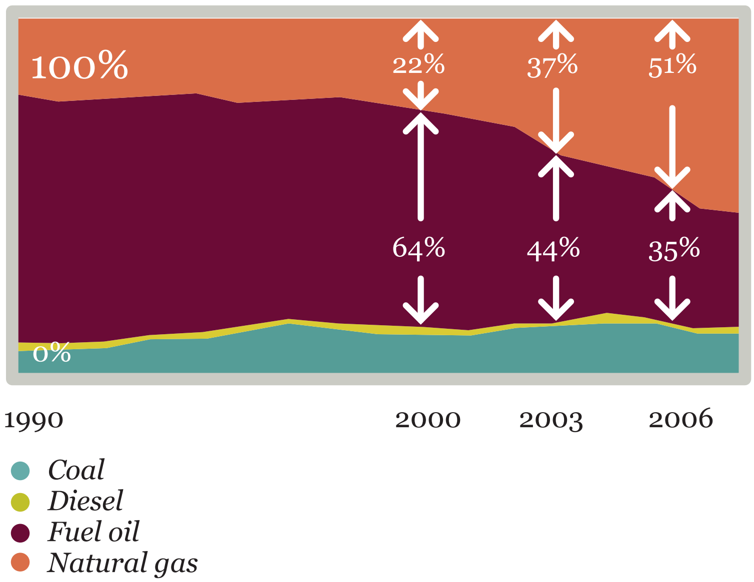


FigurE 2.11
Modification in the consumption pattern of fossil fuels for electric energy generation.

Source. Environmental and Energy Program For 2002-2003 "Towards Sustainable Development" July 29, 2003.

that generation. The burning of oil was substantially reduced to favor the use of natural gas as the primary source. The increase in the use of coal as a fuel is due in great part to the change at the President Plutarco Elias Calles thermal electric plant located at La Union in the State of Guerrero.

The CFE constantly takes into consideration the above-mentioned factors through the Program for Public Works and Investments in the Electric Energy Sector (POISE). This program reflects the result of diverse coordinated studies and looks for the integral planning of the national electric system. POISE includes an expansion program that will inform the nation about the magnitude and the regional location of the additional generation, transmission and transformation capacity required by the national electric system in order to satisfy the demand of the public sector for electrical energy during the coming years.

The following figure showcases the plan proposed for the year 2014. It shows a substantial increase in the required capacity; the bulk of this capacity will be provided by the combined-cycle plants and by giant hydroelectric, geothermal electrical and wind-powered electrical projects.

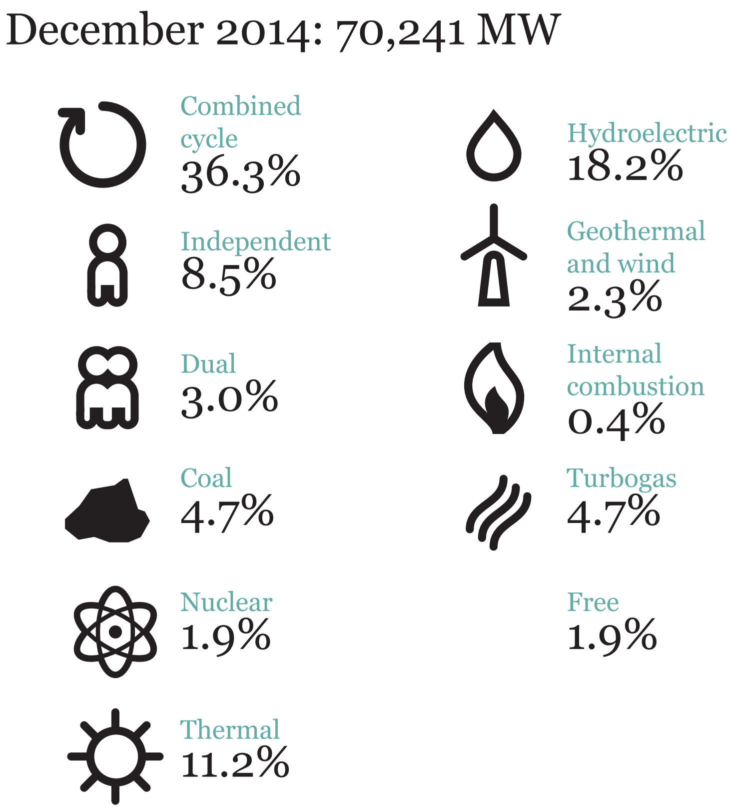


Figure 2.12
POISE, year 2014.

Source: CFE, 2005.

The IEA estimates that by 2020, Mexico will increase by a little more than 5 times its use of natural gas until it reaches 44% of the total generated. Mexico has seen a rapid increase in the imports of natural gas (from the United States of America) equivalent in 2006, to approximately 20% of the total gas used in the country.

On the other hand, estimates indicate that a percentage of CFE´s installed capacity is becoming obsolete and must be replaced in the short term which will generate a greater need to import energy. The total capacity of the installed plants as of March 2009 in the public sector is 51,105 MW not including the capacity for cogeneration and the suppliers of electrical energy. For example, in terms of biogas and according to data provided by the Energy Regulatory Commission by January 2009 two permits had been authorized using the self-generation scheme and one permit for the co-generation scheme in order to obtain energy from this source. These three permits once they are fully operational represent a little more than 23 MW that is, approximately, 0.05% of the public sector national capacity.

It's a fact that in spite of the recent reforms to the energy sector in Mexico, of the possible use of the confirmed reserves composed in the following manner: 33% proven, 34% possible and 33% probable for a total of 44.5 billion equivalent barrels of crude in December 2007) and the confirmation of the existence of estimated reserves, the depletion in the medium term of the fossil-based fuels is a reality. Consequently, the use of alternative energy sources is more important.

It should be noted that during the decade of the 90´s, the emissions of carbon bioxide into the atmosphere were stabilized due to the fact that there were no great variations in the fuel mix used by CFE. Starting in the year 2000, a drop was observed with the gradual substitution of oil for natural gas when the combined-cycle generation plants began operations. These plants besides having a greater efficiency than the traditional thermal electric plants use a fuel with a lower carbon index – natural gas – than the oil traditionally used. In addition, this decrease in the emissions of greenhouse effect gases is accompanied with a lower emission of contaminants that affect the quality of the air, such as sulphur bioxide and suspended particles that have a significant impact on the health of the Mexicans and on the economy.

According to Enerdata (2009), in the year 2000, the intensity of CO2 in Mexico was 20% lower than the world average. The intensity of CO2 in the industrial sector was 18% lower than the world average while the intensity of CO2 in the transportation sector was 10% higher than the average and 16% higher in the agricultural sector. Although the biomass was 8.7% of the energy consumed by the industrial sector worldwide, in the case of Mexico it was only 3.8%.

Mexico needs to establish a more aggressive low-carbon strategy for the medium and long term and incorporate state-of-the-art technologies as these become available. At present, some strategies exist such as the one set up by the Special Program for Climate Change (PECC, SEMARNAT, 2009). This strategy takes into consideration among other points, an increase in the participation of renewable energy sources in order to reach by 2030 that 49% of the generation will use this base and it will triple the generation of nuclear-based energy.

In the case of the transportation sector, the program identifies diverse opportunities that will reduce the amount of coal used through the use of second-generation bio-fuels. Likewise, it considers promoting efficiency improvement in public transportation through the replacement of the existing vehicles.

With regards to energy efficiency, the program proposes to substantially increase the transmission of electrical energy using a concept of "intelligent grids". Likewise, at energy-intensive industries it promotes the improvement of energy efficiency through the better use of varied opportunities in the processes and operation methods as well as the replacement of inefficient equipment. It also devotes special attention to the intelligent consumption of energy in buildings through the use of more efficient lighting and the substitution of electronic equipment and apparatus in general. It also proposes innovative solutions in the different thermal applications including insulation, air conditioning and water heating.

The use of renewable energy sources in Mexico has grown due to among other factors, the availability of renewable energy sources that offer a great potential for the development of electric generation projects or for other applications.

Among other factors, the following can be cited:

- High levels of solar radiation in extensive regions of the country;
- High potential to take advantage of the installation of mini-hydraulic plants.
- Geothermal regions with high or low enthalpy that can be developed.
- Areas with constant or high intensity wind currents.
- Grandes volúmenes de esquilmos agrícolas.
- A need to dispose of organic waste in a sustainable manner in the cities and countryside.
- Many areas with the potential to grow alternative crops that can be converted into bio-fuels.

Energy security continues to be a priority in Mexico and it will continue to be as long as oil resources diminish. Therefore, the use of renewable energy sources represents an alternative to reduce Mexico´s dependence on fossil fuels and increase energy security.

In addition, other important advantages exist behind the adoption and promotion of the renewable energy sources. In the social sphere, they will allow electrical energy to be supplied to rural communities that cannot be supplied by the national electrical grid and they offer a better quality of life and a just social development. It is also important to point out that the infrastructure associated with renewable energy sources must be installed in the regions with low economic activity. In this manner, as more communities participate in the activities for the installation, maintenance and operation of this equipment, new jobs as well as social well-being is created.

The use of renewable energy sources implies: a reduction in greenhouse effect gas emissions, a reduction in the extraction of fossil fuels, the conservation of natural resources and the preservation of more green areas as well as better air quality.

The potential and capacity that Mexico has with respect to the use of renewable resources makes it a region to be envied and, at the same time, a nation of great commitments and opportunities. Regarding its capacity, it should be mentioned that with the construction of the El Cajon hydroelectric plant, Mexico´s installed capacity for the generation of electrical power from renewable sources is over 12,960 MW, which is 23% of the installed capacity in the country. At present, 19% of the energy generated for the public services sector is produced using renewable sources.

Installed capacity (MW) for Electrical Energy Generation with Renewable Energy Sources.

Renewable Energy Source	CFE	Self-Supply	Off-Grid
Hydraulic	1093	—	—
Mini-hydraulic	36	10	—
Geothermal	96	—	—
Biomass	—	47	—
Biogas	—	2	—
Solar	—	—	1
Wind	8	16	—
Total	**1234**	**76**	**1**

Chart 2.3
Installed capacity (MW) for Electrical Energy Generation with Renewable Energy Sources.

Source: CRE, 2009.

To date, 68 permits with an installed capacity of 764 MW are in operation. The permits being developed in terms of capacity are focused principally on wind-powered energy and have a high probability of being placed in operation. In order to be able to self-supply their electrical energy requirements, the CRE has authorized 90 licensees an installed capacity of 2,428 MW using renewable energy sources.

The potential, the barriers and the opportunities associated with each one of the renewable energy sources are explained separately in the following chapters of this book

2.3 Efficiency in the use of energy

During many years low-cost fossil fuels were available and consequently the efforts to improve energy efficiency were not as great as expected. However, as the supply of low-cost fossil fuels has decreased, the cost impact has driven several consumers to change their equipment as well as their operations and energy consumption habits in order to promote energy savings.

These efforts which during certain periods were the exclusive responsibility of the energy users have received government subsidies. A coordinated effort to reduce energy demand with the support of groups seeking energy efficiency, promotion of a reduction in greenhouse effect gases particularly carbon bioxide was sought. In that sense, taking advantage of the synergy between energy efficiency and renewable energy was purported as these can be applied simultaneously and they reinforce each other. Additionally, the improvement in energy efficiency allows the renewable energy sources to satisfy a smaller demand. This, in turn, contributes to a reduction in emissions thanks to the crossover financing which is a by-product of the same reduction.

Frequently it has been stated that the potential for energy efficiency in terms of a reduction in demand is so great that an adequate supply of energy with the existing sources could be guaranteed. On the other hand, there are others that state that the potential of the renewable energy sources could exceed the potential savings due to energy efficiency. However, these affirmations are inexact. The truth is that both – energy efficiency and renewable energy – significantly insure a long-term sustainable energy supply, in the same way that synergies exist that increase the potential when these are simultaneously applied.

Therefore, in the short term, the contributions to energy efficiency constitute a simple and quick option to the reduction of the use of fossil fuels and the avoidance of the emissions of greenhouse effect gases into the atmosphere. Frequently, it is possible to increase the efficiency with changes in the operations or with the partial or total replacement of equipment. At the same time, this option is the most economical in the short term. Notwithstanding, this reduction in energy consumption is limited and therefore, a more intensive use of renewable energy sources will become increasingly important although the use of fossil fuels will continue at least during the next 20 years. These will in fact continue to be the dominant sources of energy.

The improvement in energy efficiency consists of a reduction in the amount of energy used to make a product, provide a service or undertake a certain activity. Although this reduction is associated with technological changes it is also possible that it is the result of improved operations and administration of the processes and possibly even due to non-technical reasons. Energy efficiency can be translated into economic efficiency that groups technological, technical, economic, administrative and behavioral improvements. However, usually only a reduction in energy consumption is considered as a contributing factor to energy efficiency when it adds to the global efficiency of the economy and it cannot be easily reversed.

The improvement in energy efficiency in the different sectors – industrial, services and residential – has great relevance due to the direct savings that translate into lower costs as well as due to the benefits in climate change. Even when the efforts in this area generate speedy results; a fall in the improvement of energy efficiency has been observed in the majority of the countries during the past 10 years.

Another important aspect in energy efficiency at the global level as well as in each country are the reliable statistical energy indicators that contain the sufficient levels of disaggregation that they allow for analysis of the potentials and tendencies and allow for more detailed and effective recommendations relating to energy efficiency. In this sense many countries including Mexico must make an effort to develop more comprehensive, systematic and consistent energy data bases that will facilitate the availability of more solid and homogenous indicators in order to generate comparative analysis. Likewise, they should have monitoring systems that allow for follow-up of the results of the measures that have been implemented.

The energy efficiency indicators that are internationally used are divided into three types:

- **Global macroeconomic indicators** that relate macroeconomic aspects with concepts related to energy efficiency policies that is to say that they consider the energy intensity as related to the gross national product in such a way that the level of intensity that they use to measure energy efficiency has a high level of integration.
- **Sectorial indicators,** that relate the evolution of the energy efficiency with the improvements implemented in the sector in terms of energy savings using technical economic reasons known as unitary consumption.
- **Comparative indicators** by country are those indicators that highlight the achievements in energy efficiency that can be attributed to the implementation of the policies that have been adopted.

Everyday more countries are developing national energy efficiency programs with quantitative goals and annual monitoring schemes. International attention centers mainly on the sectors that generate electrical energy, on industries that are energy intensive, transportation, lighting, office equipment, electro-domestic equipment and buildings as well as on intersectoral activities. In general terms, efforts are directed towards identifying the great opportunities for savings from low-cost energy, the detection of barriers to energy improvements and the proposal of solutions.

Concerning the barriers that limit the development of equipment and more efficient operations, policies that will serve as an incentive for the production of equipment and electrodomestic equipment with stricter efficiency standards must be legislated. This equipment can have minimum net costs thanks to the potential savings that can be achieved as well as to the adoption of more aggressive polices that include external considerations.

Policies promoting energy efficiency are diverse, among these the following standout:

- **a)** Electrical energy plants as well as the incorporation of renewable energy sources. Through these, schemes promoting greater efficiency such as combined-cycle and nuclear energy can be promoted.
- **b)** Energy intensive industries. The objective is to improve energy information in the data bases, the replacement of electric motors with new, high-efficiency ones and co-generation when it is viable.
- **c)** c) The transportation sector. The tendency is to establish fuel efficiency norms for light vehicles, look for fuel economy in heavy vehicles, promote the use of high-efficiency tires and promote the habit and rules of efficient driving.
- **d)** Lighting. Look for the installation of more efficient lamps and the disappearance of incandescent light bulbs.
- **e)** Office equipment. Establish obligatory energy consumption rules and low-powered computer equipment.
- **f)** Electrodomestic sector. Establish obligatory energy consumption rules, low-powered electrodomestic equipment with remote-controlled sensors or equipment with an existing stand-by mode as well as the establishment of standard performance tests.
- **g)** The buildings. This constitutes one of the areas with the highest potential for energy savings and has been the subject of many recommendations of ways to improve energy efficiency through the following steps: new designs and materials for windows, the establishment of new specific building codes for the construction of new buildings, the construction of buildings which closely follow the concepts of zero energy and houses applying passive energy, schemes to improve energy efficiency as well as the certification of new and existing buildings.

The energy efficiency policies include all interventions by the governments that look to reduce the amount of energy used to produce one unit of economic activity in the country. Among these actions are the following: an adequate setting of prices, an institutional structure that will promote and regulate energy efficiency and promote fiscal and economic incentives.

However, consideration must be given to the fact that measures regarding pricing are very frequently insufficient in of themselves to promote energy efficiency. It is necessary to eliminate other barriers and develop a market structure that will have enough equipment and efficient apparatus, provide good information to the consumers regarding the existing features – especially regarding energy consumption – as well as an ample supply of technical, commercial and financial services. One important element is the support given for investigation and development of technologies that will lead to greater efficiency in energy consumption and will accelerate the replacement of existing equipment with more efficient equipment allowing for decreased costs. Notwithstanding its importance as a valuable tool for the promotion of energy efficiency, the policies imply a cost to the taxpayers which means that their implementation must be carried out very cautiously.

It is very clear that for these policies and monitoring schemes to be sensible, the macroeconomic benefits derived from their implementation must be greater than the cost paid by the taxpayers. However, the evaluation is not easy as the gathering of information in order to evaluate the results of any policy is many times very complex and is usually affected by external elements. The global impact will be the result of the sum of all the individual cases that are derived as a result of the implementation of the policy. The TAR (Third Assessment Report) as well as the AR4 (Assessment Report number 4) issued by the International Panel on Climate Control contain these concepts.

Since 1989, the Mexican government has carried out diverse activities with the participation of organisms, institutions and public as well as private associations with the purpose of achieving savings and an efficient use of energy as well as for the use of renewable energy in the country. Such is the case of the Program for Energy Savings in the Electrical Sector carried out by the national electricity company, CFE. Chart 2.4 shows some of the activities carried out to promote energy efficiency in Mexico.

Notwithstanding, Enerdata indicates that in 2007 the intensity of the primary energy in Mexico was 19% lower than the world average. This average reflects a tendency towards lower intensity which has been sustained since 1980 and has dropped 33% during the period while Mexico has only achieved a 5% decrease in this indicator. However, there exist very important differences between sectors in terms of energy intensity. In the industrial sector, Mexico achieved progress which is reflected in a 33% reduction during the period placing this indicator 14 percentage points below the world average which dropped 50% during the same period. However, in the transportation sector, the indicator for Mexico in 2007 was 10% above the value registered in 1980 and 33% above the world average which dropped during the period.

Historical panorama of activities undertaken to promote energy efficiency in Mexico.

Year	Activity
1989	FIPATERM was created
1989	The CONAE was created
1990	FIDE was created
1993	The Normalization Committee was set-up
1995	The first NOM was published
1996	The FIDE incentive program started-up
1999	The APF-assets program is initiated
2000	The PEMEX-CONAE integral program begins
2001	PROSENER includes energy savings as an objective
2002	NOM standardization with USA and Canada
2005	National campaign promoting intelligent use of energy
2008	Passage of the law promoting Sustainable Energy Use
2008	The CONUEE is created
2009	National Strategy for Energy Transition and Sustainable Use of Energy

Chart 2.4
Historical panorama of activities undertaken to promote energy efficiency in Mexico.

Source: Prepared by authors with publically available information

On the other hand, in the transformation sector, global energy efficiency was 62.3% in Mexico versus 67.4% worldwide in 2007 while global electrical energy generation reached 39% in Mexico – slightly better than the worldwide average of 38.4%-. This achievement was impacted by the losses observed in the transmission and distribution of electricity which, according to the same publication, reached 15.1% in Mexico while the worldwide average was 8.7%.

The National Development Plan for 2007-2012 purports the search for sustainable human development and has in its objectives the reduction of greenhouse gas emission. Among the policies established for energy sustainability is included a decrease in greenhouse gas emissions based on the national Strategy for Climate Change and the Special Program for Climate Change. Likewise, a goal for energy efficiency was set in the Program for Sectorial Energy (SENER, 2008) which looks for savings of 16% in the national consumption of electrical energy.

The development of a reliable and timely data base which allows for an analysis of the performance of the energy sector and which will function as support for the design, formulation and implementation of public policy regarding energy matters presents important challenges. For this reason, energy efficiency indicators that have a high level of disaggregation with the objective to analyze the final use of the energy in the different sectors are necessary. With this, it will be possible to obtain complete and relevant results that reflect parameters with enhanced reliability, conceptual rigor, timeliness, comparability and accessibility. Also sought are better decision-making and development tools as well as follow-up and evaluation of the public policies related to the administration and distribution of the energy resources in Mexico.

Also standing out is the creation of a National Commission for the Efficient Use of Energy (CONUEE in Spanish) within the framework of the Energy Reform of 2008 using as a starting point the National Commission for Energy savings (CONAE in Spanish). The CONUEE plans to promote energy efficiency and become the technical organism regarding energy sustainability understanding this as the optimum use of energy in all the processes and activities for its exploitation, production, transformation, distribution and consumption including its efficiency.

Regarding the legal framework, the Law for Energy Sustainability (SENER, 2008) defines energy efficiency as a group of activities that lead to an economically viable reduction in the amount of energy needed to produce the goods and services required by society assuring a level of quality equal to or greater than these needs as well as a reduction of the negative environmental impacts from the generation, distribution and consumption of energy. This definition includes the replacement of non-renewable with renewable sources of energy. The law calls for the creation of two programs – The National Program for Energy Sustainability (which is still in the discussion phase but which must incorporate topics such as scientific and technological investigation) and the Energy Efficiency Normalization Program – two strategies – one for the modernization of the public transportation sector and the other to replace incandescent with fluorescent lamps throughout the country. Additionally, it proposes the creation of a Steering Committee for Energy Sustainability to evaluate the level of completion of the program´s activities and goals. Given the importance of reliable timely records of the energy generation and usage, this law creates the National Information Subsystem for Energy Use with the objective of providing energy efficiency indicators for the country allowing for comparison with other nations.

Energy efficiency normalization has shown to be, in the countries that have adopted this measure, a useful tool in promoting the rational use of the energy generated. In 1993, the SENER, through the CONAE, established the Steering Committee for the Preservation and Rational Use of the Energy Resources (CCNNPURRE in Spanish) thus formally kicking-off the energy

The Impact of Energy Efficiency NOMs on equipment in operation in 2007

NOM	Objective	GWh/year	MW
001-ener	Vertical pumps	145	52
004-ener	Centrifugal pumps	34	125
005-ener	Clothes washers	647	0
006-ener	Pumping systems	2,312	52
007-ener	Lighting in buildings	1,373	55
008-ener	Building enclosures	314	77
010-ener	Submersible pumps	120	39
011-ener	Central conditioners	281	39
013-ener	Street lighting	22	5
014-ener	Single-phase motors	375	279
015-ener	Refrigerators	6,318	1,296
016-ener	Three-phase motors	2,415	806
017-ener	Florescent lamps	173	4
018-ener	Thermal isolation for buildings	83	7
021-ener	Conditioners	2,192	325
022-ener	Commercial refrigeration	1,158	139
Total Electricity Savings		17,963	3,299
		MBep/year	
003-ener	Water heaters	4.68	
009-ener	Thermal industrial insulators	0.58	
Total Electricity Savings		5,26	

Chart 2.5
Impact of Energy Efficiency NOMs on equipment in operation in 2007

efficiency normalization process in Mexico. The work carried out by this group led to the first three Mexican norms published in September 1994 and which came into force in January 1995. The products that were regulated by these three norms were refrigerators, air conditioners and three-phase motors. To date there exist 18 energy efficiency norms in effect in Mexico, 13 relating to products and 5 relating to systems.

Regarding energy efficiency, Mexico through the CONUEE participates internationally in the North American Energy Working Group (NAEWG), in the Council for Harmonization of Electrotechnical Standardization of the Nations of the Americas (CANENA), in the Pan-American Commission for Technical Norms (COPANT in Spanish) and in the Mesoamerican Energy Integration Program (PIEM in Spanish).

The CONAE (currently CONUEE) working jointly with the IEA and the Inter-American Development Bank coordinated the activities for the development of national energy efficiency indicators using an approach similar to

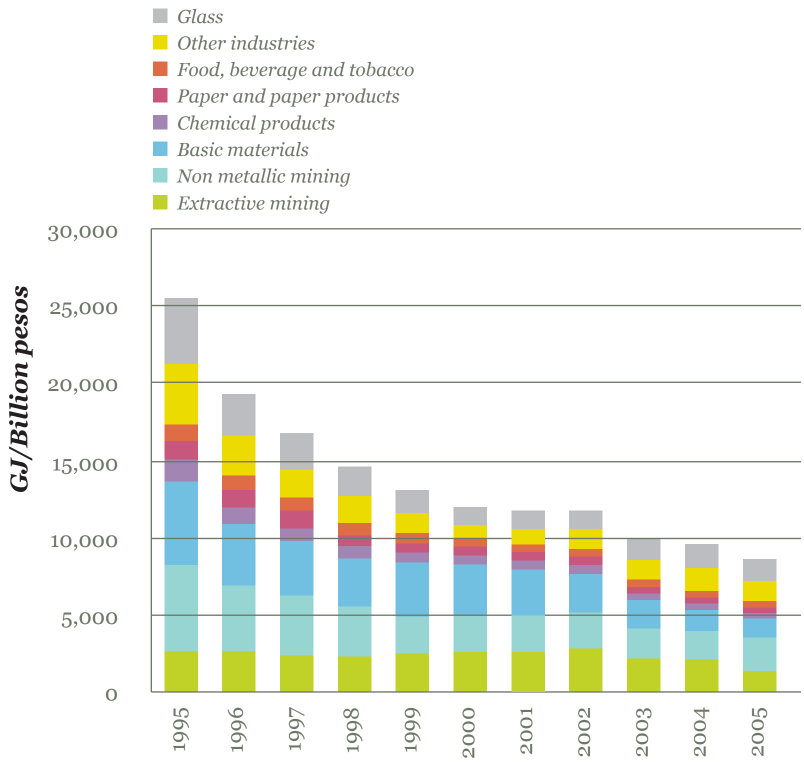


Figure 2.13
Evolution of Energy Intensity by Industry (GJ/MM$).

Source: CONUEE, 2008.

the one used by the G-5 countries – Brazil, South Africa, India and China as well as Mexico in order to develop these. Preliminary results show that the currently available information allows for the development of first level energy efficiency indicators and second level disaggregated indicators for some areas in the industrial sector.

2.4 Intensity in the Use of Energy with a High Carbon Content

In spite of all the efforts carried out in order to reduce energy intensity, the exploitation and the supply of energy will continue to increase although differentiated according to the level of development. If there is no substantial change in the energy policies, the mix of energy sources that supply the economy will not change during the next 20 years which means that more than 80% of the primary energy will come from fossil fuels. That is to say that the energy structure will continue to be carbon-based.

In that sense, the parties that form the United Nations Framework Convention on Climate Change (UNFCCC) and the coming into effect of the Kyoto Protocol have allowed for the implementation of different mitigation measures. However, these are still insufficient in order to reverse the effect of greenhouse gas emissions. The experience of the different countries included in Addendum 1 of the Kyoto Protocol has shown that tremendous barriers exist for the implementation and coordination of the mitigation measures. Add to this, that the impacts generated by population growth, economic development, the patterns of technological development and the social aspects of the consumption negate the efforts to improve energy intensity and reduce carbon intensity – although there exist considerable differences between the different regions of the world.

That is why; article 2 of the Protocol sets the recognition of the differences in responsibilities and the respective capacities of each country to establish commitments and cooperation requirements. The last one implies a sharing of information concerning the carbon effect on climate change and air quality as well as the willingness to transfer adequate technologies to face this problem.

Moreover, it is necessary to remember that the climate as well as the socioeconomic system has inertias that must be considered when setting up specific goals and objectives which relate to the turnaround time of the atmospheric cycles and of the carbon. The principal source of greenhouse gas emissions is the burning of fossil fuels. Proof of this is the increase in the atmospheric concentration of CO_2 which grew from 100 ppm in the pre-industrial period to its current value of between 433 and 477 ppm CO_2 equivalent.

The use of carbon-based fuels has led to the fact that energy generation and the transportation sectors have the greatest impact on climate change, in addition to others which also contribute such as the industrial, residential and services sectors. For this reason, the energy policy measures that are more frequently mentioned to reduce climate change are the improvement of energy efficiency and the change to other fuels with lower carbon content. To generate electricity, the move to co-generation processes and in the long term, nuclear electric plants are mentioned.

In spite of the substantial increase in non-traditional renewable energy sources including wind and solar energy, the participation of fossil fuels continues to be slightly greater than 80% while in 1980 it was 86%. The principal reason for this difference is the use of nuclear energy. The continuous reduction in the energy intensity rate implies structural changes in the global energy system. The drop in carbon intensity in the energy supply was very significant during the decade of the 80´s as a result of the oil crisis of the 70´s; however it stalled during the second half of the decade of the 90´s and starting in 2000 it began to rise. Among the emerging nations, China and India registered reductions in the energy intensity. Notwithstanding, at the same time, their carbon intensity increased which is very common in the early stages of industrialization in any country.

In the specific case of Chine, a major part of its growing electric generation is carried out at carbon-electric installations. Additionally, these countries have one of the fastest growing transportation sectors in the world comprised by vehicles that use fossil fuels.

Both the 2008 IEA World Energy Outlook and the International Energy Outlook consider that energy dependence will continue with fossil fuels. That is to say that, that the energy economy can evolve but not offer radical changes if the substantial policy changes are not previously carried out by the main current and future energy consumers. Due to the fact that there is a growing energy demand in the developing countries, the effect that their carbon index has on the rest of the world is relevant. This group of nations will be in the short term, the ones that consume 50% or possibly more of the total of fossil fuels.

The technological investigation and development will be a fundamental part of the primary energy structure that we will have in the future and the manner in which these will be utilized. Given that the energy infrastructure requires a long time to mature its projects and that its installations have a long useful life, the inclusion of technological advances to influence long term development is indispensable.

There exist several types of technology that will be relevant including the new energy efficiency schemes, solar and wind energy, fourth generation nuclear fission and nuclear fusion, biomass and geothermic. The technological advances in traditional energy sources will also be essential such as the capture and storage of coal and the generation of energy from waste and hydrogen cells. Some of these are still in the development stage while others are mature but still require some type of support.

The widespread acceptance of the need to detain climate change and the fact that CO_2 is the principal greenhouse effect gas per volume has allowed that the reduction in the carbon content has become a principal talking point of international policy. That reduction or decarbonization constitutes a major challenge for the world as the economies of various countries developed during the last century based on carbon-based fuels. Even though it may be for the heating purposes, production, transportation and, in general to provide a modern lifestyle, this fuel generates CO_2 and other gases that affect air quality or lead to a greater climate change. Due to this, there exist several decarbonization possibilities among which are included improvements in energy efficiency, alternative methods for generating and taking advantage of the energy and finally, changes in social behavior.

As already mentioned, among the alternative forms of generating energy are included renewable energies such as hydraulic and wind. In a longer term, marine energy in its different forms, solar and fuel cells and the development of new generation nuclear electric plants will play an increasingly important role. The technologies based on bio-energy will also play an important role for heating purposes and electric energy generation as well as for transportation. One way to control the carbon content while maintaining the use of some fossil fuels – a method that will be available in the following years – is the capture of CCS. As the generation of low-carbon electricity will represent an important decarbonization effect, the great potential of CCS technology is very attractive due to the impact that it would have on the electric system. However, while the decarbonization cost increases as the first phases are easy to achieve and have a marginal cost; as advances are achieved the options are more complex and costlier. Notwithstanding, the contribution that the emerging technologies have on carbon reduction have not been calculated.

The development of strategies should not consider exclusively the infrastructure and the available technologies; on the contrary, it is desirable that more advanced technologies be developed that are competitive and that significantly contribute in the following years to the solution of this problem. However, consideration should be given to the fact that along the way, divergences will appear in the availability, the performance and the supply of low-carbon technologies that are effective in terms of cost. For example, the intensive use of renewable energies to supply electrical energy must follow operation and supply rules that facilitate its performance. In the case of new technologies, the learning curves will demand economic support which has been the case for wind-powered electric plants as well as support for investigation and technological development which will guarantee it development in the long term without the need for subsidies.

The carbon reduction schemes applied to energy generation imply changes in the production, distribution and consumption systems. The problem lies in that up until now the changes in the energy policy have referred exclusively to the supply side. Due to this fact, the opportunities in the whole energy system must be considered from primary exploitation up to final consumption in such a way that the identification of specific development points is viable.

There exist diverse options for the adoption of technologies that imply a reduction in carbon content. For example, the greenhouse gases emitted during the generation of electrical energy, transportation and heating come mainly from the use of fossil fuels. However, it is foreseen that in the next 20 years, bio-fuels will substitute between 20 and 30 percent of the fuels currently used. In the generation of electricity, the participation of low-carbon fuels such as renewables and nuclear, could double in the next 20 years, while the low enthalpy geothermal energy could have a more generalized use in water and buildings heating systems. On the other hand, also considered is the installation of electric turbines capable of operating at low wind speeds in order to feed small systems or communities located far from the national distribution grid as well as the installation of photovoltaic systems in regions that have a medium solar radiation level.

In the residential sector, the decarbonization includes diverse activities. One of them is the technological change by which heaters that use natural gas or LP gas are replaced by heat pumps to heat water and spaces. In the transportation sector several decarbonization options exist such as the use of electric or hybrid vehicles or the use of vehicles that use preferably second-generation bio-fuels. In this sector, the decarbonization is also based on an improvement in fuel efficiency.

A society with a low use of carbon must pursue measures that are compatible with the principles of sustainable growth that will guarantee the satisfaction of the diverse social groups. It must also contribute to the global initiative to stabilize the concentration of greenhouse gases particularly CO2 and thus, avoid the effects of climate change. Also, technologies that allow for an increase in energy efficiency and the use of low-carbon energy sources must be incorporated. Finally, the adoption of consumption patterns that avoid an increase in carbon intensity must be promoted.

Consequently, both the technological aspects as well as the social behavior patterns are important in order to achieve a reduction in carbon intensity. In this sense, diffusion and information are fundamental in the move toward the future societies – within and horizon of 20 years – whose vision must be different from the current one. Although it is a long-term objective, action must be taken in the short term.

2.5 Conclusions

The governments of the different countries have a responsibility and will play a decisive role in the development of technologies, markets, goods and services with a low-carbon content. Although it would appear that the actions required to achieve this goal have a high cost, consideration must be given to the fact that inaction has an even higher cost. Each government must evaluate the desirability and in each case the manner in which to apply price measures such as taxes, fees, incentives, etc.

Well designed strategies to reduce carbon content constitute a fundamental aspect to the achievement of sustainable economic development as well as important benefits in terms of the environment, economic growth and energy security. The sectorial policies that promote low carbon intensity at all levels must be consistent. On the other hand, the investments in energy infrastructure must be designed with solutions for low carbon intensity in mind. Likewise, the investments in buildings and transportation must reflect the advancement in technologies in terms of efficiency and taking advantage of the renewable energy sources.

The reduction in the use of fossil fuels will allow Mexico to increase the potential of oil exports and reduce natural and LP gas imports. This will contribute to the improvement of energy security and the balance of payments and also, constitute a real possibility of a reduction in greenhouse gas emissions, an improvement in the air quality and to obtain the benefit of supports due to the sale of Clean Development Mechanisms (CDM). This window of opportunity is finite which means that it is imperative that the correct legal framework is established and that the existing barriers are eliminated so that the advantages can be effectively reached.

Mexico has developed diverse regulations that take into account the characteristics of the renewable energy sources with intermittent availability which facilitates their competitiveness. Among the opportunities that these regulations present, the following can be highlighted:

- The generated energy will be delivered to the transmission grid when it becomes available in accordance with each energy source.
- The energy generated during a certain period and not consumed will be stored by CFE and delivered during a different period.
- The exchange of energy will be carried out using the tariff at the point of interconnection and the tariff at the end of the year. The user can sell the residual energy back to CFE at the Total Short Term Cost thus allowing CFE to function as an energy bank.

In November 2008, the Mexican government published the National Program for the Sustainable Use of Energy. Among the aspects that it contemplates is the establishment of strategies that promote technological development, the training of specialists, a normalization program, and the application of technologies and the use of lighting, equipment, apparatus and efficient vehicles. The same as in the majority of the countries, the potential in the short term for the reduction of carbon intensity in Mexico is limited and it will be necessary to increase renewable energy participation and pursue the use of alternative sources. At the same time, greater efficiency should be promoted both in generation as in the use of energy.

In addition to the different public and private projects based on renewable energy sources that are in development, the new projects must be vigorously pursued, assign resources to investigation and technological development, establish an adequate legal framework that will reflect the structural changes that can be observed worldwide, internalize the environmental impacts in the energy costs and develop financial mechanisms that will allow for the generation of new projects. The legal framework and the policies should be continually reviewed in order to monitor their impact on the carbon intensity reduction process in Mexico.

One of the principal observations that have surfaced as a result of the reunion of experts in energy topics is that the public policies represent one of the most important incentives to promote the expansion and the use of renewable energy sources. It is therefore necessary to continue to define and publish stable government strategies that are predictable and independent of the changes in government every 6 years. In this manner, the sector will emerge as an important component for achieving a stable economic development and low carbon emissions.

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3.
The regulatory framework for the use of renewable energy

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3.1
Introduction

The development of renewable energy (RE), also called green energy, alternative energy or sustainable energy is a world-wide imperative and a principal component of national energy policies. Some of the elements that characterize the integration of RE into the regulatory framework is as follows:

- RE have by definition a low environmental impact and comply with the criteria for sustainability as they satisfy the current needs of the population without putting at risk the possibility that future generations will be able to satisfy their needs. This type of energy offers public policy alternatives directed towards the reduction of the effects of climate change for example, the reduction of greenhouse gas emissions (SENER, 2005).
- With regards to their efficiency, the RE reduces the risks associated with price volatility which characterizes conventional energy sources.
- To deal with the energy independence that every country must insure demands the development of new technologies. In that sense, energy diversification is viable through promoting the use of alternative energy generated from other sources such as solar, wind, mini-hydraulic and biomass.

- Full coverage of the energy demand is essential in order to achieve the social and economic development in any country. That is why RE is the alternative to resolving the energy supply problem in those areas where traditional technologies are difficult to implement.[2]

Due to these considerations, national energy policies have looked not only to design financial instruments and mechanisms that will eliminate the barriers and open windows of opportunity for the implementation of projects based on the utilization of RE but also, to develop an effective regulatory and institutional framework to meet these objectives. Mexico, according to estimates by different organizations, possesses tremendous potential in RE.

Regarding solar energy, the country as an average solar radiation of 5 kWh/m2, one of the highest in the world. On the other hand, the potential in wind energy, according to studies by the National Electric Investigation Institute is upwards of 40,000 MW – the Isthmus of Tehuantepec and the Peninsulas of Yucatan and Baja California have the greatest potential - . With regards to the geothermal energy potential, it is estimated that in hydrothermal systems with high enthalpy (more than 180 °C) more than 2,400 MW can be generated while in the systems with low enthalpy (less than 180 °C) more than 20,000 MW can be generated. Lastly, the National Commission for Energy Savings estimates a mini-hydraulic energy potential of 3,250 MW in plants with under 10 MW capacity.

Such positive figures lead us to ask the question, has the Mexican judicial system the necessary regulatory mechanisms to promote the development of RE? On November 28, 2008, the government published the Law for the Better Use of Renewable Energy Sources and the Financing of the Energy Transition (LAERFTE).[3] in the Official Gazette. Although, the legislation could be considered appropriate – not only because it eliminates the existing legislation and addresses our country's international commitments regarding sustainable growth and the preservation of the environment,[4] but also because it recognizes the enormous potential that Mexico has in RE.[5]–, the precise evaluation of the regulatory map of this segment of energy generation requires the identification of those indicators that better allow for the execution of this exercise. The objective of this chapter is to offer a parameter for the evaluation of the LAERFTE and of the convergent norms.

3.2 The framework for decisions and the regulatory strategies for the LAERFTE

Regarding the framework by which the LAERFTE is incorporated into the Mexican judicial system, it is important to point out that that it is a legislative process which was developed in the middle of the debate and the approval of the recent reforms to the hydrocarbon sector.[6] More specifically, the LAERFTE decree was introduced in the Senate on October 23rd, 2008 as the result of the decision to integrate into one proposal two pre-existing initiatives:

- The initiative presented by Representative Manlio Fabio Beltrones Rivera of the Institutional Revolutionary Party (PRI) to reform diverse articles and issue new laws covering energy matters (July 23, 2008). Concretely and as part of a group of energy reforms, the Law for the Financing of the Energy Transition proposed incentives for the better use of RE through the creation of a financing scheme that would be executed by the National Energy Transition Fund designed to support projects related with the preservation of the environment and that would be operated by the Energy Secretary as a public trust fund.
- The initiative presented by Senator Arturo Escobar y Vega of the Green Ecology Party of Mexico (PVEM, initials in Spanish) which explicitly issues the Law for the Better Use of Renewable Energy of the PVEM (October 2, 2008).

In general terms, it can be affirmed that in the legislative context, the LAERFTE enjoyed wide-spread support from the different national political parties. This was owed to the team work carried out by the parties and the intense communication between the different actors in the energy sector that participated in the long public debate sessions organized by the Senate of the Republic regarding the so called "energy reform" [7].

The objective of the LAERFTE is to regulate and foment the better use of renewable energy in a manner compatible with the social and environmental context. This will be achieved by not only setting the manner of participation of the private and public sectors but also by setting up the regulatory and financial instruments needed for the better use of RE.

Under this premise and in the understanding that the diversification of energy sources requires a gradual and sustained process - leads to the use of the concept “energy transition”[8] –, the Mexican legislators formulated the following regulatory strategies.

3.2.1 Objective of the regulation (activity, means and authorized persons)

The LAERFTE centers its regulation and foment strategies in one concrete activity: the better use of the renewable energy sources and clean technologies in order to generate electricity for other uses besides public supply of electrical energy (article 1). According to the LAERFTE, the RE is that energy whose source resides in nature, in processes or materials that can be transformed by man into usable energy and which regenerate naturally. This allows them to be available in a continuous or periodic basis. Concretely, the group of renewable energy sources selected by the legislators (article 3) includes the following:

- Wind.
- solar radiation, in all its forms.
- El movimiento del agua en cauces naturales o artificiales.
- marine in its different forms (tidal, marine currents and different grades of salt concentration).
- the heat from geothermal fields.
- the bio-energies determined by the Law for the Promotion and Development of the Bio-energies[9].
- others as established by the Energy Secretariat (SENER), whose source meets the characteristics as defined in the law.

To define the object subject to the law, the legislators excluded the following primary sources: radioactive material to generate nuclear energy, hydraulic energy from sources capable of generating more than 30 MW, industrial residuals or of another type when they are incinerated or are subject to some other type of thermal treatment and sanitary landfills that do not comply with environmental norms (article 1).

In terms of the persons authorized to take advantage of the RE, the law points out all persons of Mexican nationality or companies that operate according to Mexican law, domiciled within Mexican territory, which generate electricity from renewable sources (article 3) as authorized.

Lastly, the law establishes that the better use of renewable energy will be for the public welfare and will conform to the principles of efficiency, sustainability and independence from hydrocarbons as the primary energy source[10] (article 2).

3.2.2 Conditions for the incorporation of the energy generated from RE into the national electric grid

According to the LAERFTE, the better use of RE can be based on two consumption premises: self-consumption by the generator and incorporation of the electrical energy to the national grid for general consumption. As basis for these two aspects, the LAERFTE functions from the premises for generation established by the Law for the Public Service of Electrical Energy (LSPEE) –self-supply and co-generation in the case of surpluses–, which opens the possibility that the National Electric System (SEN) can incorporate into its operation the electricity generated from RE (articles 17 and 18).

The law establishes that the Federal Electricity Commission (Comisión Federal de Electricidad -CFE) must adapt the operation of the SEN to the conditions of scale, geographic distribution and of variability of the different technologies for the better use of renewable energy. In the same manner, it must comply with its responsibility to guarantee the quality and the stability of the electrical energy supply (article 19). In terms of the contracts to supply from renewable energy, the law distinguishes between the projects included in the planning by the CFE that will be managed through long-term contracts and the contracts derived from the purchase, by the suppliers, of the surpluses based on self-supply or co-generation from renewable energy. (articles 17 to 20).

In order to allow for the access of energy generated from RE sources to the National Electric System, the Energy Regulation Commission (CRE initials in Spanish) will establish the methodology, technical requirements and the rules and processes for the delivery of the electricity, procedures for the exchange of energy and the rules for the contractual schemes between generators and suppliers (articles 15 to 18).

3.2.3 Cost, incentives and price schemes

According to the scheme of jurisdiction distribution set forth by the law, the CRE, prior opinion from the Tax and Public Credit Secretary (SHCP, initials in Spanish) and the SENER, is charged with setting the maximum charges to be paid by the suppliers (CFE) to the generators that use renewable energy. Those charges, included in the long-term contracts, must contemplate payments for the costs derived from the generation capacity and for the generation of energy associated with the project, according to the regulations set-up by the CRE. The charges will depend on the technology and the geographic location of the projects (article 14)[12].

Due to the important contribution of the RE to price stability in the sector, the Law notes that one of the responsibilities of the SENER is the elaboration of the methodology that will allow for the evaluation of the economic advantages that the use of the technologies for a better use of the RE represent in the long term. This element will be a criterion of evaluation of the projects undertaken by the suppliers for the better use of RE (articles 12 and 13).

The SENER, with the opinion of the SHCP, of the Environment and Natural Resources Secretariat (SEMARNAT, initials in Spanish) and the Health Secretary (SS, initials in Spanish), will write a methodology to value the external factors associated with the generation of electricity based on renewable energy in its different scales, as well as the policies related to these external factors. Based on this methodology and on concrete action regarding energy policy, the SEMARNAT will design environmental regulatory mechanisms for the better use of renewable energy[13] (article 10).[14]

3.2.4 Sectorial planning

Renewable energy will be better used within the law, within the legal framework of an integrated long-term energy policy, through the Program for the Better Use of Renewable Energy,[15] a program that will establish specific goals and objectives based on their economic viability. In addition, it will include and update the National Renewable Energy Inventory, with long-term development plans and perspectives that will heed the principles of maximum diversification and regional development.[16]

Along the same lines and with the objective to guarantee greater participation of renewable energy to satisfy the demand and insure the energy security of the country, the goal for 2012 was established calling for an RE minimum participation of 8% in the total generation of electricity excluding the giant hydroelectric plants (article 11, chapter III).

Additionally, the law states that in the planning proposals made at the SEN working as part of the SENER, the CFE must include projects related to the expansion of the transmission and distribution grids necessary to insure that the goals established by the Program for the Better Use of Renewable Energy (article 11, chapter IV) are reached.

3.2.5 Interregional coordination

The SENER, in conjunction with the entities and dependencies of the Federal Administration and with the diverse government branches, will establish incentives to promote the better use of renewable energy. Likewise, the three branches of government are charged, within their spheres of competence, to celebrate agreements with the suppliers in order to carry out joint projects for the better use of renewable energy available in the territory (articles 8 and 30).

3.2.6 Regional development and public order burdens

The law states that in all projects related to the generation of electricity with a capacity greater than 2,5 MW, the participation of the local and regional communities, of the groups that are potentially affected and of the groups and individuals that are interested in the follow-up of the project must be obtained before authorization is given to change the use of land (article 21). The objective of these strategies is to reconcile sustainable rural development, protection of the environment and land rights.

3.2.7 Financing schemes

Just as the Law points out, it is necessary to establish and guarantee the permanency of a group of financing and budgetary schemes as part of the "Strategy", with the objective of promoting the policies, programs, actions and projects to insure greater utilization and better use of the renewable energy sources and of clean technologies. Likewise, they should be earmarked to promote energy efficiency and sustainability as well as to reduce Mexico's dependency on hydrocarbons as the primary source of energy (articles 22, 23 y 25).[17]

The principle actions that comprise the "Strategy" are the following (article 24):

- Promote and provide incentives for the use and application of technologies to achieve a better use of renewable energy, efficiency and energy savings.

- Promote and disseminate the use and application of clean technologies in all production activities and domestic use.

- Promote the diversification of the primary energy sources increasing the supply of renewable energy sources.

- Establish a program for the normalization of energy efficiency.
- Promote and disseminate measures for energy efficiency as well as for energy savings.

- Propose the necessary measures so that the population can have access to information that is reliable, timely and easy to consult regarding the energy consumed by the equipment, appliances and vehicles that require the supply of energy for their use.

The SENER updates the "Strategy" every year and presents forward-looking information regarding the progress to date in energy transition and the sustainable use of renewable energy. Additionally, it includes a diagnosis concerning the application of clean technology and renewable energy, as well as over the savings, and the optimum use of all types of energy (article 26).

Concerning the budgetary scheme, it establishes that the Federal Executive, when it sends the proposed expenditures budget for the corresponding fiscal year to the House of Representatives, will consolidate the public sector funds proposed for the "Strategy". The minimum amount of funds programmed for the subsequent fiscal years will be updated every three years, in relation to the actual economic growth and the actual growth of the public sector expenditures in line with the provisions in the Federal Expenditures Budget for the corresponding exercise (article 25).

In addition, the Law stipulates that the House of Representatives will provide the necessary funds for the Federal Expenditures Budget such that, the SENER shall have the sufficient human and material resources to dutifully comply with the attributes conferred by the law (2nd Transitory article).[18]

One of the central elements of the LAERFTE is the creation of the Fund for Energy Transition and Sustainable Use of Energy (FTE, initials in Spanish) (article 27).[19] This financial instrument will allow for the administration, assignment and distribution of the public and private resources, from national or foreign sources, that have been earmarked to achieve the objectives established in the "Strategy". Likewise, and in order to optimize the funds available for the energy transition, for energy savings, for clean technology and for the better use of renewable energy, non-recoverable funds can be used to guarantee credit lines or provide other types of financial support for the RE projects.

The LAERFTE facilitates the national and international sale of renewable energy certificates through a certification system defined by the SENER. In effect, the Federal Executive will design and establish the policies and measures to facilitate the flow of resources derived from the international financing mechanisms related to the reduction of the effects of climate change.[20]

The abovementioned policies and measures will promote the application of the international mechanisms that are oriented towards the reduction of greenhouse gas emissions in accordance with the applicable environmental legislation.[21] The competent agencies will be able to carry out the same as the suppliers, the role of intermediaries between those projects which promote the better use of renewable energy and the buyers of certificates of emission reductions in the international markets (article 31).[22]

Lastly, the LAERFTE states that the financial and budgetary resources must be exercised based on the principles of honesty, legality, productivity, efficiency, effectiveness, accountability, governmental transparency and maximum publicity and subject to control, audit, evaluation and accountability mechanisms established by the legal provisions (articles 28 y 29).

3.2.8 Jurisdiction distribution and institutional convergence

From reading the LAERFTE it becomes evident that, in the case of the better use of renewable energy, the concurrency and convergence of the jurisdiction of the different public agencies that interact in this sector must be guaranteed. Among the principal actors involved with renewable energy –directly named in the LAERFTE–[23] are the SENER, the CRE, the CFE, the now extinct Central Light and Power Company (LyFC, initials in Spanish), the SEMARNAT, the Secretary of Social Development (SEDESOL, initials in Spanish) and the SHCP.

Each one of the administrative organisms has different jurisdictions which makes it possible to distinguish the following areas of regulation:

- Design and instrumentation of the national and global energy policy (by way of plans, programs and financial instruments).
- Direct regulation faculties over generators and suppliers.
- Convergente faculties by area.
- Interregional coordination faculties.

The abovementioned faculties comprise the institutional diagram presented in Figure 3.1.

To this point we have referred descriptively to the elements used to conceive the LAERFTE. What follows, and applying the same methodology, is what we consider to be the aspects that best allow us to reflect on the scope and the effectiveness of this regulatory instrument.

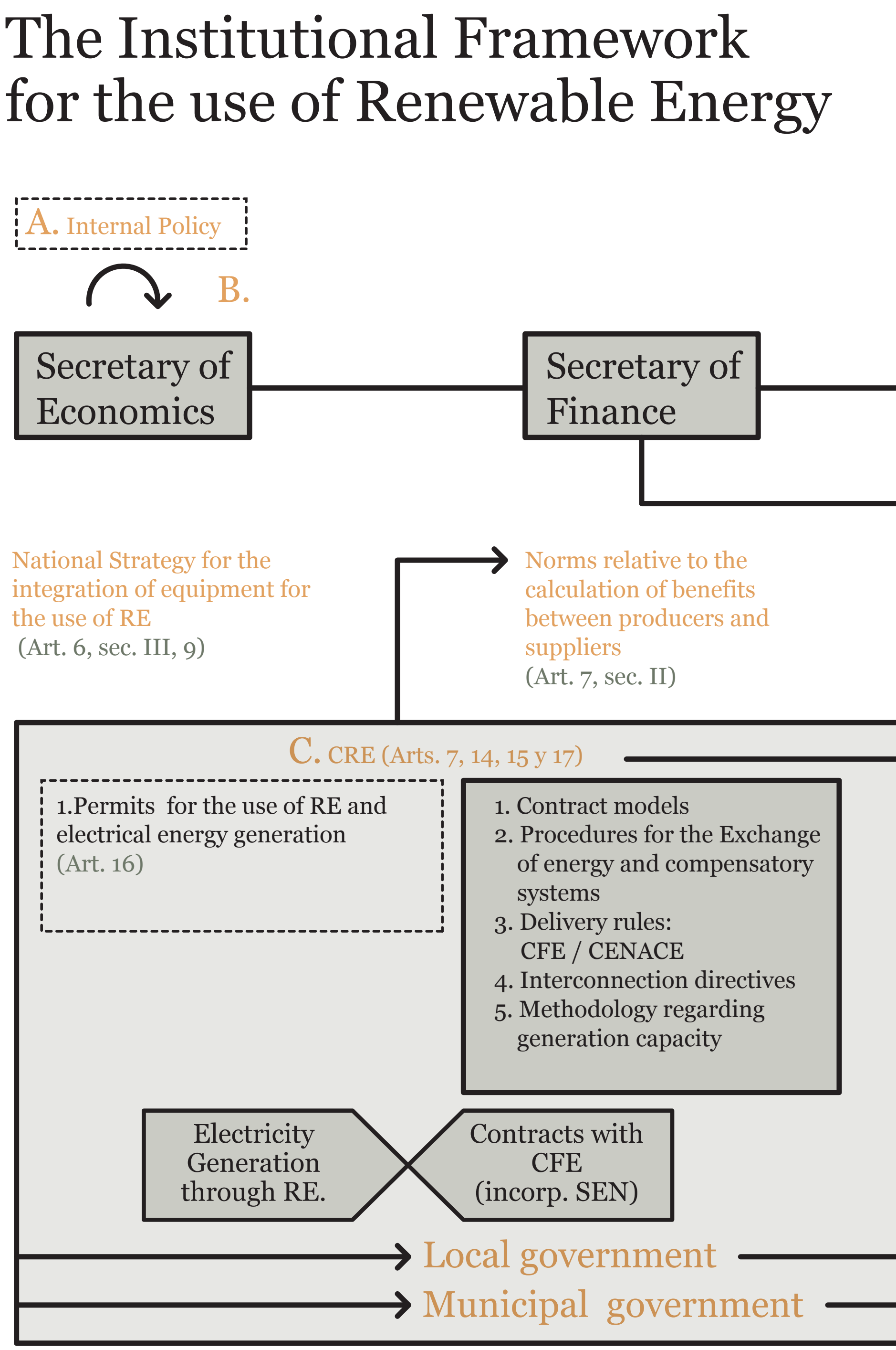
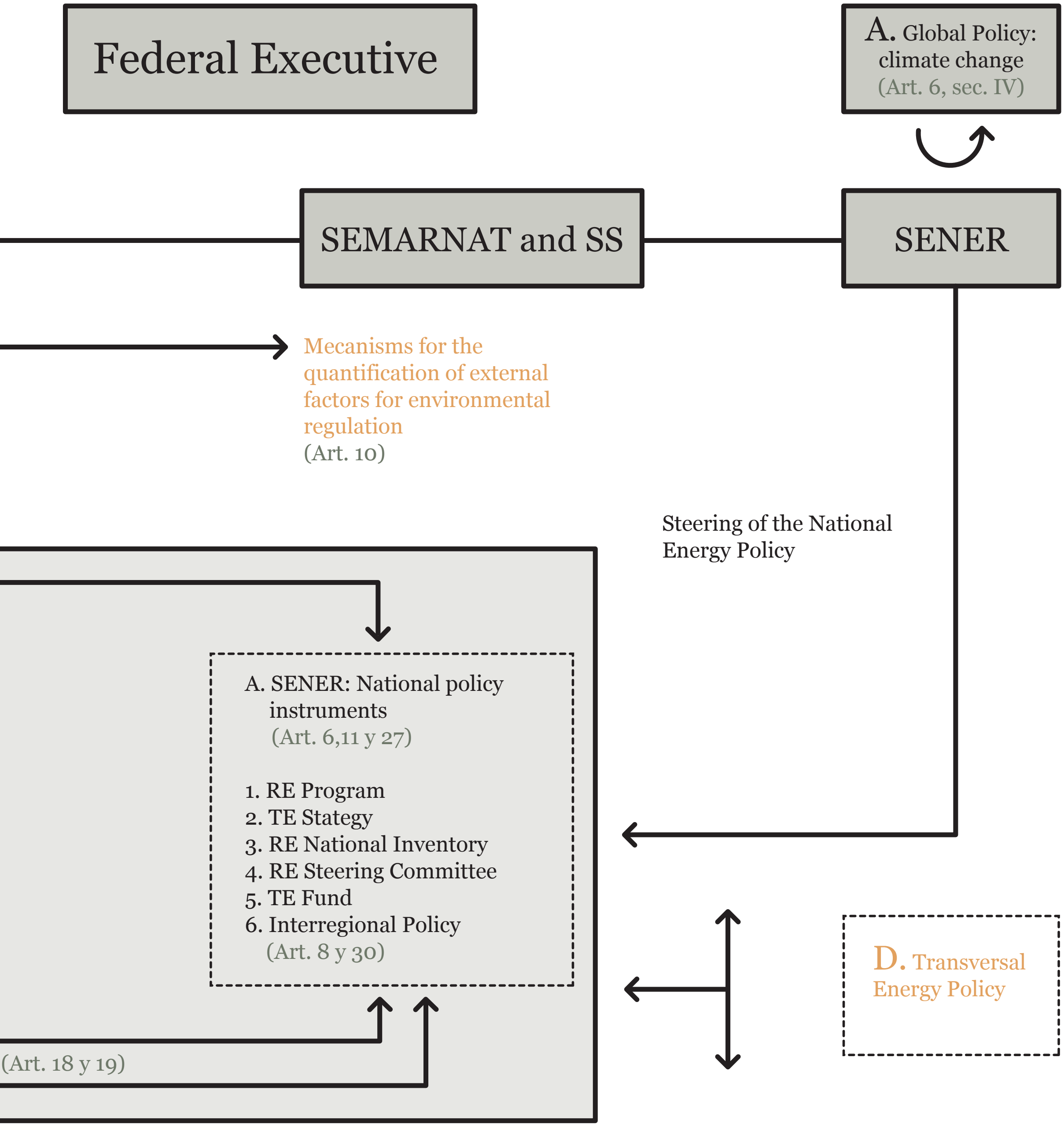


Figure 3.1
The institutional framework for the use of renewable energy.

Source: Own elaboration.


Federal Executive
A. Global Policy: climate change
(Art. 6, sec. IV)
SEMARNAT and SS
SENER
Mecanisms for the quantification of external factors for environmental regulation
(Art. 10)
Steering of the National Energy Policy
A. SENER: National policy instruments
(Art. 6,11 y 27)
1. RE Program
2. TE Stategy
3. RE National Inventory
4. RE Steering Committee
5. TE Fund
6. Interregional Policy
(Art. 8 y 30)
D. Transversal Energy Policy
(Art. 18 y 19)

3.3
General clauses and regulatory dependence: notes for a partial evaluation

> Instead of resolutely carrying out the constitutional modification which is indispensable in order to provide a solid base for the new law, the government turned to a well-worn subterfuge normally used in the pitch of legislative fever which is so frequent in the country, of making a simple statement of principle with imprecise administrative processes and reserving for future regulations the complete enunciation of the attributes that are given to the public sector and the procedures for its implementation. […] this vicious practice leads to the fact that the regulations innovate or expand the law instead of complementing it substituting, in many cases, the essential aspects. On the other hand, this procedure has the shameful quality that it does not disturb the fetishists scruples ordinarily attributed to the Constitution; of evasion and deferral of contentious sticking points to later regulations; of sugarcoating the opposition and of soothing the natural alarms that invariably go off among the interested parties whenever new legislation is presented.[24]

If we look once more at the distribution of jurisdictions utilized by the legislators for the integration of the LAERFTE in order to review the regulatory instruments upon which depends the effectiveness of this norm, the evaluation is necessarily partial.

This is due to the fact that at the close of this work, the general administrative norms referred to in the LAERFTE have not yet been issued. Consider, for example, that article 2 of the LAERFTE states that “The regulations in this Law will establish the specific utilization criteria for the different sources of renewable energy as well as promote the investigation and development of the clean technologies for its better use”, or that article 6, chapter II, states that it shall be the regulations that directly determine the integration and attributes of the Renewable Energy Consulting Committee. It is this type of clauses that are so general in nature that led to the quotation at the beginning of this chapter. Look at the following diagram:

LAERFTE implementation scheme.

	Type of Regulation	Duration/ date of publication (DOP)	Responsibilty	Article	Emission
1	LAERFTE	November 28, 2008	—	—	✓
2	Special Programs for the use of Renewable Energy	May 2009	Energy Secretary	Article 11 and Third Transitory	✓
3	Operating Rules for the Energy Transition Fund	At the latest May 28, 2009	Federal Executive	Article 27 and 4th Transitory	✕
4	Mecanisms for the Regulation of the Environment	At the latest May 28, 2009	Environment And Natural Resources Secretary	Article 10 and 6th Transitoy	✕
5	Regulation[25]	September 2, 2009	Federal Executive	Articles 2, 6, sec II, and 5th Transitory	✓
6	National Strategy for the energy Transition and the Use of sustainable energy	June 30, 2009	Energy Secretary	Article 12	✓
7	Polícies and measures For the integration of equipment and components	Augsut 2009	Energy Secretary	Article 9 and 7th Transitory	✓
8	Methodology to evaluate external factors associated with the generation of electricity in Mexico	2009	Energy Secretary	Article 10 and 9th Transitory	✓
9	Models for supply contracts	At the latest August 28, 2009	Energy Regulatory Commission	Article 15, 16 And 8th Transitory	✕
10	Norms to calculate benefits between producers and suppliers	Without time limit for publication	Energy Regulatory Commission	Article 7, sec II, y 17	✕
11	Procedures for the exchange of energy and compensatory systems	Without time limit for publication	Energy Regulatory Commission	Article 7, sec VII	✕
12	Adjustments to the delivery rules	Without time limit for publication	Energy Regulatory Commission	Article 7, sec III and IV	✕
13	Interconnection directives	Without time limit for publication	Energy Regulatory Commission	Article 7, sec VI	✕
14	Methodology for generation capacity	Without time limit for publication	Energy Regulatory Commission	Article 7, sec V	✕
15	National inventory of renewable energy	Without time limit for publication	Energy Secretary	Article 6, sec VI	✕

Chart 3.1
LAERFTE implementation scheme.

Source: Own elaboration.

Based on the state of the norms contained in the Mexican legal framework regarding RE, in the following pages we evaluate some of the central themes of the Law and we point out a series of recommendations applicable to the general administrative norms to be issued shortly.

3.4 Technological, legal and constitutional limits

The first point that must be analyzed is the one regarding the norms that limit the generation of electricity from RE. As indicated by the LAERFTE, the production of electricity for self-consumption or its incorporation into the SEN is regulated by the LSPEE; however, it is clear that this legislation is based on constitutional limitations.

In that sense, if we see this as an exercise in constitutional interpretation in order to determine how far the public and private sectors can intervene in the economy (articles 5, 25, 26, 27 and 28) we reach the following conclusions:

- Industry and commerce can develop in those segments not considered strategic or priority areas.
- The strategic areas are exclusively public domain (no concessions are allowed). The federal government will maintain at all times not only control of the area but also proprietary rights over the organisms established to operate in these areas. The Constitution states that, the functions carried out exclusively by the state in the strategic areas are not considered monopolies, as these are prohibited by legislation. In the Constitution, the strategic areas are not determined for tax purposes as in this sense; the same legislation grants the state jurisdiction.
- The priority areas allow for the participation of the social and private sectors through a concession and with certain legal limitations. In this segment, incentives and subsidies are allowed if they meet certain constitutional limitations and conditions (generality, temporality and financial sustainability). The priority areas are not determined for tax purposes in the Constitution; the legislators have convergent faculties in this area.

- The regime under which public services will be managed will be determined by constitutional norm and by the legislators. The constitutional notes regarding the public service sector emanate from the fact that they are found in strategic or priority areas.

With respect to the generation of electrical energy, and even though there exists a systematic interpretation,[26] articles 27 and 28 of the Constitution qualify the definition of a strategic area (that is to say, exclusive title by the State and not subject to concessions) to the generation, management, transformation, distribution and the supply of electric energy destined to provide a public service. At this point the question to be answered is the following: in which situations is the electric energy destined to public service and in which situations is it not?

Article 28 states that: "Classification as a public service will be determined by the Constitution and the law". Therefore, as there is no other premise in the Constitution related to the definition of the electric sector as a public service other than articles 27 and 28, the legal definition of the electric public service is determined by the secondary legislation and its regulatory provisions.

The use of RE for the generation of electricity is limited to the norms that the LSPEE considers as not constituting a public service and in conformance with the following regulatory provisions:[27]

- **Self Supply.** Consists in the utilization of the electric energy to satisfy the needs of the permit or license holder or of the co-owners or associates (article 101 of the Regulations).
- **Co-generation.** Is the energy that is obtained from the energy potential generated by the industry through the efficient use of the secondary energy for the production of electric energy as a sub-product. The energy can be produced jointly with steam or some other type of secondary thermal energy. Co-generation is allowed when the thermal energy not utilized is used for the direct or indirect production of electric energy or when fuels produced during the process are used, and always when the electricity is destined to cover their own needs or of the businesses associated with this type of generation. This type will be sponsored by the State in order to increase energy efficiency and protect the environment (articles 103 to 107 of the Regulations).

- **Small production.** Is derived from the generation of electric energy produced at plants with a capacity which is lower or equal to 30 MW - and the electricity will be sold, in its entirety, to the supplier or be exported – or at plants with a capacity that is lower or equal to 1 MW – at which the electric energy is for the self-consumption of small rural communities or isolated areas that do not have electric energy service - (articles 111 to 115 of the Regulations).
- **Independent production.** Is the generation of electric energy at plants with a capacity greater than 30 MW, under the condition that the electric energy is sold to the supplier (with a long-term sales contract) or is exported (article 36, chapter III, paragraph C of the Law). This provision allows the private sector to generate electric energy to be sold, in its entirety and exclusively, to CFE which will distribute this energy to cover the public service needs. Although the private sector will generate electric energy which will be added to the national grid, no legal relation will exist between these and the users (articles 108 to 110 of the Regulations).
- **Exportation of the electric energy** Is the generation of electric energy within the national territory (derived from the co-generation, independent production or small production) to be used in another country. This activity facilitates the efficient use of all the energy produced (articles 116 to 119 of the Regulations).
- **Importation of electric energy.** This is electric energy that is generated at plants outside of the country and is to be used efficiently within the country by persons or businesses. It is to be used exclusively for self-consumption (articles 120 to 123 of the Regulations).
- **Electric energy destined for emergency uses.** Derived from electric energy service interruptions (article 141 of the Regulations).

At this point, the possibilities for generation of electricity proposed by the LSPEE must be analyzed compared to the proposals contained in the LAERFTE and concretely in the following regulatory precepts:

- Article 16: the suppliers must enter into long-term contracts with the generators that use renewable energy and that have a permit issued by the Commission that conforms to the regulations issued by the same.
- Article 17: in the case of the sale of the surplus energy after self-consumption of the production, in line with the Public Service and Electric Energy Law covering self-supply projects using renewable energy or electricity co-generation, the charges are set in accordance with the methodology approved by the Commission.

- Article 18: the SEN will receive the energy produced with surplus renewable energy from self-supply projects or electricity co-generation projects in accordance with article 36 “A” of the Electric Energy Public Service Law and the present legislation.
- The generators will be subject to the conditions established by the Commission for services rendered in the management, transformation and delivery of electric energy in accordance with the provisions of the CRE.

The legislators do not exclude any of the assumptions regarding the generation of electricity indicated by the LSPEE as not constituting public service. It could be concluded that the RE can be legally used under any of the schemes that have been mentioned. However, after a second review and including other precepts included in the same Law, the answer could vary.

On the one hand, based on the terms of the LAERFTE and in accordance with the concept of “generator” (person of Mexican nationality or company constituted in accordance with Mexican law and domiciled in the country, that generates electricity from renewable energy – article 3-), the assumption of importation of electric energy as stated by the LSPEE would not be covered by the LAERFTE. On the other hand, in the case of the independent energy producers, their activity would be beyond the scope of the LAERFTE when the electricity originates from hydraulic energy utilized in sources that have a capacity greater than 30 MW.

As regards the two generation assumptions, it is not coincidence that the LAERFTE is characterized as having a regulatory deficiency that could lead to the risky exercise of interpretation of the limits of the Law. In addition, although almost all the types of generation of electricity mentioned in the LSPEE can be used to take advantage of renewables, there are financial, economic and technological questions that could further limit the scope and the objectives of the legislation.

The Renewables require intensive investments in fixed and hidden costs, with very low marginal costs but elevated median costs. On the other hand, they could be used in projects with a useful life that averages higher than 30 years.[28] To this are added two critical elements: intermittency of production of some types of energy (which assumes the existence of a fixed back-up in order to avoid service interruptions) and the traditional location of these types of generation plants (that will impact the energy transmission conditions).[29]

In the first place, it's clear that for the development of the RE it is necessary to operate using long-term contracts between generators and suppliers as a condition for the return on the investment. Following is an explication of how some of the other cited elements function.

In general terms, the LAERFTE punctually indicates that the suppliers will receive the surplus in accordance with the operating and economic conditions of the electrical system as well as of the geographical distribution and variability of the different technologies to make better use of the RE (article 19). However, and taking note of the discretionality that the law places in the hands of the regulator regarding the criteria of "reasonability", the truth is that one of the main challenges faced by the legal establishment is the need to insure that the RE attain the economic retribution necessary to promote their use thus achieving the energy transition.

This topic requires examination of the LSPEE's article 36 A which decrees that for electric energy service to be considered public service it must be the lowest cost energy available to the CFE, in the short as well as long-term, and must also provide stability, quality and security. On this point, the technical constraints presented by RE are in direct opposition to the promotion of the same.

The portage (delivery), for example, represents a significant cost for RE projects. These are conditioned not only by the fact that the energy sources are not always available – due to the nature of the source – but also because, in the majority of the cases, the energy which is generated must be transported from the production area – many times, very distant from its consumption point – through the SEN transmission network and some times, through local distribution grids.

However, the cost of this portage, in accordance with the current legislation, does not distinguish if the energy is from renewable sources or conventional projects. The CFE sets a minimum portage cost and sets additional charges according to the manner in which the delivered energy affects the stability of the grid. These charges form part of the total cost of the project.

If we consider that the supplier is obligated to pay the lowest short-term marginal cost at the interconnection node for the energy delivered to the grid, the legislation (in the opinion of some experts) would have to contemplate a scheme that would allow the generators to deliver the totality of the energy to the grid at a cost which is higher than the referenced marginal cost; that is to say, higher than the supply curve cost at a given moment (P/E peak demand). In this manner, the projects could be economically viable without sacrificing efficiency. An additional alternative would consist in reducing the interconnection costs by crediting the investment in infrastructure as the expansion of the grids generates a positive external effect which should benefit the developer of the project.

In summary, given that cost is one of the principal economic barriers to the introduction of renewables, energy generated from conventional sources could automatically become the number one option. This, without a doubt, would hinder the achievement of one of the main objectives of the law: the energy transition.[30] Recognizing these barriers, the legislation would need to establish mechanisms that would allow it to promote the better use of renewables such as economic and fiscal incentives.[31] However, there also are examples that challenge the scope or the effectiveness of the LAERFTE. Let's examine some of the reasons behind this affirmation.

One of the obstacles that arise from the traditional energy policies is that the country's energy planning is based on methods that only evaluate the short-term economic cost of energy generation. In other words, the lack of assessment of the benefits that renewables bring to the national economy such as long-term energy price stability and a reduction of supply risks and the abundance of fossil fuels makes the national energy policies highly dependent on fossil fuels.[32] The LAERFTE, as was expected, proposes a methodology to evaluate the economic advantages that renewables long-term price stability represents.[33]

However, in an interesting treatise García Ochoa (2008) reflects on the fragility of the budgets used by the legislators to regulate renewables. The author states that renewables long-term price stability is one of their comparative advantages over fossil-based resources. In the medium and long-term, due to shortages and increasing demand, the prices of fossil-based resources will continue to be unstable. If this is borne out, renewables would become economically viable and consequently, their participation in the energy market would increase.

Notwithstanding, if international statistics are consulted and consideration is given to the complexity of formulating an energy policy in a crisis scenario, the following can be observed:

- It is not possible to establish a frame of reference that allows an evaluation of the economic advantages of price stability in the future.
- Looking forward to a medium term global energy policy, the participation of the fossil fuels will increase.[34] Although a slight increase in renewables participation in the world's energy supply is expected, it will be insufficient to allow for an energy transition based on price stability.

- The fact that the LAERFTE does not recognize the weight that each sector has in the national energy consumption is questionable.[35]

Considering that in Mexico final energy consumption is 75.2% hydrocarbons, 14.9% electricity, 5.8% wood and 4.1% other fuels, the orientation and the tight margins within which the LAERFTE operates become evident, as it only considers the electric sector and not the productive sectors that have a greater environmental impact.

3.5 Transversal effectiveness of the LAERFTE

Another of the aspects which needs to be highlighted, when referring to the effectiveness of the LAERFTE, is that all public policy that looks to effectively promote taking advantage of the renewables must take into consideration the distribution of jurisdiction within the legal framework.

As it is a federal system which is characterized for its convergence of attributes, it is foreseeable that the electric generation projects using renewables must face a series of administrative decisions relating to electricity, environment, water and land use. These are subjects –particularly relative to land use– in which the local and municipal authorities play a predominant role even before civil organizations that could try to detain the project.

Areas of regulation and governmental[36] competence.

Area of Regulation	Federal Competence	Local Competence	Municipal Competence
National Defense	×		
International Relations	×		
International Commerce	×		
Monetary Policy	×		
Air Transportation	×		
Railroad Transportation	×		
Postal Service	×		
National Commerce	×	×	
Culture	×	×	
Industry & agriculture	×	×	
Environment	×	×	×
Water	×	×	×
Urban planning		×	×
Health	×	×	×
Public Transportation	×	×	×
Education	×	×	×
Housing	×	×	×
Markets			×
Slaughter Houses			×
Sewage & Waste			×

Chart 3.2
Areas of regulation and governmental competence.[36]

Source: Own elaboration.

The provisions of the LAERFTE especially articles 8 and 30, are directed towards achieving a convergence of attributes through mechanisms of institutional coordination in order to promote the development of renewables electric generation projects. However, the coordination agreements contemplated in the Law are far from being the most effective strategy to harmonize the different jurisdictions that are needed to effectively promote the electric generation projects from renewables as they are closely linked.[37]

For example, there are projects that require vast territories in order to take advantage of the renewable energy sources, particularly wind and hydroelectric resources. As a general rule, they require a technical study in order to evaluate the viability of the project (in the areas relating to environment, geology and costs) before initiating the corresponding administrative paperwork, and obtaining the funds from the developer. For this type of project, ideally it should have a strategy covering administrative simplification which is defined in the Law so as to standardize the decisions of the different administrative entities involved (SEMARNAT, SAGARPA, CONAGUA) in order to assure the developer. As part of this strategy, the experts propose the creation of one Paperwork Collection Point as well as the possibility that the projects receive a preliminary filing guaranteeing, if necessary, the confidentiality of the information.

Along the same line, another obstacle is that the institutional scheme is very complex particularly in relation to the segmentation of attributes between the CRE and the suppliers. Proof of this is the paperwork related to the interconnection. If the convergence and clear delimitation between the provisions of the CRE and the commitments of the suppliers as stated in the LSPEE is not reached (article 36 a),[38] the project developer could face regulatory and administrative problems.

To illustrate this situation the discretionality with which the LAERFTE allows the SENER to operate must be evaluated –and in particular the CFE– mainly in relation to the development of the infrastructure necessary to carry out the interconnection of the renewables project (articles 19 y 11, chapter IV). As a result of this, the generator could end up absorbing the cost of the upgrade or construction of the infrastructure based on the conditions allowed by the interconnection.

Also in relation to the infrastructure it should be noted that it is difficult to line up the objectives of the generator and the supplier. Traditionally, the CFE handles the public service supply of electric energy and supports the projects that have an elevated generation capacity. In that sense, the legislation could optimize the effective use of the renewables if the energy generated is destined for some other agents such as self-suppliers. This should be accompanied by a strong investment strategy in order to develop the necessary infrastructure to transport the energy generated at remote locations where normally these types of sources are concentrated.[39]

Lastly, it is necessary to refer to the initiatives related to public interest. In terms of article 2 of this Law, the better use of renewables and the use of clean technologies are in the public interest. Based on this clause, the State may develop different promotion strategies for the better use of renewables such as the use of subsidies, tax mechanisms and other financial instruments (article 24). However, the public is allowed to use mechanisms as mentioned in article 21, when the following is highlighted:

The projects to generate energy from renewable sources with a capacity greater than de 2.5 MW will have to:

- Assure the participation of the local and regional communities through meetings and public forums organized by the municipal, communal and ejidatario authorities. In these meetings, agreement will be reached regarding the participation of the projects in the development of the community.
- Pay the lease to the owners of the land that is used by the renewable energy Project as stipulated in the contract. The frequency of the payments shall be negotiated with the interested parties but, under any circumstance, it shall not be lower than two times a year.
- Promote social development in the community in which the Project is executed in accordance with the best international practices and enforce the applicable regulations regarding sustainable rural development, protection of the environment and agricultural rights.

We consider that it is a provision that can operate with unlimited administrative discretionality that by itself does not exclude the generators of the energy supply; if it does not line up with other provisions of the LAERFTE in order to balance charges and incentives, it could compromise the development and viability of this type of project.

3.6 The reading of the entry barriers or of the enabling titles in strictly legal terms

As a group of general administrative norms that the legislators can depend on in order to complete the legal framework regarding the better use of renewables does not exist, it is difficult to talk with certainty about the LAERFTE. In any case, it will be the enabling titles applied to the generators which will spur or limit the developers of the projects. For example:

- Through the permits or the contract models, the rights and obligations that will bind the generators as well as the suppliers will be defined. They are legal instruments that in order to become incentives will depend on the system of incentives dictated by the CRE prior authorization from the SHCP.

- Given the directives for interconnection and the methodologies dictated by the CRE, the capacity contribution that these projects will provide to the electric grid will be calculated and accredited. These as well as the dispatch or delivery rules are important considerations in terms of cost and return of the investment.
- Through the Official Mexican Norms (NOM, initials in Spanish), the integration of the components and equipment, from a national energy planning perspective, is contemplated; however, they are technical requirements that could represent regulatory barriers in the renewables market.[40]
- Using the Operation Rules of the Energy Transition Fund, the recipients of the funds and the conditions for application of the incentives derived from the same will be defined.

It is worth noting that the LAERFTE has operated with very few –almost deficient– set of norms, in such a way that the conditions for the instrumentation of the renewables projects are not found in the Law, but are defined through a set of minor regulations.[41] See, for example, articles 16 y 17 of the LAERFTE, which allow for the contract models and the incentives between suppliers and generators to de dictated directly by the norms issued by the CRE although these are not based on provisions in the Law.[42]

We consider that the decision of the legislators added to a regulatory practice which is scarcely defined leading to scenarios with a greater potential for litigations and sparse regulatory effectiveness. On the other hand, the administrative norms will be based on the “white paper” issued by the legislators. In this way, their validity depends on the interpretations and the possibilities of justifying the maximum administrative discretionality.

In addition, it should be noted that the regulatory mechanisms usually directly affect property rights and the freedom of the project developers. This can lead to questions regarding principles such as legality and legal reservation (for example, regarding tender bids).[43] Lastly, it’s about instruments that have a tendency towards regulatory capture, which can promote conditions of inequality among the different project developers.

It is also true that concerning renewables, the Mexican legal system already had some regulatory instruments directed towards the better use of renewables before the LAERFTE was approved. Proof of this is: the interconnection contract for renewable energy sources, the agreement for the transit of electric energy for renewable sources, the contract model for the interconnection of small scale solar energy and the methodology to determine electric energy transit charges for renewable energy sources.

Of the regulatory instruments some elements could be rescued, such as the incentive to store renewable energy produced and to be used in a tariff period which is different from the one in which it was produced and which has a higher remuneration. Another element is the establishment of an "energy bank" which operates taking into account the balance between energy surpluses and deficits, with the possibility that the intermittency can be overcome using the conventional energy available in the grid. This would have a positive effect on the tariff (for example, in peak hours) and a direct effect on price volatility. Lastly, regarding energy transit, an important element is that the payment is based only on the capacity effectively used.

3·7 Conclusions

The fact that the evaluation of the LAERFTE can only be partial does not keep us from qualifying the decision to regulate the exploitation of renewables through the implementation of a specific legal framework as accurate. However, in accordance with our exposition and without having as yet emitted all the administrative norms on which the effectiveness of the law depends, everything seems to point towards the fact that the legislators, operating with general rules, did not directly confront the totality of economic, financial and technological constraints in this energy sector. Specifically, the participation of the generators is determined by the LSPEE, instead of setting up a scheme exclusively for the renewables.

Lets us hope that the panorama can be more promising, in terms of legal certainty as well as in terms of operative viability once all the administrative regulations on which the effectiveness of the LAERFTE depends are issued. In any case, the addition of a series of convergent regulation mechanisms is indispensable among which could be included methods that qualify the external factors that affect the renewables or that impose a system of emissions certificates. Some of the mechanisms that we refer to are the following: more agile tax and customs tariffs that allow for the use of this type of technology and do not promote, in conjunction with the energy demand, the use of conventional technologies; obligatory minimum contents of electric generation using renewables; minimum limits of efficiency in industrial production; systems of voluntary payments for non-polluting energy and of course, a convergent consumption-based efficiency and energy saving policy.

Finally, it is necessary to consider that from a regional perspective, the step taken to promulgate the LAERFTE can be optimized with more visible effects if the administrative norms as contemplated in the NAFTA agreement are issued; thus taking into account the direction that the energy policy in the United States of America is taking which seems to favor the development of renewables in a market of contaminating emissions (Falcón, R., 2009).

1 The reflections and commentaries by Professor Ramiro Tovar Landa are greatly appreciated. We hope that they have been correctly expressed in this book.

2 In Mexico, electrical service coverage is at 96%. Therefore, five million people are without electricity in their homes. The majority of these live in isolated areas where the use of the conventional grid is not economically viable.

3 The law was published in the Official Gazette of the Federation on November 28th ,2008.

4 Some of the commitments that Mexico has acquired in the mentioned fields are contained in the United Nations Convention Framework for Climate Change and its Kyoto Protocol as well as in the framework of the International Renewable Energy Conference in Bonn in 2004.

5 The proposed goal in the LAERFTE of 8% participation of RE in the Generation of electricity is viable in the opinion of the SENER given that the renewable energy resources are vast. This is also shown in the international goals which are over 10% such as 12% for the European Union, and specific cases such as Brazil and Canada which have a participation rate of over 25% (SENER y GTZ, 2006).

6 The package of reforms referred to were published in the Official Gazette on November 28th, 2008 and is comprised by the following reforms: 1. Decree by which the Law for Mexican Oil is issued and article 3º of the Federal Law for State-owned Companies is added; article 1 of the Law On Public Works and Related Services and a third paragraph to article 1 of the Law covering the Acquisition, Rental and Services in the Public Sector; 2. Decree issuing the Law for the Better Use of Renewable Energy and the Financing of the Energy Transition; 3. Decree issuing the Law for the Sustainable Use of Energy; 4. Decree issuing the Law creating the National Hydrocarbon Commission; 5. Decree by which several paragraphs of Article 27 of the Constitution which deals with the Oil Sector are added or reformed; 6. Decree by which Article 33 of the Law Governing the Public Administration are added or reformed ; 7 Decree reforming, adding or derogating several paragraphs of the Law governing the Energy Regulatory Commission; and 8. Decree which modifies and authorizes until December 31, 2008, the decree published December 28th, 2007, by which liquid gas derived from oil is subject to a sales price ceiling.

7 This affirmation is confirmed if we consider that the initiative in the Senate Chamber was approved after the First Reading in committee and approved overall by a vote of 113 in favor and 5 against. In the house of representatives the following occurred: a) in the economic vote, the Second Reading was dispensed with; b) the articles not questioned were approved under a normal vote by 407 votes in favor and 68 against; c) the initiative was subject to one prívate vote by Representative José Antonio Almazán González (PRD), who considered that the initiative ran contrary to the sprit of Article 27 of the Constitution ; and d) regarding the proposal by Representative Rojas Gutiérrez –that the Fund for the Energy Transition should have a technical committee different from the one originally proposed and that it should incorporate representatives from the National Autonomous University, and the National Polytecnical Institute and other public universities including the Mexican Science Academy - an economic vote was discarded and the initiative was approved as originally stated by a vote of 327 in favor, 128 against and 11 abstentions. Only 5 days went by from the date the initiative was presented in the Senate (October 23rd) and the date that the House of Representatives sent the initiative to the President's office for signature into law (October 28th).

8 In the LAERFTE carried out by the Senate (October 23rd 2008), it is clearly stated that the energy transition is a process that leads to the substitution and diversification of the primary energy sources utilized in the different regions of the country. The objective is to use resources that are also abundant such as wind, micro-hydraulic or solar paying close attention to the relation between market prices and output (performance) and also to external social and environmental factors in these projects.

9 As concerns this source of generation, the generation potential must meet with the articles included in the Law for Bio-energy and its regulation, as well as with the norms that derive from the LAERFTE.

10 According to figures from the SENER (2007), 90% of the total primary energy comes from fossil-based sources.

11 These premises are found in article 36A of the LSPEE.

12 Article 29 in the Regulations of the LAERFTE, dated June 18, 2009, points out that the Commission will establish the methodology for the calculation of the charges for the services rendered between the supplier and the renewable generators or efficient co-generators. In effect, the Commission must take into consideration the efficiency costs associated with these services. Additionally, the Commission could consider both totally or partially the net economic benefits derived from the cost relation, positive effects and relative risks, directs and indirects, for the generation of renewables, in the context of the energy transition (article 46). Finally, article 47 proposes, that the conventions for the proposals related to this chapter contemplate mechanisms to promote those units that can be available during the hours of peak demand of the electrical grid, among which can be included a capacity charge proportional to the average capacity available during the hours of maximum demand. Regarding generation capacity, article 33 states that the probability of the availability of capacity during the hours of maximum demand be considered according to the characteristics of the technologies used for the generation of renewables and an efficient co-generation.

13 Article 14 of the LAERFTE regulations, dated June 18th, 2009, establishes that the external factors related to the of the technologies for the generation of renewables will be evaluated on a comparative basis against those technologies based on fossil fuels as considered by the Energy Secretary for the installation of new power generation plants.

14 The SEMARNAT published the mechanisms referred to in this chapter (article Six Transitory). In this topic, it is convenient to remember that México has carried out intensive and committed activity to face the risk of climate change. In 1993, Mexico signed the United Nations Convention for Climate Change; in 2000, it ratified the Kyoto Protocol; in 2004, it created The Mexican Committee for Projects to Reduce Emissions of Greenhouse Gases; at the World Summit for Sustainable Growth in Johannesburg, it supported the Latin American and Caribbean Initiative for Sustainable Growth, which established the goal for 2010 of at least 10% renewable energy in the total energy supply. In this regard, it should be pointed out that although our country is not obligated to reduce carbon emissions, it can participate in the emissions market by selling the emissions that it does carry out to countries that are obligated. This would generate an additional economic value for the RE projects (SENER, 2008).

15 According to the Third Transitory article of the LAERFTE, the Energy Secretary submitted the Program for consideration and approval to the Presidency of the Republic, in accordance with the law. On the other hand, the Tenth Transitory article establishes that the Secretary in order to establish RE participation goals will consider the financial resources called for in the conventions and agreements to which Mexico adheres, as well as the international financing programs that have been designed or executed prior to the date of publication of the law.

16 Article 6, chapter VI, states that the National Renewable Energy Inventory will be updated and will be integrated into short-term programs, as well as into medium and long-term plans and perspectives included in the Special Program for the Better Use of Renewable Energy and in the National Strategy for Energy Transition and Sustainable Energy Use.

17 In June of 2009, the Federal Executive through the Energy Secretary, presented the National Strategy for the Energy Transition and the Sustainable Use of Energy (12th Transitory article).

18 In accordance with the provisions in the 11th Transitory article found in the LAERFTE, earmarked in the Federal Expenditures Budget for fiscal year 2009 are $3 billion for the Fund for the Energy Transition and Sustainable Use of Energy. At the same time, the SHCP is the agency charged with the consolidation of the information regarding the provision of public funds included in the Federal Expenditures Budget for each fiscal exercise referred to in article 24 of the Law. Based on this information, the minimum amount of resources to be programmed for subsequent fiscal years will be established. This information will be sent to the Honorable Congress of the Union for their information. In addition, for each of the fiscal exercises for 2010 and 2011, the amount proposed in the Expenditures Budget for the Fund referred to in article 27 of this Law will be $3 billion. The amount must be updated in line with the variations in the National Consumer Price Index between 2009 and the budget year.

19 In line with this premise, the Fund will have a technical committee formed by representatives from the Secretary of Energy (who will preside), SHCP, Secretary of Agriculture, Livestock and Rural Development, SEMARNAT, CFE, Mexican Petroleum Institute, Electric Investigation Institute, and the National Science and Technology Council. The Committee will issue the rules to promote the objectives of the “Strategy”.

20 The 10th Transitory article points out that the SENER will take under consideration the financial resources earmarked by the agreements and treaties adhered to by Mexico as well as the international financing programs that were designed or executed prior to the date of publication of the LAERFTE, in order to establish the participation goals for renewable energy.

21 The specialist indicate that “Mexico is a Non-Annex I country and has no GHG reduction obligations. This is exactly the country’s main incentive to seek benefits from the carbon trading global market. Mexico’s participation in this area is currently limited to the generation and sale of Certified Emission Reductions (CERs) or “carbon credits,” mainly through projects under the Clean Development Mechanism (CDM)—and to a lesser extent through the Voluntary Emission Reductions (VER) scheme. According to the UNFCCC Mexico currently supplies about 3.2 percent of expected annual CERs globally and is the fourth largest supplier of carbon credits, with 112 CDM projects (or 7.83 percent of the total) under way. As the world’s thirteenth largest GHG emitter, Mexico has significant potential to intensify current annual emission reductions from 8.5 mt of CO2 to nearly 100 mt. (R. Falcón, 2009).

22 The Federal Executive is charged with establishing the mechanism referred to in article 31 and with publishing the rules for its implementation (4th Transitory article).

23 It should be noted that this is not a complete list of all the organisms that interact in the renewable energy sector as we can also include the National Energy Savings Commission (CONAE, initials in Spanish), which promotes energy savings, energy efficiency and the use of RE; the Electric Investigation Institute (IIE, initials in Spanish), which works in the area of technological investigation in the electric sector including RE, and the Shared Risk Trust Fund (FIRCO, initials in Spanish), as an organism that specializes in rural development programs which include the use of RE in productive agricultural activities. Among the most important agencies that promote the use of RE in the private sector are the National Solar Energy Association (ANES, initial in Spanish), The Mexican Wind Energy Association (AMDEE, initials in Spanish), the Mexican Bio-energy Network and the Mexican Energy Economy Association (AMEE, initials in Spanish).

24 This quotation appears in J. Herrera y Lasso (1933).

25 When reviewing the LAERFTE regulations, it is necessary to note that even though this project can be consulted as of June 18th, 2009 at www.sener.gob.mx/webSener/res/0/RLAERFTE_GT.pdf,. Insofar as these are not valid norms, we prefer not to anticipate any evaluation although we do make reference to some of the proposals presented throughout the chapter.

26 For a study about the complexity of the interpretation of the economic chapter of the Mexican Constitution, particularly regarding the electric sector, see J. Cortés Campos (2007).

27 Includes article 3 as well as articles 36 to 39 of the LSPEE and Chapter IX of the LSPEE regulations.

28 In accordance with the information from the SENERand GTZ (2006).

29 In this sense, the specialized literature points out that “renewables have significant operational challenges, in particular with reliability. Wind, for example, has hidden operational costs associated with a low capacity factor, usually demanding additional investment in turbines in order to compensate for the randomness of the power they generate —wind turbines can generate power at any time of the day, and that includes those hours when outputs are not needed. Any ambitious wind program in Mexico would require more stable fossil fuel generation capacity to back up wind turbines’ low capacity factors and unreliability. These operational challenges call for huge financial commitments, and the risk here is the inadequacy of public funds to invest in renewable energy projects that certainly cost more than conventional fuel-based projects. At a time of low oil prices but still-high industry costs, expensive projects involving renewables are likely to be put on hold by the government, inhibiting movement toward energy diversification. (R. Falcón, 2009).

30 Faced with this regulatory challenge, the LAERFTE states in its Article 35 that the Commission will request from the CFE the review and, if necessary, the adjustment of the rules that apply to renewables and to efficient co-generation as well as a justification of the adjustments it deems necessary. The National Energy Control Center will carry out the necessary initiatives that will allow for these adjustments within the timeframe set by the Commission which cannot exceed 50 working days from the date the request is received.

Likewise, article 45 proposes that generation projects can receive a credit due to capacity and associated energy in accordance with the norms and criteria established.

31 Some of the examples that the Mexican legislation has tested prior to the LAERFTE, are the establishment of financial mechanisms such as the Infrastructure Investment Fund (FINFRA-BANOBRAS) and concrete fiscal strategies. Examples follow:

a.Income Tax law (article 40, chapter XII): accelerated depreciation equal to 100% for investments in machinery and equipment for the generation of renewable energy. Likewise, from the supply side (housing) a tax credit of 30% for investment in equipment for renewable energy generation has been proposed.

b.Special Law for Production and Services: a special tax of 0.5% over disposals or imports of electric energy, and over the monies collected that are earmarked for promoting the use of renewables in the generation of electricity.

c.Federal Law Over Duties & Fees: fossil fuels could pay a duty based on CO2 emissions in line with the principle "he who contaminates, pays". For liquid fuel, duties of $0.52 to $0.97 per liter, and a higher charge for solid fuels. For natural gas, a duty of $0.197 per thousand cubic feet. The fees collected would be used to promote the use of renewables.

32 This is explained in R. Flores García (2008).

33 In the Regulations issued by the SENER, article 13 states that to determine the net economic benefits of renewables that will be considered in the elaboration and evaluation of the Program, the Secretary will consider the following: I. The savings generated by renewables generation in the SEN; II. The amount of estimated capacity for each one of the different technologies used to generate renewables in accordance with the methodology written by the Commission referred to in article 32, chapter III of the current Regulations; III. The economic benefits derived from the use of renewables in communities without access to the electric energy grid; IV. The risks and costs of the different combinations of generation technologies for the SEN; V. The external factors evaluated in accordance with the methodology referred to in the following article; VI. The benefits derived from carbon bonds or other resources from international financial mechanisms, and VII. All the other aspects that the Secretary may consider are necessary and important.

34 Based on data from the International Energy Agency - "The participation of the fossil resources for the period 2008-2030, rose from 40.3% to 44%; on the other hand, nuclear and hydro energy stayed practically unchanged 1.2% and 0.3% respectively; renewables show a slight increase going from 4.3% to 8%".

35 In the same context, R. Falcón (2009) explains: "Under the current financial crisis the first negative signs for further carbon market growth have appeared, and Mexico will undoubtedly bear the brunt of withdrawn investment. Since mid-2008 average spot market prices for carbon credits dropped from a record 22 to less than 8 in February 2009. It may be too soon to anticipate a general trend for the next years, but short-term forecasts suggest that low CER prices could remain through much of 2010 […] Today it accounts for about 61 percent of total carbon emissions in Mexico, with around 90 percent of energy generated through fossil fuels. Because of the aging infrastructure and the heavy fiscal burden in the energy industry, public utilities such as PEMEX and the Federal Electricity Commission (CFE) will find it difficult to reinvest their profits in energy efficiency projects through the 2008 energy reform plans. As long as oil prices remain low, costly efficiency-oriented projects will likely be deferred or abandoned in favor of projects already online—which are perhaps the most capital- and emissions-intensive ones. Thus, the country's movement toward energy efficiency and sustainability could go through a major slowdown. This makes the reform's goals hard to achieve, especially given Mexico's prevailing dependence on fossil fuels for economic development, which also threatens energy mix diversification goals".

36 The scheme is based on the contents of the publication by the OECD (1998), as well as on the revision of the scheme of constitutional competencies (articles 73, 115, 117, 118 y 124).

37 It only deals with promotional activities which will not lead to a coordinated energy policy. Article 8 states: "The Federal Executive through the Energy Secretary can issue coordination agreements with governments in the Federal District or the States, with the participation of the Municipalities with the objective, within their jurisdiction of: I. Establishing the basis for the participation of the Federal Executive in the writing of the provisions of the present Law; II. Promote industrial development to obtain a better use of the renewables; III. Facilitate access to the areas with high potential of renewable energy sources and promote the compatibility of the land use; IV. Write regulations for land use and construction that take into consideration the interest of the owners or holders of the land in order to better use renewable energy, and V. Simplify "the administrative procedures in order to obtain licenses and permits for the renewable energy projects". Article 30, on the other hand, states that "The Federal Executive, the state governments, Federal District and the municipalities, can sign agreements with the suppliers with the objective to jointly carry out other projects to better use the renewable energy sources available in the country".

38 In article 36 "a" it states that: For the public service supply of electric energy, in the short and long term, the CFE should use the electric energy with the lowest production cost and additionally, it should offer optimum stability, quality and security for public service, observing the following:
I. Based on the planning carried out by the CFE for the SEN, the Energy Secretary will determine the growth or replacement of the system's generation capacity;
II. When this planning requires the construction of new installations for the generation of electric energy, the CFE will inform the Secretary of Energy about the characteristics of the project. Based on comparative cost information, this entity will determine if the installation is built by the CFE or if instead, private parties are called to supply the necessary electric energy;
III. For the acquisition of electric energy destined for public service, the energy generated by private parties under any of the types mentioned in article 36 of this Law should be taken in consideration;
IV. The terms and conditions of the agreements by which the CFE purchases electric energy from private parties will be adjusted to the Regulations in relation to the firmness of the deliveries; and
V. The works, installations and other components will be subject to Official Mexican Norms or be previously authorized by the Secretary of Energy.

39 This is found in CONAE (2001).

40 In the Mexican legal system the following Official Mexican Norms exist: 1. NOM for the protection of the environment during the

construction, exploitation and abandonment of wind energy projects (in the approval phase); 2. NOM issued in order to determine the thermal performance and functionality of the solar heaters (in force); 3. NOM pertaining to solar heaters whose objective is to establish the criteria to take advantage of solar energy at new and remodeled establishments in the Federal District (in force).

41 We are referring in particular to the provisions that must be issued by the la CRE and that appear in article 7 of the LAERFTE: I. Issue the norms, directives, methodologies and other administrative provisions that regulate the generation of electricity from renewables, in conformance with what is written in this Law, in line with the energy policy established by the Secretary; II. Establish, prior opinion of the SHCP and the Energy Secretary, the regulations for the calculation of the incentives for the services rendered between the suppliers and the generators; III. Request from the supplier the revision and, if required, the modification to the dispatch or delivery rules in line with the dictates of this Law; IV. Request from the National Energy Control Center adjustments to the dispatch or delivery rules thus assuring compliance with the Law;
V. Issue the methodologies to determine the generation capacity participation of renewables technology to the SEN. In order to issue these consideration will be given to the information provided by the suppliers, the investigation carried out by specialized institutes, industry best practices and other national and international evidence; VI. Issue the general rules for interconnection to the SEN which must be given to the suppliers, listening to the opinion of the generators, and VII. Issue the energy exchange procedures and the corresponding compensation systems for all the self-supply projects and systems, co-generation or small producers connected to the SEN networks.

42 Article 14 of the LAERFTE dictates that the incentives must include payments for the costs derived from capacity generation and for the energy generation associated with the project. The incentives could depend on the technology and the geographic location of the projects.

43 Along the same line, we consider that the provisions contained in the Regulations regarding tender bids generate a parallel contract scheme that does not have sufficient legal basis and that could operate within the limits of Article 134 of the Constitution. We refer expressly to some provisions. Article 38 establishes: The supplier will carry out a separate tender bid for renewables projects and for efficient co-generation projects, in accordance with the goals established by the program, referred to in chapters I y II of article 17 of this Regulation. The invitation notices and the bidding rules issued for the renewables is in line with the goals established in the program and must adhere to the following principles: I. The invitations can be national or regional; II. They will indicate the maximum capacity requested and the variability range allowed; III. The participants can offer the total capacity requested or a partial amount; IV. The basis of the tender bids will look to provide the maximum flexibility possible to the interested parties allowing them to present the technical aspects of their proposal in terms of specific technology, design, engineering, construction and installations location, and V. Mechanisms to promote generation projects that provide firm capacity to the system as well as those projects that can be available during peak demand hours. Article 39 dictates that: The Commission will prepare the necessary criteria and the methodology to determine the maximum incentives applicable to the different tender bids with basis on the estimated efficient costs for the development of the projects plus a reasonable profit. The determination of the maximum incentives will be subject to any of the following schemes: I. Incentives per capacity and energy that reflect, respectively, the fixed costs, including the return on the investment, and the variables incurred by the permit holder, and II. Incentives per a unit of energy that will include the remuneration received as a result of capacity and energy. Article 41 states: The agreement will adjudicate to whomever offers the required electric energy at the lowest cost, considering the following: I. In the case that the bases of the tender bids are the incentives referred to in chapter I of article 39 of the current Regulation, the proposals will be compared on the basis of the total long-term economic cost, and II. In the case that the basis of the tender bids are the incentives referred to in chapter II of article 39 of the current Regulations, the proposals will be compared on the basis of the incentives included in each one of them. Article 43 shows that: The Commission will publish the contract models and the precedence rules that will regulate the acquisition by the supplier of the electric energy produced by the renewables generators and by the efficient co-generators outside of the invitation to bid, in accordance with the goals established in the Program. Likewise, it will regulate the incentives in possession of the supplier that shall provide the contracts for the delivery of the energy. Article 44 establishes: The delivery of electricity to the SEN by renewables generators and by efficient co-generators outside of the invitation to bid can be carried out with the corresponding permits issued by the Commission, in line with the Law of Public Service of Electric Energy and its Regulations, as deemed necessary.

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4. Hydropower

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4.1 Introduction

Hydropower is a renewable source, whose origin is the solar radiation that reaches the Earth, generated by the "water cycle" (Figure 4.1). As the water warms seas, clouds are formed. Most clouds rise, cool and release into the sea, while the wind moves the rest to the continents. When rain falls, it partially infiltrates underground, some more evaporates and the remainder drips. Mountain streams are thus formed, then become rivers and finally run their course into the sea.

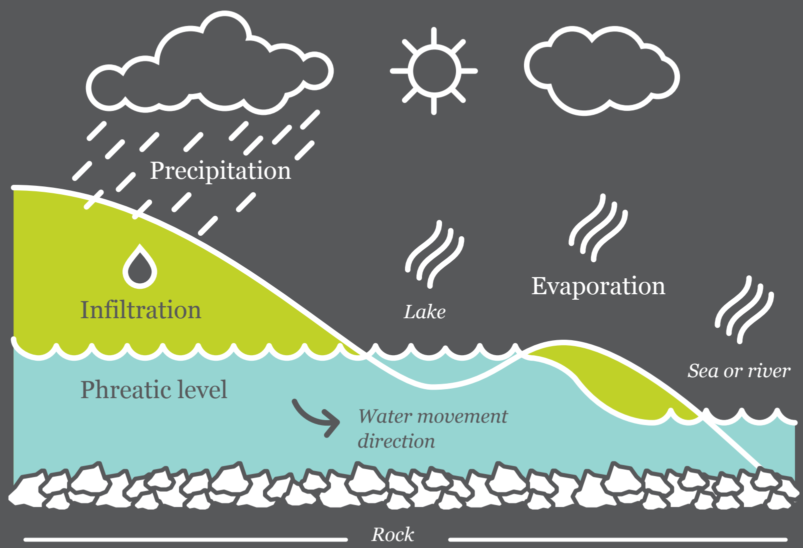

Figure 4.1
Water cycle.

Source: Mataix, 2005.

The slopes and falls of the rivers and the amount of water that can be used are important to harness energy from water (Mataix, 2005). Usually slopes tend to be steep in the upper parts of the rivers, forming cascades of tens of meters or "rapids". As water moves toward the lower parts, the river tends to reduce its profile or pending and there are not so many "rapids", but water flow is greatly increased. Therefore, it is wise to say that despite being "flat", or making small slope in coastal areas, rivers have so much water that in many cases one can navigate with medium or large boats.

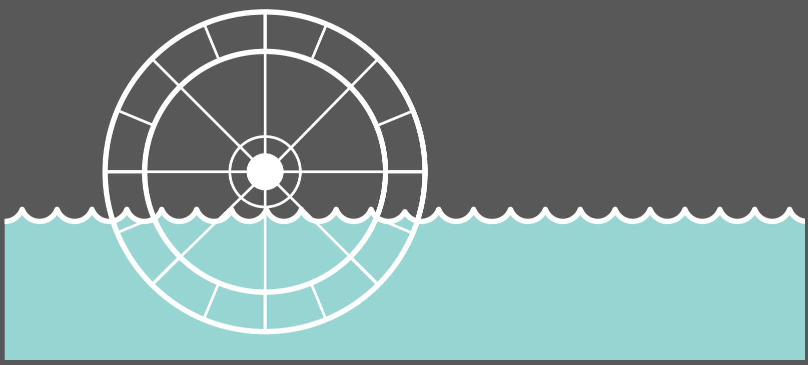

Figure 4.2
Lower powered waterwheel.

Source: Valdez, 2009.

Apparently, the use of water power dates back to the second century BC, when the first water wheels, driven by the bottom and used for grinding wheat, appeared in Asia Minor. Then it was discovered that if water propelled to the top of the wheel, the grinding efficiency was increased.

In the Roman Empire, around the year 300 of our era, watermills of important dimensions were built, and were mainly used for grain milling. (Viejo et al 1977). These were coupled with wooden gears and reached a capacity of 3 tons of grain per hour. This capacity was sufficient to serve a population of 80,000 inhabitants, which at that time, was considered a big city. Later, during the Middle Ages in Europe, the use of hydraulic wheels was generalized, building complex systems of wooden gears. Thanks to this technology, a maximum mechanical power of 50 horses was achieved.

Development in hydropower is largely due to the participation of the Briton John Smeaton. Implementing his skills as a mechanical engineer, he designed a hydraulic machine for the Royal Botanic Gardens at Kew in 1761 and a water mill in Alston, Cumbria in 1767. Several historians regard him as the inventor of the first axis and large cast iron water wheels.

The first hydraulic turbines, (mechanical devices that efficiently converted kinetic energy of a flow of water in a mechanical rotation or torque) were designed in the middle of the XIX century . Of these turbines, the most outstanding was the one developed by French engineer Benoit Fourneyron (Parres 1966). In his design, the wheel is horizontal (as opposed to the traditional large vertical wheel) with two sets of blades curved in opposite directions, thus generating a greater water flow power. Moreover, turbines for large falls and little expense appeared in the US, designed by engineer Allis Lester Pelton, and Francis type, for average costs and falls, created by English engineer James B. Francis.

At the beginning of the twentieth century, with the development of the AC electric generator invented by engineer Nikola Tesla, the first major hydroelectric plants on the Niagara River in Canada were built . By 1915, in the former Czechoslovakia, engineer Victor Kaplan designed a turbine that leveraged a large flow and a short fall or hydraulic load. Some other turbines, considered as variants of the top three and that were born around the middle of the twentieth century, are Banki, Turgo, and Deriaz. Figure 4.3 shows some examples of the most commonly used turbines.

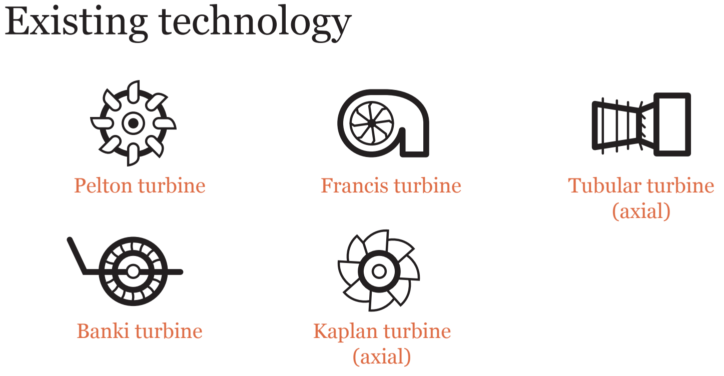

Figure 4.3
Most common hydraulic turbines.

Source: Illustration from pictures of different manufacturers.

4.2
Operating Principle

Natural factors which affect the potential of small hydraulic systems are the quantity of water flow and the height of the slope by which water precipitates. The flow is related to the annual rainfall average, and the slope depends mainly on the topography of the region. In order to make a hydroelectric installation successful , it requires a high head (the length from the highest point of the plant), either artificial or natural, by which water is diverted through a pipe to a turbine directly coupled to a generator. This generator changes the kinetic energy from falling water into electricity. Finally the water is discharged into the river through a pipe at a lower level.

The available theoretical energy for a hydroelectric system is the product of the mass of water by the height of the head. The losses caused by imperfections in the design of equipment and conduits have to be considered in all hydraulic systems. As water travels towards the turbines, the internal friction of the pipes and channels causes a loss of potential energy in the system. Similarly, there is friction and heat loss in the turbine, in the gearbox and in the electric generator. Considering a 70% efficiency of the hydraulic system, the energy produced by these systems is about seven times the water flow product by the height of the head. This is expressed in the following formula:

$$P\,[kW] = 7\,Q\,H$$

where Q are the cubic meters per second and H is the height of the head in meters.

A hydroelectric plant needs the potential energy and the flow of water to produce electricity or motive power for productive uses. The potential energy of water is directly related to the elevation it has with respect to a given point. For example, the potential energy of a water tank located on the roof of a house will be greater if the house has two levels than if it is a single plant. After opening the faucet and the water comes out with pressure, it is discharged to the drain at low speed. That is, potential energy was transformed into speed and pressure energy.

Potential energy is directly associated with the water height with respect to a point or "zero" level. In the case of the water tank, height is measured from the water level of the tank to the kitchen faucet (zero). - In the case of a hydroelectric plant, height is obtained by building a dam or by using a waterfall or "rapids" of a river. The other component of interest in hydropower plants is the amount of water that can be exploited.

In synthesis, a hydroelectric plant requires:

- A fall or height
- An expenditure or flow (m^3/s)

4.3 Classifications of plants

Hydraulic systems are divided into three categories, depending on the type of head and the nature of the plant. High head plants are most common and generally include a dam to store water at a greater height. These systems are used in mountainous areas. On the other hand, low-head plants often use few meter high heads and are commonly installed in rivers. There is also another category which includes additional hydroelectric systems. In these generating facilities, hydroelectric plants are subordinate to other activities such as irrigation, industrial processes, drinking water supply or waste water disposal. Electricity production is not the main objective of the plant but it is certainly a useful by-product.

In general, and regardless of its scale, a typical hydro-generation system consists of a structure that is used to divert water to a cell where there is a dam or a turbine, a structure that supplies water to the turbine to achieve a suitable flow rate, an entry point that channels water into this structure, turbines, electrical generators, electrical installations and converters. Filters are also needed to prevent the passage of garbage, debris or sediment to the turbine, and an artificial channel to pour the water back into the river, if it is too far away.

Water enters a pressurized pipe by the entry point which uniformly feeds to the turbine at a speed that ensures optimal efficiency. For effective regulation of water flow velocity, in some cases an automatic valve which doses the flow to the turbine is used, allowing to make adjustments to changes in power demand.

The hydraulic and electrical equipment that is installed on solid ground is located in the hydroelectric plant (or machine room). Most of the operating equipment lies there, including generators. Turbines are placed at ground level or below it, according to the type of the required turbine.

According to its capacity, hydroelectric plants are mainly classified as follows:

- Micro-hydro: from 1 to 100 kW
- Mini- hydro: from 100 to 1000 kW
- Small plants: from 1 MW (1000 kW) to 30 MW
- Macro-hydro: over 30 MW

In Mexico, the largest hydropower plant has eight generating units and a maximum capacity of 2,400 MW.

Plants are also classified according to its architectural design and how height is used:

- Centrals with no reservoir or “water wire”
- Centrals with reservoir or storage dam

Micro, mini and small hydro-centrals are usually centrals without reservoir, or “water line”, where water fall is achieved by leveraging any significant slope along the river course. Macro-hydro-centrals, however, usually have a reservoir or a storage dam.

4.3.1 Centrals with no reservoir or “water line”.

Figure 4.4 shows an overview of this type of plant. To determine the site where it is convenient to construct the plant, topographic or hydrological studies must be done. The main components of these centrals are the following:

- A diversion dam, diverting part of the river flow.
- A conducting channel that leads water in a controlled way.
- A cargo tank with a spout. With this, pressure pipes can be fed, and allows control of phenomena such as water or flow hammering when turbines stop.

- A powerhouse with turbines and generators as well as the control and voltage transformation equipment.
- The transmission line to the consumption center or for direct use by the powerhouse.

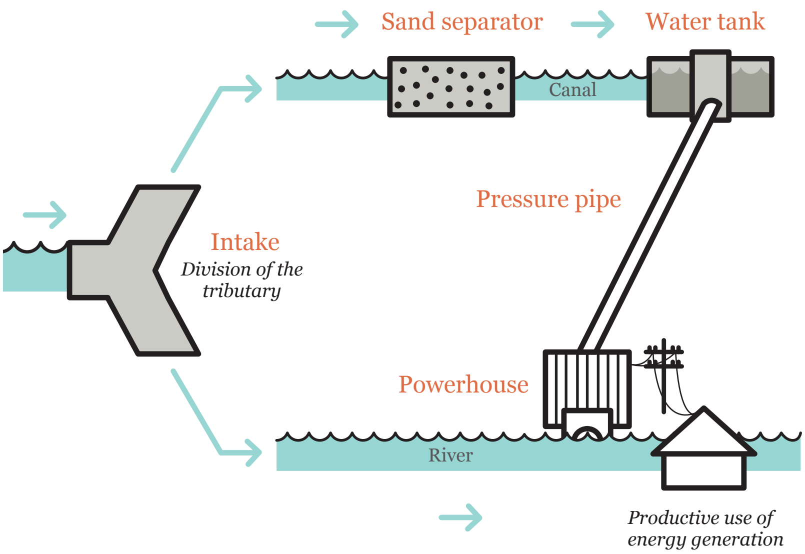

Figure 4.4
Schematic of a plant without a reservoir (run-of-the-river).

Source: Peniche et al., 1998.

4.3.2 Plants with storage reservoir or dam

Its construction can target any of the multiple uses of water: irrigation, cities or generation supply, hydropower. They also help to prevent flooding by rivers. The typical construction of such plants is shown in Figure 4.5, and consists of the following parts:

- A dam constructed of various materials or rocks that are relatively close to where it is located. Its height can be substantial, from 50 meters to 200 meters. The volume of water stored is measured in billions of cubic meters.
- A power house at the foot of the dam or in a cave. Usually there are no channels or driving tunnels and pressure pipes are next to the dam. Turbines and generators are located inside them together with its controls and protection systems.
- A forklift substation to feed one or several high voltage transmission lines.

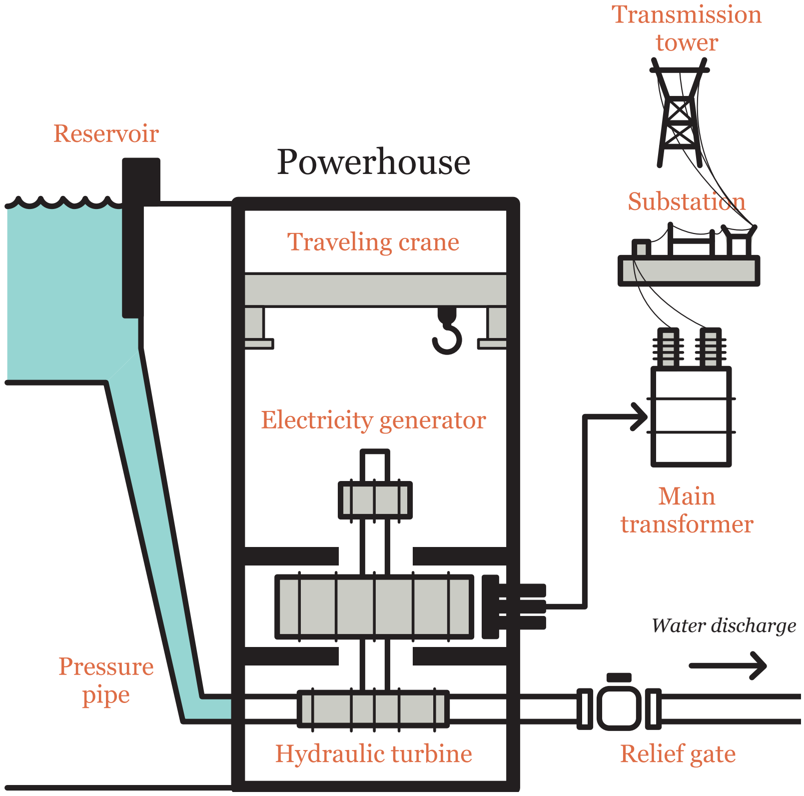

Figure 4.5
Diagram of a central with damming.

Source: CFE, 2009.

Most of the plants with reservoirs belong to the Federal Electricity Commission (CFE). In the last decade, and following amendments to the Electricity Public Service Act of 1992, powerhouses have been built and equipment machines have been installed to generate electricity for "remote self-supply" of individuals in several dams for irrigation purposes. Likewise, CFE overhauled several disused power plants by changing turbines, rewinding generators and making other adjustments to increase its generation capacity or to implement them again.

4.3.3 Types of turbines and application range

In the upper part of a river basin there can be good waterfalls (over 100 meters) but with little flow (less than 5 m3 / s). As the river runs its course, the amount of available water increases (5-10 m3 / s), but falls are not as large. In the lower river basin, water flow grows considerably (more than 10 m3 / s), but the usable fall is reduced to less than 20 meters. Hydraulic turbine technology allows the adaptation to each of these conditions. This is how various types of turbines originate.

The efficiency of a turbine is directly proportional to its size and its age. For this reason, it is important to consider that hydroelectric micro-plants use small turbines that have an efficiency of between 60% and 80%. So a newer and larger plant will achieve greater efficiency. Hydraulic turbines operate through two mechanisms, depending on their degree of reaction, and are classified as follows:

- **Reaction turbines:** Those with a nonzero reaction degree. The turbine rotor is fully immersed in water and enclosed in a carcass to contain its flow. The blades or vanes are profiled in such a way that the pressure differences on both sides of them exert force on the blades causing them to rotate. The most common turbines for small hydro- plants are Francis and Kaplan. In Francis turbines, water inlet has a spiral shape. Kaplan turbines are used for axial flow and with adjustable vanes. Reaction turbines require a more sophisticated manufacturing than those of impulse, as the arrangement of the blades and the carcass of the turbine is more complicated and require greater precision. This factor makes them less attractive for use in micro-hydro-generation in developing countries. However, since these are more suitable for use in low-head sites (more numerous than high-head and closer to towns), easy-to build reaction turbines are being developed.

- **Impulse turbines:** Those in which the degree of reaction is equal to zero and the flow is tangential. These turbines do not operate from pressure differences within a water chamber, but based on a water jet that hits the vanes causing the rotor to rotate. The most common type of turbine is the Pelton. They are generally used in installations with a head greater than 50 meters. It is the most efficient for applications with a large unevenness of water.

The selection of the most suitable turbine for a specific site depends on the fall and the available flow. The selection must also be made according to the operating speed to be obtained from the generator. Each turbine has a "specific speed", a measure of their commitment. Generally speaking, reaction turbines are better when the fall is not large and impulse turbines are more suitable when downfall is large. Figure 4.6 shows the range of application of the various types of turbine, depending on the fall and spending that can be leveraged. The range shown here corresponds to small plants, mini-centrals or micro-centrals.

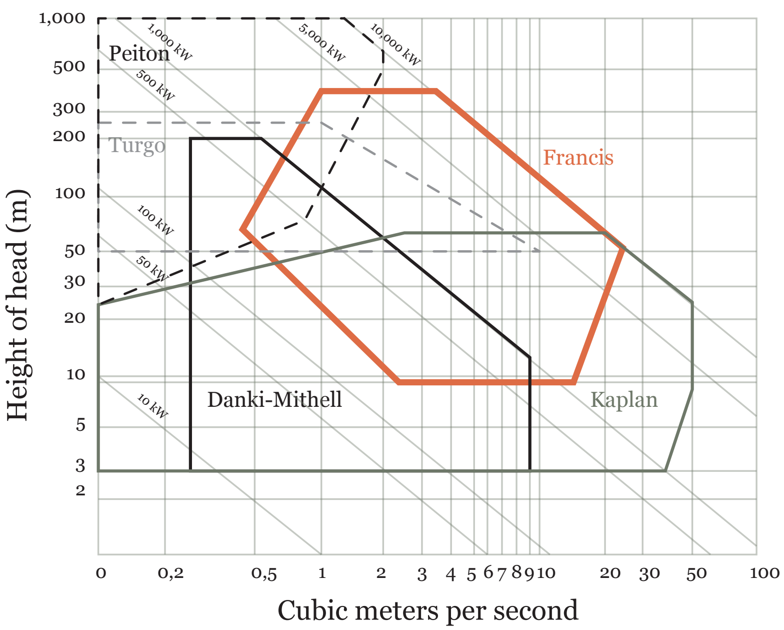

Figure 4.6

Source: Peniche et al., 1998.

It should be noted that two or more turbines are usually installed in a hydroelectric plant. The graph in Figure 4.6 indicates the range of application for a single turbine. For example, if there is a flow of 40 m^3 and a fall of 10 meters ,installing two Kaplan units would be considered.

4.4 Current use of global potential

An important aspect to consider is the potential for electricity generation. Hydropower generation represents a large percentage of total generation from renewable sources in the world. Chart 4.1 shows the percentage of renewable energy in electricity production in 2003 in various countries and regions.

Percentage of renewable energy in the production of electricity

	Percentage of renewable energy in the domestic production of electricity	Percentage of non-hydro renewable energy in the domestic production of electricity	Percent of global use of hydropower in electricity generation	Percent of global use of non-hydro renewable electricity generation
OECD				
United States	9.3%	2.4%	10.5%	30.2%
Canada	59.2%	1.7%	12.8%	3.1%
Mexico	13.1%	4.0%	0.8%	2.7%
OECD Europe	17.5%	3.6%	17.6%	37.0%
Japan	11.2%	2.1%	3.6%	6.8%
Korea	2.0%	0.6%	0.2%	0.6%
Australia	8.0%	0.9%	0.6%	0.7%
Transition Economies				
Former Soviet Union	16.7%	0.2%	8.4%	0.8%
Non-OECD Europe	24.4%	0.1%	1.7%	0.0%
Developing Countries				
Africa	17.1%	0.3%	3.2%	0.5%
China	15.0%	0.1%	10.7%	0.8%
India	12.8%	0.9%	2.8%	1.7%
Asia (others)	18.3%	3.2%	5.0%	8.6%
Latin America	70.9%	2.6%	21.4%	6.6%
Middle East	2.9%	0.0%	0.6%	0.0%

OECD = Organization for Economic Cooperation and Development

Chart 4.1

Source: IEA, 2003.

At present 19% of the world's energy is produced by hydropower (Paish 2002). Micro-hydro-generation only represents 5% of the energy produced by hydropower worldwide (Energy Technology Perspectives 2006). In some countries of Africa and Latin America , 90% of the energy is produced by this process, while in the United States only 9% is produced by this process (Masters 2004). Currently about 30 million people in China obtain energy by hydropower (Boyle 2004).

Micro-hydro-generation contributes to the production of 40 GW and it is expected that, in the coming years, it will produce 100 GW. It is also expected that China, the largest producer, will generate 10 GW in the next decade (Paish, 2002). Economically exploitable potential worldwide based on data from the International Energy Agency (2005) is as follows:

• Capacity	2180 GW
• Average annual generation	8180 TWh

According to the same source, the exploited potential by 2007 was as follows:

• Installed capacity	836 GW	(38%)
• Average annual generation	3000 TWh	(36%)

The main producers of hydroelectricity are:

Principales países en generación hidroeléctrica.

Country	Average Annual Generation TWh	Percentage %
China	397	13.3%
Canada	364	12.1%
Brazil	337	11.3%
United States	290	9.7%
Russia	175	5.8%
Norway	137	4.6%
India	100	3.3%
Venezuela	75	2.5%
Rest of the world	1,119	37.4%
	2,994	100%

Chart 4.2
Main hydroelectric generation countries.

Source: Valdez, 2009.

As it can be seen, there is still more than 60% of unexploited world economic potential , both in these countries and in other regions.

In March 2009, the World Bank presented the data of the regions and the unexploited hydropower potential. Chart 4.3 presents this data.

Unexploited hydroelectric potential by regions

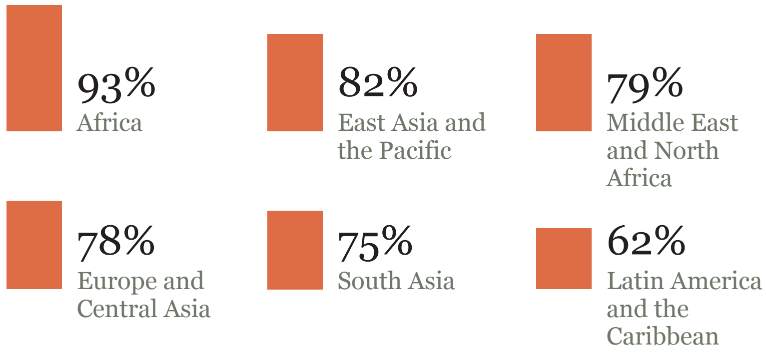

Chart 4.3
Unexploited hydroelectric potential by regions.

Source: World Bank Group, 2009.

Great opportunities for hydropower growth are found in developing countries . However, Chart 4.2 shows that Latin America and the Caribbean are the regions where there is a lower percentage of unexploited potential in comparison with other regions. This is partly due to the development of large hydroelectric plants in Brazil and Venezuela in the past 30 years.

In the case of micro, mini and small plants one can make a statistical subdivision. Published data (United Nations, 2005) are:

- Total global potential 76 GW
- Exploited potential 48 GW (63%)
- In construction (year 2010) 8 GW

China's case is outstanding, because it concentrates 55% of the exploited potential . The rest of Asia represents 14% , Europe 22% and Latin America only 3% . However , there are plans that allow us to predict that in the next 10 years Latin America will increase its installed capacity of 1,350 MW mini-hydro plants to 3,000 MW.

4.5
Current utilization of the national potential

In the case of Mexico, most renewable energy is generated from hydroelectric processes. These belong to large hydropower plants, the problem is that they require high financial investments, long periods for construction and government intervention for installation. They could also lead, at some point, to environmental and social problems due to the large surface area (with a special topography) occupying the reservoir and the need to resettle the displaced population. These drawbacks and the high costs that mitigating the impacts imply, have caused generation with large hydroelectric centrals to become an increasingly untenable option.

4.5.1 Macro-hydroelectric potential

The Federal Electricity Commission estimates the national hydropower potential in 52.427 MW (Chart 4.4). The above figure includes both, economically exploitable potential and that which is not. For example, it appears that there are about 5,000 MW of feasible power in 30 sites and 11.380 MW in operation. The total installed power in operating plants represents 22% of the total potential. It can be seen that there are still opportunities to continue developing the national hydroelectric potential.

Potencial hidroeléctrico nacional, 2007.

Level of Study	Code	Number of Projects	Installed Capacity MW	Average Annual Generation GWh
Identification	ID	330	21,934	64,476
Great Vision	GV	116	7,890	18,720
Prefeasibility	PF	34	5,307	13,040
Feasibility	F	30	4,986	14,815
Construction	C	1	750	1,413
Operation	O	57	11,380	21,908
Total		583	52,427	132,959

Chart 4.4
National hydroelectric potential, 2007.

Source: Own elaboration from CFE, 2000 and CFE, 2009.

CFE coordinates, by means of the Electrical Sector Investment Works Program (POISE), the way in which future generating plants will start operating (CFE, 2009). In the latest version of the program (2009-2018) the following aspects of hydropower, among others, can be seen:

- In 2007, the total installed capacity (of all energy sources) was 51.029 MW.
- Of the above figure, 11.328 MW corresponded to hydroelectric power, that is equivalent to 22.2%.
- Overall capacity for 2018 is estimated at 63, 184 MW.
- Hydropower could increase by 2.124 MW in four new plants, and maintain, approximately, its contribution to the total installed capacity in the country.

In terms of annual gross generation POISE figures indicate that:

- In 2007 the total gross generation was 232.552 GWh. Hydropower represented 11.6%.
- In 2018 that figure will be 329.912 GWh. Hydroelectric participation will then represent 10%.

Regarding benefits to the environment, it is known that the production of electricity from renewable sources such as hydro prevents the emission into the atmosphere of about 0.54 tons of CO_2 per MWh. So the "kidnapping" of CO_2, thanks to new planned hydropower , will be 6,015,000 MWh x 0.54 equivalent to 3.24 million tons of CO_2.

4.5.2 Mini-hydroelectric potential

In Chapter 1 of a 1995 CONAE study, it was observed that the global potential of small hydroelectric plants was 30,000 MW , including those that were under construction or in the design phase. In 2004 that number increased to 48,000, of an estimated total of 131.100 MW. This means that, in total , 36% has been developed. On the other hand, and according to potential macro studies conducted in other countries, it is known that in Mexico, the potential for small generation accounts for 7.13% of macro potential.

Mini-hydraulic national potential figure, published by CONAE in 1994, is 3,250 MW, representing 6.2% of the potential indicated by CFE in the macro stage of "identification" or very preliminary. In 2009, a new estimate of the national mini-hydroelectric potential based on data published by the Commission (CFE, 2000) was presented by different regions in the country (Chart 4.5).

The figure of 3.456 MW compares well with the data published by CONAE in 1994. It is worth remembering, however, that the average power is a preliminary estimate based on the average expenditure shown in the river throughout the year. The power to install results from more detailed studies that have been optimized or where it has been determined that the economic cost can be leveraged. Note that some of the sites mentioned are in pre-construction phase.

Updating of national mini-hydro potential.

Region	Number of sites	Average Capacity	Average MW/plant
Golfo	42	303	7.2
Papaloapan	35	390	11.1
Grijalva	26	428	16.4
Costa Oaxaca and Guerrero	36	550	15.2
Costa Michoacán and Jalisco	53	750	14.1
Costa Nayarit and Santiago	22	390	17.7
Pacífico Norte	38	642	17.0
Total	252	3,453	13.7

Chart 4.5
Updating of national mini-hydro potential.

Source: Elaboración propia, con datos de CFE, 2000.

Moreover, it is known that in the Regulatory Energy Commission (CRE) there are a total of 22 permits for small hydroelectric generating electricity, for a total of 217.7 MW , and with an authorized generation of 1,082 GWh per year (CRE, 2009).

To complete the picture, Chart 4.6 presents the status of all the existent mini-hydroelectric plants or those under construction.

Mini hydro plants in Mexico.

Type of plant	#	Installed Capacity MW
CFE owned and operated	41	390
Privately operated	12	70
Private plants in construction in 2010	8	104
Total	61	564

Chart 4.6
Mini hydro plants in Mexico.

Source: Own elaboration from CFE, 2009.

It can be seen that the installed capacity of private plants under construction represents about 150% of the installed capacity to date. There was also a tendency to use already-built dams to install hydropower plants, which reduces investment costs compared to a “water line” central.

4.6 Technology of hydropower plants

Hydropower technology is divided into two: civil construction and electromechanical equipment. And Mexico is recognized worldwide for its expertise in the design of civil constructions and installation of electromechanical equipment. The first important central , Mazatepec plant , was built in 1958 in the state of Puebla (CFE, 1994) with an installed capacity of 55 MW. Over the following 50 years, 18 more large hydropower plants were built, and La Yesca plant, of 750 MW is currently under construction and it is estimated that it will be open in 2012.

In Mexico, despite their experience in civil engineering, the main equipment such as turbines and generators are manufactured abroad and only some components are integrated in the national territory. In that sense it is not expected that this situation will change in the future due to the design of a large hydraulic turbine (over 100MW) which is unique. In order to change the current picture it would be necessary to have the support and experience of many decades of the few manufacturers in the world.

In the case of small centrals, the scenario is different. Main equipments of plants under construction are partially integrated in Mexico. This is the case of electric generators up to 5 MW, designed and manufactured with proprietary or licensed technology. Other partially produced components are protection controls and boards. As the potential market for the supply of equipment for small hydropower becomes more attractive, more components may be produced in the country.

The cost of these projects varies in a range of $ 0.02 to 0.06 per kWh (Energy Technology Perspectives 2006). This variation is due to the location and to the country that is developing them. This cost can exceed $ 10,000 USD / kW. However, it is possible to reduce it by using the available technology at a cost of USD $ 1.000 kW (Paish 2002). In the following Figure 4.7 the range of costs of a micro-hydro-generation project is shown.

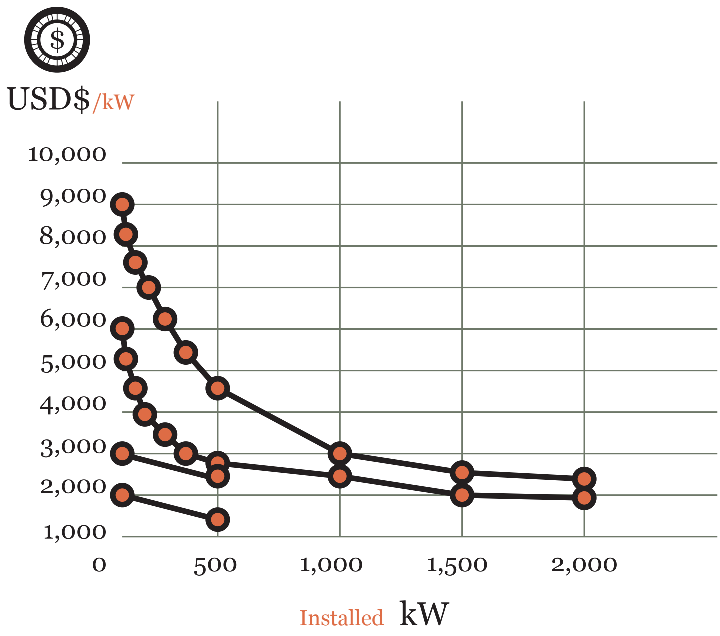

Figure 4.7
Costs range for a micro-hydro-generation project

Source: Paish, 2002.

The electric generator is less than 5% of the total cost of the plant. In general, costs for the small, mini and micro-hydro-generation are minimized faster due to the reduction potential of electrical equipment in these systems (Natural Resources Canada 2004).

Regarding investment costs for small water systems, these may vary depending not only on the specifications of the place, topography and hydrography, but also local characteristics, such as planning and management issues, social acceptance or financial schemes. The key elements for defining the costs are civil engineering, equipment and turbine. Civil engineering costs are higher for systems with high head because they need longer lines.

Turbines are the most expensive standard component (in contrast to civil engineering , which is specific in each country). Most of these are not mass produced, but designed and manufactured individually, so as to optimize the energy to be obtained. Their costs are higher for plants with low head, while the required investment is lower at high head plants, because the slope allows the amount of water required for generating power to be less.

Meanwhile, electric equipment represents about 25% of the total cost of the plant, whatever the height of the head. This includes the generator, transformer, controller, protection system and access lines.

Although small, mini or micro-hydro, high head plants tend to produce electricity at a more expensive cost, their value may be higher, as they generally have greater storage capacity and can inject energy in high demand periods and charge higher fees. Furthermore, the investment is compensated with a low operation and maintenance cost, and only require an operator to run them. (Energy Technology Perspectives 2006). Finally, they have a longer life, 50 years or more.

4.7 Support for small hydro developers

Since the adoption of the changes to the Electricity Public Service Act in 1992, support has been given to companies or groups who want to develop small hydro . Below are the main benefits:

- The Interconnection Agreement for Renewable Energy Sources was created. Through this agreement, any excess energy produced can be accumulated in the CFE Bank's Energy for its use or sale in the next 12 months.

- Investments in machinery and equipment for energy generation from renewable sources are deductible at 100% of the investment in one year.
- CFE pays the self-supply surplus kWh at 85% of the Short Term Average Cost (CMCP) in the node where it is delivered, or at 70% if the plant is still on probation. For example, the average MAPE for Veracruz in January 2009 was $ 0.048 kWh.
- Small producers are paid 95% of the CMCP.

4.8 Challenges for small hydro development

To date, there are some challenges to overcome to make Mexican mini generators proliferate. The main ones are:

- It is planned that by 2012, mini-hydraulic sources provide 3% of the national electricity capacity, (1,700 MW) a seemingly elusive goal.
- The Law on the Use of Renewable Energy and Energy Transition Financing states that the facilities for power generation, may not exceed 30 MW.
- Lack of coordination efforts among institutions for the publication of national, economically exploitable potential.
- Mini-Hydroelectric development should be allowed in close-season rivers if it is shown that it does not affect agriculture and that it has minimal environmental impact.
- CFE, with INEGI´s support, must publish state power distribution network plans (lines and substations).
- Norms that regulate safe interconnection or distributed generation up to MW must be adapted or adopted.
- CFE must analyze and demonstrate, case by case, the interconnection point determination and voltage to distribution lines.

4.9 Conclusions and recommendations

Hydropower technology is mature and represents an opportunity for sustainable energy supply. Globally, the exploited Macro Hydroelectric potential is 38%, while in Mexico the figure is 22%. Meanwhile, the exploited mini-hydro-electric potential exploited in the world, and particularly in Mexico, is 36% and 6% respectively.

The major central development in the world began in the early twentieth century. In the case of Mexico , the first large hydropower centrals for the national grid were built since the fifties. Therefore, the country has a Macro-Hydroelectric potential of 137.977 GWh / year and a potential of 52.427 MW at 583 sites or projects. The exploitation of this potential in 72 plants in 2000 was 18.2% in terms of annual average generation, and 19.4% in terms of installed capacity.

The Mini Hydroelectric potential is not fully known yet. While in 1995, CONAE (before CONUEE) estimated it at 3,200 MW, it is now known that Mexico has developed only 6% of its potential. To contextualize, one fact: in 40% of the state of Veracruz, the feasible Mini Hydraulic potential is 475 MW, while there are at least six similar regions in the south of the country that require an evaluation to determine their similar potential . Therefore, a coordinated effort must be made in order to finish analyzing the National Mini-Hydroelectric economic potential as soon as possible . If this could be achieved, from 500 to 800 MW from this energy source could be developed in the next 10 years.

However, CFE only considers the project study whose generation capacity is greater than 40 GWh / year as "attractive". Although they estimate that there are a large number of sites with a lower capacity of 40 GWh / year, CFE does not consider them useful to meet the demands of the national electricity system. However, under the concept of "self-supply" it is possible to develop mini-centrals to service the industry or municipalities. In this sense, potential savings would go from 10% to 40%, compared to CFE rates.

On the other hand, it is possible to develop small hydro industry with produced equipment, up to 80% in Mexico. The Regulatory Energy Commission has issued permits to operate small hydropower by 217 MW, and some of them are under construction. Moreover, small-scale hydroelectric projects are environmentally friendly because their impact is minimal and fully identified. By encouraging their implementation, they will contribute to sustainable watershed management and improved quality of life in surrounding communities.

One advantage of hydropower plants is that they adapt well to the different uses of water in agricultural activities in urban or industrial use. In most dams, it is possible to build a hydroelectric plant ; in most dams it may be possible to build a hydroelectric plant; One can even take advantage of residual water in large cities and harmonize its activities with ecotourism. Fortunately, the legal and regulatory framework allows the development of mini-hydro plants in Mexico with a capacity of 174 MW.

Finally, power generation from micro-hydro could represent a great alternative for rural regions of the country, and would offer a type of clean, affordable and relatively easy-to obtain energy . The above, therefore, would mean a major breakthrough to respond to the lack of current supply and the environmental impact associated with the construction of large dams and hydropower plants.

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5. Bio-energy, part I; Biomass and biogas

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5.1 Introduction

Bio-energy is obtained from biomass, that is, organic material originated from a biological process in which plants exploit the sun's radiant energy and convert it into chemical energy through photosynthesis. A portion of the chemical energy is stored in the form of organic matter, which can be recovered by burning it directly or converting it into fuel.

This type of energy is usually produced from solid bio-fuels, liquid bio-fuels and biogas. Firewood, charcoal and agricultural waste are solids liable to be burnt directly or to be gasified, to produce heat and electricity. Meanwhile, liquid fuels (bioethanol and biodiesel) are mostly produced from energy crops such as sugar cane and oilseeds, among others. Finally, municipal, industrial and livestock waste are precursors of gaseous fuels, known as biogas (REMBIO, 2009).

Bio-energy is undoubtedly one of the leading actors in the global energy supply. According to the International Energy Agency (IEA, 2009), the supply of energy from solid biomass, liquid biomass or biogas represented, in aggregate, more than75% of global primary energy from renewable sources.

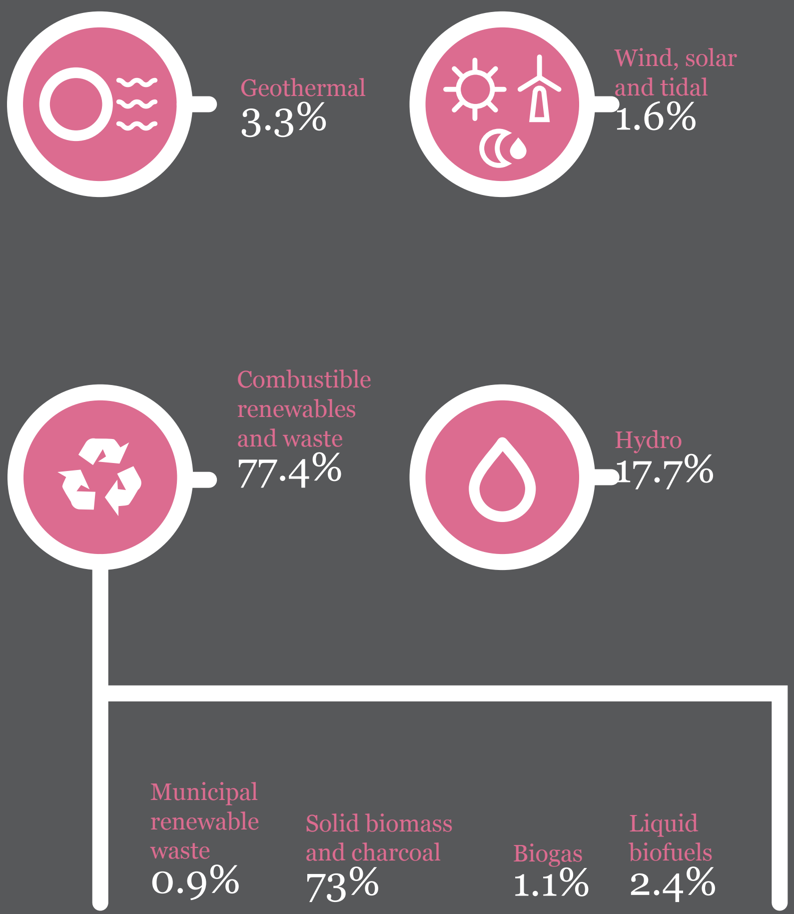

Figure 5.1
Distribution of global primary energy supply from renewable energy sources in 2007 (total 1492 Mtoe).

Source: IEA, 2009. Partial percentages have been rounded.

In Mexico, the potential of bio-energy widely contrasts with its use. The value range of bio-energy potential in the country goes from 3.035 to 4.055 PJ per year. However, these figures are not close to what actually happens in the present scenario, where only 408 PJ are generated (GBEP, 2008).

This chapter outlines the basic aspects of solid biomass and biogas, while in the following chapter the topic of liquid bio-fuels will be discussed. Below is a more detailed analysis of bio-energy.

5.2 Biomass

For millions of years, biomass has been a major source of energy for living things. For humans, it became one of the main sources of energy, especially the one found in the form of firewood or dried dung from the development of agricultural production. Currently, one third of the world population gets energy from solid biomass (IEA, 2007). Except for charcoal, this resource is usually collected and used directly, unlike other energy sources that are generally sold.

5.2.1 Overview of biomass

Biomass is any organic available matter in a renewable or recurring form. In other words, it is any material derived directly or indirectly from photosynthetic reactions occurred recently (Van Loo, 2008). Therefore, the term biomass covers a wide range of organic materials, recently produced from plants and animals that feed on them, and which can be collected and converted into useful energy (IEA, 2007).

This material is classified as primary, secondary and tertiary, depending on the processing stage it is derived from (ORNL, 2007). Thus, primary biomass is produced directly by photosynthesis and includes all terrestrial and aquatic plants used for food, fiber and fuel. This type of biomass is used only in small portions as a feedstock for the production of bio-energy.

Waste and by-products from food and plants, fiber and wood, among others, are the main secondary biomass source. This generally undergoes a transformation process which implies a substantial chemical or physical decomposition of primary biomass. The processing entity may be a factory or an animal. Some examples of secondary biomass are sawdust from sawmills, black liquor (which is a byproduct of paper manufacture) and cheese whey.

Meanwhile, tertiary biomass includes “post-consumer” waste and scrap such as fats, oils, wood debris of construction and demolition , other wood waste from urban surroundings, packaging waste, urban solid waste (except plastics and non-organic components), and sanitary landfill gas.

According to the Unified Bio-energy Terminology (UBT, for its acronym in English), published by the United Nations Organization for Food and Agriculture (FAO, 2004), bio-fuels are classified according to: (i) the production systems, such as energy crops, by-products and end-use products, (ii) economic sectors, among which woodfuels, agrofuels and municipal by-products are included, and (iii) the types of wood, such as woody biomass, herbaceous biomass, fruits and seeds, including mixtures. Chart 5.1 summarizes this classification. Fuel properties are remarkably uniform when compared with coal or oil.

Clasificación de los recursos biomásicos según su origen y características.

		Woody biomass	Herbaceous biomass	Biomass from fruits and seed	Others (including mixtures)
		Woodfuels	***Agrofuels***		
Energy crop	***Direct***	Energy forest trees Energy plantation trees	Energy grass Energy whole cereal crops	Energy grain	
By-products	***Indirect***	Thinning by-products Logging by-products	*Crop cereal by-products*		Animal by-products Horticultural by-products Landscape management by-products
			Straw	Stones, shells, husks	
		Wood processing industry by-products - black liquor	Fibre crop processing by-products	Food processing industry by-products	Biosludge Slaughterhouse by-products
End use materials	***Recovered***	Used wood	Used fibre products	Used products of fruits and seeds	Municipal by-products Kitchen waste Sewage sludge

Chart 5.1
Classification of biomass resources according to their origin and characteristics.

Source: FAO, 2004. According to the source, the term "by-products" includes the residues and wastes improperly called solid, liquid and gaseous elaboration activities derived from biomass.

For example, biomass has a much lower calorific value than that of common fuels (between 17 and 20 MJ per ton compared to 54 MJ per ton for gasoline). Moreover, it is composed mostly of cellulose. Below are some "typical" values, or range of values for some chemical, physical and biomass composition.

Chemical and physical properties and biomass composition.

	Chemical properties		Composition			Physical characteristics	
Properties / Types of biomass	***Gross Heating Value (Gj/t)***	***Ash (%)***	***Cellulose (%)***	***Hemi-cellulose (%)***	***Lignin (%)***	***Cellulose fiber length (mm)***	***Chopped density at harvest (kg/m3)***
Corn stover	17.6	5.6	35	28	16-21	1.5	—
Sweet sorghum	15.4	5.5	27	25	11	—	—
Sugarcane bagasse	18.1	3.2-5.5	32-48	19-24	23-32	1.7	50-75
Hardwood	20.5	0.45	45	30	20	1.2	—
Softwood	19.6	0.3	42	21	26	—	—
Hybrid poplar	19	0.5-1.5	42-56	18-25	21-23	1-1.4	150
Bamboo	18.5-19.4	0.8-2.5	41-49	24-28	24-26	1.5-3.2	—
Switchgrass	18.3	4.5-5.8	44-51	42-50	13-20	—	108
Miscanthus	17.1-19.4	1.5-4.5	44	28	17	—	70

Chart 5.2
Chemical and physical properties and biomass composition.

Source: ORNL, 2006.

5.2.2 Technologies of energy use of biomass

There are many methods to produce heat, motive power, electricity and even fuel from biomass. Some of these methods are presented in Figure 5.2 and are discussed later in more detail in the following sections.

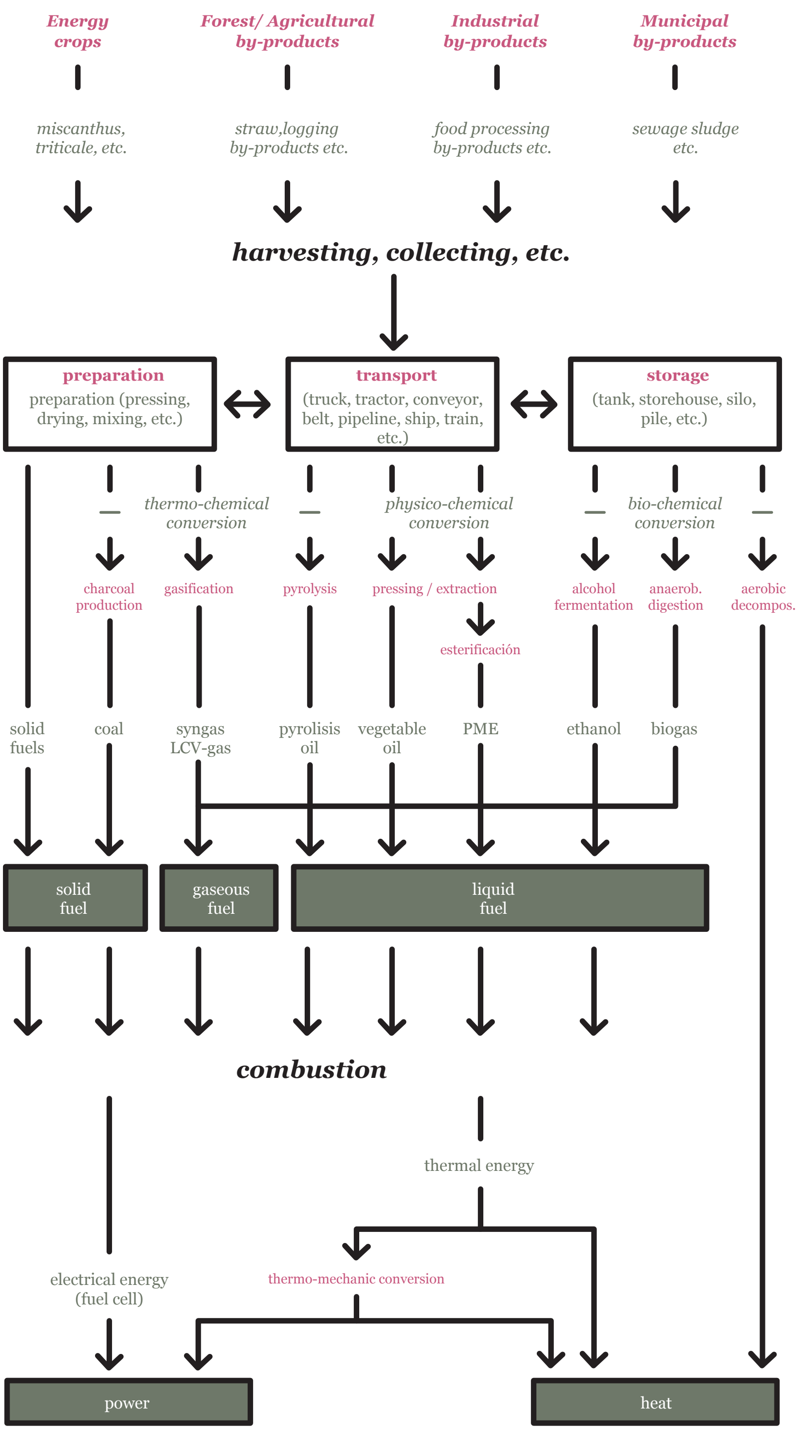

Figure 5.2
Methods to produce heat, motive power, electricity and fuel from biomass.

Source: FAO, 2004.

Methods to exploit biomass are classified according to their quality and energy in traditional biomass energy, biomass energy improved and modern biomass energy.

Traditional biomass energy refers to the direct, and often inefficient combustion, of wood, charcoal, leaves, agricultural and animal residues and human and urban waste; it is generally used for cooking, drying and production of coal. Traditional biomass energy is a local, easy- to-access energy source that meets the energy needs of a significant percentage of the population. It also has a low cost and does not require processing before use.

Improved technologies of traditional biomass energy (ITB, improved traditional biomass) are efficient for direct combustion of biomass, for example, improved stoves and ovens. These technologies include a redesign of the devices where combustion takes place, although their purposes are similar to those of traditional methods (for cooking, heating, etc.).

The enhanced biomass energy refers to its conversion into advanced fuels with higher energy density (greater amount of energy per volume) as liquid fuels and gas. This change also includes the processes that transform biomass into electricity. Finally, the modern biomass energy includes the use of raw materials such as sugar cane or agricultural processes waste, and trade in liquid fuels used in transportation. There are a lot of existing technologies for the use of solid, liquid or gas biomass. Some of these are shown in Chart 5.3.

There are four primary types of electricity generation from biomass: direct trigger (direct-fired), or co-combustion firing (co-firing), and gasification systems that use liquid fuels.

Conversion technologies of biomass for heating and electricity are quite similar to those that use fossil fuels, which facilitates replacement. There are four primary types of electricity generation from biomass: direct trigger (direct-fired), or co-combustion firing (co-firing), and gasification systems using liquid fuels. The advantage is that they can be used in small-scale projects (such as farms) or large scale (to provide electricity even to small towns).

Biomass fuel is burnt in a boiler to produce high pressure steam. The steam is introduced into a turbine where flows, through a series of aerodynamic blades, cause the rotation of the turbine, which in turn is connected to a

Technology for power generation,
by raw material.

Electricity Generation Technology	Raw material (biomass): *Rapeseed*	*Sunflower seed*	*Corn*	*Wheat*	*Barley*	*Switchgrass*	*Poplar*	*Willow*	*Miscanthus*	*Reed*	*Sweet sorghum*
Biogas cogeneration dumps gas (gas engine) - small and large scale			×	×	×	×	×	×	×	×	×
Wood gas CHP (fuel cells) - small scale							×	×			
Cogeneration wood gas (gas microturbines and gasifier) - small scale							×	×			
Cogeneration wood gas (gas engine and gasifier) - small scale							×	×			
Miscanthus gasified cogeneration (gas engine)							×	×	×	×	
Co-combustion or co-firing (in gas plant combined cycle)			×	×	×	×	×	×	×	×	
Local CHP plant with wood shavings							×	×			
Local cogeneration plant with wood chips organic ranking cycle							×	×			
Co-combustion or combustion combined coal combustion plant (steam turbine)							×	×			
Cogeneration plant rapeseed oil or biodiesel (diesel engine) - small and large scale	×	×									
Solid waste incineration plant	×	×									

Chart 5.3
Technology for power generation, by raw material.

Source: EEA, 2008.

generator to produce electricity. These boilers have a capacity of between 20 and 50 MW, unlike coal plants ranging from 100 to 1,500 MW . Combustion plants are less efficient than conventional coal plants, because they have an efficiency of about 20%, and at the very best and under specific techniques, up to 40% -.

The most efficient and cost effective way to convert biomass into electricity is from co-firing of combined firing of biomass and coal in modern power plants. As for the integrated biomass gasification in gas turbine plants (BIG integrated biomass gasification), this is not yet commercial. However, the integrated gasification combined cycle (IGCC, integrated gasification combined cycle) with black liquor is already in use. Gasification can also be applied in bio-refineries, which could open the door to the production of bio-chemicals, electricity and bio-fuels which are more cost-effective. Another case is that of anaerobic digestion (AD) for biogas production, which is already used in farms or in off-grid applications. In Mexico, some of these methods are in operation in bovine and swine farms.

Plants that employ liquid fuels generated from biomass of vegetable oils such as palm oil or sunflower, commonly work with diesel engines. In most cases, this oil is mixed with an alcohol (usually methanol) for conversion to biodiesel (as explained in the next chapter). Although biodiesel is used in transportation, it can also be used to generate electricity.

Finally, the CHP (combined heat and power) and are used for combined heat and power plants worldwide. In full cogeneration mode, energy efficiency can reach 85% to 90% (IEA, 2007), which is why the technology is becoming increasingly attractive.

For systems that are used to generate electricity, co-firing (firing) will remain the most profitable and the most effective in the short term. This is because the electricity that comes from coal plants still accounts for 40% of world production. In the long term, bio-refineries and plants could be extended considerably. In fact, some IEA projections indicate that the share of biomass in electricity production would increase from the current 1.3% to 3% or 5% by 2050.

The points already mentioned represent only a small contribution compared to the total estimated biomass potential (between 10% and 20% of primary energy supply in 2050), if it were also used for heat generation and the production of transport fuels (IEA, 2007). Estimates are based on the assumption that there will be no shortage of water and that the yield of food crops will increase in the coming decades, partly due to genetically modified crops. The use of non-arable land might also play an important role. Current estimates, however, are uncertain.

5.2.3 Current and potential exploitation

While improved biomass technologies are used mainly in developed countries, traditional biomass technologies are still the most important for developing countries. For example, in some regions of the developing world, biomass energy plays a vital role to meet local energy demand, since it is responsible for meeting the demand of about 200-400 million people (IEA, 2007). Also, several industries base their operations on biomass and contribute significantly to strengthen business and to increase income generation in rural areas.

As for usage trends, available statistics indicate that the proportion of biomass in global energy consumption has been constant over the last 30 years. Energy from biomass represented 11% and 14% of final energy consumption in the world in 2000 and 2001, respectively. The IEA in 2003 estimated that, globally, the share of biomass in total energy consumption was comparable with that of electricity by 15% and the gas by 16%.

Approximately 40% of the world population depended on energy from biomass in 2000 (IEA, 2008), and this value is expected to continue increasing, particularly in developing countries. In that sense, the IEA estimates that the final energy consumption of biomass will increase in most regions, although at a slower rate than conventional energy consumption. However, the proportion of biomass energy in the total global energy supply will not increase, and it is expected to remain at about 10% (FAO / GBEP, 2007). It is also expected that the proportion of biomass in the total energy supply in developing countries (Africa, Asia and Latin America) will decrease in the same period due to the substitution of biomass for kerosene and liquefied petroleum gas, among other factors.

A study by the International Institute for Applied Systems Analysis (IIA SA) and the World Energy Council (WEC) expects a global increase in the use of biomass energy. The document indicates that global consumption in 1990 was 5.4 Gtoe and, by 2020 it will be between 6.7 and 7.5 Gtoe. In 2050, biomass energy potential will have increased and will be between 8.8 and 10.8 Gtoe (Fischer and Schrattenholzer, 2001). In the IIASA-WEC scenarios the competition for land between bio-energy and food production are taken into account, and can therefore be considered as more optimistic scenarios. Other studies also suggest the growth of biomass energy in the world supply, but at different rates.

Chart 5.4
Potencial de biomasa.

Source: Fischer y Schrattenholzer, 2001.

World biomass potential – IIASA-CME
(Million tonne of oil equivalent, Mtoe).

Resource	Agricultural waste	Wood	Energy crops	Animal waste	Solid waste	Total
2020 (Mtoe)	480 a 499	1,791 a 2,925	2,971 a 3,535	994	516	6752 a 7569

Regionally, the proportion of biomass energy in total energy consumption varies significantly among developing regions, which show a high consumption in developed regions. According to the IEA, approximately 50% of the population in developing countries relies on biomass energy, although some regions, such as Africa, recorded a higher proportion. This seems to confirm several studies that show a correlation between poverty levels and the traditional use of biomass in many developing countries. That is, the poorer the countries the more dependent they are on traditional biomass for energy (IEA, 1998).

The use of bio-energy in Mexico represents 8% of primary energy demand and is focused on the consumption of residential wood fuel and in small industries, as well as sugar cane bagasse in sugar mills. It is worth noting that, in the case of wood, consumption is reported only residential, as there is no consumption data in public and commercial sectors. Currently, about a quarter of Mexico's population, between 25 and 28 million people, use firewood to cook. (INEGI, 2004). In 2002, the use of firewood for energy accounted for nearly 40% of total energy use in the residential sector in Mexico (320 PJ).

In particular, 89% of rural people cook with firewood. In a recent study it was estimated that the technical potential production of biomass sources in Mexico amounts to 3.641 PJ per year (SEMARNAT, 2008), and a large percentage of the total corresponds to biomass . Chart 5.5 provides more detailed information on the potential technical production of biomass sources in Mexico.

Origin or source of the biomass	*Primary product*	*Units*	*Quantity primary product*	*Processed energy carrier*	*Secondary production units*	*Processed energy carrier*	*Possible competing uses*	*Calories PJ / year*
				Woodfuels				
Natural forests	Wood	Mt (dry matter) /year	101	Several	Several	N/A	Firewood and charcoal for domestic use	1,515
Forest plantations (eucalyptus)	Wood	Mt (dry matter) /year	23	Several	Several	N/A	Construction wood and cellulose	345
By-products from forest	Wood waste	Mt (dry matter) /year	3	Several	Several	N/A	Cellulose Industries	63
				Agrofuels				
Agricultural by-products (A-b), crops	Several	Mt (dry matter) /year	15	Several	Several	N/A	Food for livestock	227
A-b, dedicated crops (d-c)	Several	Mt (dry matter) /year	6	Several	Several	N/A	Food for livestock	86
Agroindustrial by-products, c-d	Several	Mt (dry matter) /year	29	Several	Several	N/A	Bagasse for heat and power processes	431
Agroindustrial by-products, from industry	Several	Mt (dry matter) /year	8	Several	Several	N/A	Bagasse for heat and power processes in the sugar industry	114
Livestock by-products	Excreta	Mt / year	35	Biogas	Mm3n	14,449	Fertilizers	35
Energy crops (E-C), sugarcane	Stems	Mt / year	206	Ethanol	Mlts/year	8,615	N/A	338
E-C, grain sorghum	Seeds	Mt / year	10	Ethanol	Mlts/year	2,040	N/A	202
E-C, corn	Seeds	Mt / year	5.2	Ethanol	Mlts/year	3,472	Food and fodder	72
E-C, oil palm	Fruits	Mt / year	13	Biodiesel	Mlts/year	1,646	N/A	121
E-C, jatropha	Seeds	Mt / year	3	Biodiesel	Mlts/year	1,646	N/A	57
				Municipal by-products				
Municipal waste	Organic matter	—	—	—	—	—	—	35
								3641

Chart 5.5
Potential technical production of biomass sources in Mexico.

Source: SEMARNAT, 2008.

Regarding their end uses, the energy generated by biomass combustion is mainly intended for thermal uses: cooking, water heating, process heat in the mills (which also contributes to the generation of electricity for own consumption) and small industries. However, there are prospective studies of bio-energy penetration in Mexico which show that in a high inclusion scenario, it could represent about 16% of primary energy supply for electricity generation, transportation and the rural residential sector in 2030 (Islas, 2007). For this reason, it is important to understand the implications of using and promoting their use in these activities.

The most used cooking technology in Mexico are fuel-wood-based open fires, which are versatile and economic, but lead to a wasteful use of the resource and indoor pollution. Moreover, this material is also used in small rural industries such as brick plants, pottery workshops, bakeries and others. Fortunately, the design and construction of more efficient stoves gained momentum in the country again, preventing the passage of smoke into the kitchen and decreasing respiratory and eye disease. Additionally, furniture and other stuff are kept free of soot.

Implementing new cooking technologies represents savings of approximately 40% in the amount of wood that an open fire normally consumes, which reduces the collection time of the fuel for the home. Moreover, its construction generates a low cost, which means an economic saving for owners (SEMARNAT, 2008). As an example of this technology, the efficient stove “Patsari “ was designed in the central part of the country, as part of the efforts to disseminate these assets and promote the social benefits associated with its use. (Masera, 2005).

Besides its importance as energy, firewood is the main use of forest resources in Mexico (79%) (SEMARNAT, 1999, Diaz, 2000). Note that the impact on the resource is not directly proportional to the volume used, because most of the wood comes from trees or dead branches from trees outside the forest, wood waste and fallows. Meanwhile, bagasse consumption is concentrated in the industrial sector (88.8 PJ in the production of sugar and 0.2 PJ in pulp and paper). However, much of the potential energy is wasted due to obsolete technology such as low-pressure boilers, and combustion of wet bagasse.

5.2.4 Effects of the use of biomass

Biomass has many advantages over fossil fuels and other renewable fuels, as humanity has turned to it for centuries as a local energy source ready to become, relatively simple, a source of heating or cooking. In that sense, biomass could be a source of constant power 24 hours a day, unlike other renewable sources like the sun or wind.

The question is whether it could be sustainably used to generate electricity or heat if necessary, that is, if in all cases the production and use of biomass would be sustainable in social, environmental and economic terms. It must be an energy source that does not compete with food, that does not affect health and does not generate emissions (associated with its cultivation and transportation) higher than those expected to decline.

Social impacts

Biomass as energy, contributes to poverty reduction in developing countries. From a social perspective, bio-energy projects promote rural employment, provide new jobs and provide learning opportunities to transfer knowledge, introduce new technology and provide training and educational opportunities. The possibility to get biomass in all states of the country also provides an incentive for the adoption of decentralized schemes for heat and electricity generation. This, in turn, increases the chances of economic activities in the field.

The impact of biomass energy technologies in the population of limited economic means, represents, however, a double edged sword as it could encourage competition for the available biomass resources and for the land. On the one hand, the risk is that modern large-scale biomass energy leads to the marginalization of the poorest rural population, if they do not proceed with caution and proper planning. On the other hand, it is possible that the growth and development of these technologies could lead to an increase in income of these people (for example, small producers of sugar).

Added to this, if not properly planned, the development of biomass as an energy source would lead to competition for land between those who want to produce food and those using biomass resources (Masera et al., 2006) This, undoubtedly, remains an issue. Therefore, it is necessary to continue studying the potential and use of crops to continue breaking down the problem and identify specific solutions.

Below this line, the ownership of biomass resources represents an additional challenge. Forests are often public property (communal) and all the community use their products (firewood and wood for building structures, for example). However, little is done to recover resources through protection and reforestation. Some experiences in community forest management in Mexico are references in the international arena, as in the case of San Juan Nuevo, Michoacan. The question of ownership of biomass resources, better known as the “crisis of the commons” affects public policy makers. Often, this is aggravated by the relationship between the control of the resources of biomass energy, practices of land tenure and policy and regulatory frameworks (FAO, 2008)

Some producers say that reducing the wholesale price of electricity is an entry barrier to electricity projects. However, there are other schemes that appeal to some independent power producers wishing to supply electricity in remote rural areas of distribution networks.

Economic Impacts

Biomass, however, can be much cheaper compared to other renewables, particularly co-firing, with fairly low capital costs. Co-firing in coal power plants has a capital cost of between $ 50 and $ 250 per kW, and the cost of electricity can be competitive (USD $ 20 per MWh) if low cost, local raw materials are available (without transportation).

The main concerns regarding biomass derive from the high cost of capital generated by the construction of some plants. This generally implies not only a long period of return on investment, but also the difficulty of attracting investors. For this reason, it is essential to ensure a supply of biomass fuel in the long run. The problem, if anything, would be related to the fact that many biomass fuel suppliers are farmers , and so they are not used to long-term contracts.

Some of the technologies that use biomass are in the early stages of development and, in general, are still going through the learning curve. This represents a risk for those investors who are not willing to accept unanticipated increases in the costs of building a new plant. This can also be seen as a virtuous circle: the more experience they have, the higher the incentive will be. Overall, for every doubling in the total installed capacity of energy technology, such as a biodiesel manufacturing plant, the capital costs will be reduced about 20%.

Often, investors tend to seek a short payback period from two to four years, which favors the conversion of plants with low capital cost. For heat generation, power plants have a capital cost relatively high (between $ 1,300 and $ 2,500 per kW), compared to gas or coal (at a cost of between $ 900 and USD $ 2,000 per kW) . Transaction costs are relatively high, especially in the development of small-scale plants, as it has a similar price in time, effort and money to get financing for an investment project.

Effective risk management and the establishment of demonstration plants could help reduce these barriers, increasing in this way the number of people willing to invest. The granting of this increase in depreciation rates would help reduce the high cost of capital and eliminate barriers for investments in bio-energy plants.

Another critical aspect is the access to finance and government incentives. Currently, there are few or no incentives that contribute to the development of these technologies rather than traditional methods. In the vast majority of biogas successful cases , projects have some government support for its realization. Moreover, government support is essential if we aim to obtain credits for unreleased carbon emissions as stated in the Kyoto Protocol.

Environmental impacts and energy balance

Biomass is an alternative way to generate energy, as it is a neutral source in terms of carbon dioxide emissions. This is because vegetables capture carbon dioxide from the atmosphere and store it until the biomass goes through a combustion process. If biomass is stored properly, it can, in some cases, act as a carbon drain. In addition, biomass has the ability to restore degraded and unproductive lands or increase biodiversity, soil fertility and water retention (IEA, 2007).

The energy balance of a bio-energy project is not always favorable. This is especially true of some bio-fuels produced from energy crops annually. In such cases, the amount of energy input into the overall system may be similar, or even superior, to the amount of bio-energy that provides a product unit. In contrast, in the case of biomass produced from perennial crops used for the production of heat, useful output energy is at least 10 to 20 times greater than the input power. There is no single answer to the energy balance, nor is always right to extrapolate the results of other studies to the conditions of our country. The best tool to accurately understand the environmental and energy impacts of bio-energy systems is the life cycle analysis (LCA, for its acronym in English). The next chapter illustrates an LCA of ethanol from corn in Mexico, and a summary of the main results obtained from several LCA's in the world.

In terms of the environment, the combustion of any kind of biomass also generates emission of suspended particles, nitrogen oxides and other substances. Traditional biomass (especially in the form of charcoal) also contributes to land degradation and deforestation in countries where charcoal (from natural forests and forest plantations) is widely used. Indoor air pollution arising from the use of stoves run on bio-fuels without adequate ventilation, is linked to respiratory diseases in many mountain areas in developing countries. In addition, women and rural poor children spend a significant part of their time collecting firewood, crop residues and animal dung to use them as fuel for cooking and heating.

New technologies, benefits and challenges

ITB technologies may contribute to more efficient and environmentally sound energy from biomass. Improved stoves, for example, are designed to reduce heat loss, reduce air pollution, improve combustion efficiency and achieve greater heat transfer. This translates into cost savings, lower local emissions and better health and quality of life for its users. Initiatives to disseminate ITB technologies have yielded important benefits for vulnerable groups in urban and rural media in some parts of the world. Mexico has experience in the dissemination of this type of efficient stoves, with very good results: 60% reduction in fuel consumption and 80% of indoor pollution (Masera et al 2007).

Modern biomass technologies are able to provide better services based on the available energy resources and agricultural biomass waste. The availability of low-cost biomass energy in rural areas will provide cleaner energy and more efficient services to support local development, promote environmental protection and improve domestic fuels and rural livelihood means.

In addition, modern technologies of biomass energy would contribute to better management of bio-waste.

Existing studies indicate that, compared with other sources of primary energy, the job creation potential of modern biomass is among the highest. For example, in Brazil, the annual production of 14 million liters of ethanol from sugarcane is responsible for the creation of 462 thousand direct jobs and 1 million 386 thousand indirect jobs in the country, which corresponds to an annual rate of 263 000 jobs created.

5.3 Biogas

Biogas is a mixture consisting primarily of methane and carbon dioxide with lower quantities of hydrogen sulfide and ammonia, the decomposition product of organic matter (biomass). Generally the gas mixture is saturated with water vapor.

One of the oldest records held about the use of biogas dates back to 10 BC, when Assyria used this resource to heat their baths. Similarly, hundreds of years ago, the Chinese dug deep cone-shaped pools, where human and animal manures, together with food waste and other organic materials were stored. The methane produced by these materials was collected and used for cooking and as a heating fuel. This method of producing methane has remained ever since.

The first documented mention of biogas dates back to 1600, when it was identified by scientists as a gas from the decomposition of organic matter. Later, in 1890, the first full-scale bio-digester was built in India, and around 1896, in Exeter, England, street lamps were powered by gas collected from the digesters that fermented the city sewage sludge. After the World Wars in Europe, the so-called "biogas producing factories" began to spread , whose product was used in tractors and cars of the era. Later, Imhoff tanks , for sewage treatment, began to spread. The generated gas was used for the operation of the plants themselves, in municipal vehicles, and it was injected into the public gas network in some cities. The dissemination of bio-digesters in rural areas started during World War II in Europe, China and India, countries that would become leaders in the field later.

This relatively wide distribution was interrupted by the easy access to fossil fuels, and it was not until the energy crisis of the seventies when research and outreach was retaken with renewed energy, virtually worldwide, even in most American countries. The last 20 years have been fruitful regarding discoveries made on the functioning of microbiological and biochemical process, thanks to new laboratory technologies. This, in turn, facilitated the study of microorganisms interacting under anaerobic conditions

Progress in understanding microbiological process has been accompanied by major achievements of applied research, with major advances in technology. At present, some problems of a global nature, such as climate change coupled with the threat of declining energy reserves, make biogas a topic of interest again. Although the construction of biogas plants in Mexico is incipient, it is still growing. Most buildings are micro scale, and similar to those found in several locations in Asia, , with small reactors between 2 m^3 and 10 m^3.

5.3.1 Overview of biogas

Biogas is a product of biological degradation of organic substances in the absence of oxygen. This bacterial degradation process is known as anaerobic digestion (AD). Biogas contains between 50% and 70% methane, 20% to 45% carbon dioxide and trace gases. Its high content of methane makes it an excellent source of renewable energy, with the potential to replace natural gas and other fossil fuels. There are many different types of DA systems, used on farms (to treat manure and other agricultural waste), industry (for food waste, beverages or pulp and paper), in municipalities (for the treatment of municipal sludge and organic fraction Solid urban waste-RSU-), or in plants employing different combinations of substrates.

When the content of methane is higher than 45% of the mixture, it is considered flammable. It also presents various impurities such as carbon monoxide, saturated or halogenated carbohydrates and siloxanes, that are occasionally present in the mixture. Its general properties are shown in the following Chart:

Properties of Biogas

Parameter	Value
Composition	55-70% methane (CH_4)
	30-45% carbone dioxide (CO_2)
	Other gases
Energy content	6.0-6.5 kWh m^{-3}
Fuel equivalency	0.6-0.65 l oil m^{-3} of biogas
Explositon limits	6-12% biogas in the air
Ignition temperature	650-750 ºC (with the above-mentioned methane content)
Critical pressure	75-89 bar
Critical temperature	(-)82.5 ºC
Normal density	1.2 kg m^{-3}
Smell	Bad eggs (the smell of desulfurized biogas is hardly noticeable)
Molar mass	16.043 kg $kmol^{-1}$

Chart 5.6
Properties of biogas.

Source: IEA, 2007

The formation of methane is a natural biological process which occurs when organic matter (biomass) is decomposed in a humid environment, in the absence of air, but in the presence of a group of natural microorganisms metabolically active (that is, methane bacteria). In nature, methane can be found in swamps, where it is known as swamp gas, in the digestive tract of ruminants, in plants for wet compost , and in flooded rice fields. Suitable biomass to be fermented is called “substrate”.

In general, all kinds of biomass can be used as substrates, as long as they contain carbohydrates, proteins, fats, cellulose and hemi-cellulose as main components. There are other elements which voluntarily or involuntarily accompany substrates, and, in some cases, improve or impair the process of biogas generation.

5.3.2 Biogas energy utilization technologies

Biogas can be created from the DA process with technologies that exist today. DA is essentially a microbial fermentation in the absence of oxygen, which results in a mixture of gases (mainly methane and carbon dioxide), biogas and a slurry or “sludge” containing components that are difficult to degrade minerals found in biomass. The raw material used, preferably, to be subjected to this treatment is residual biomass, with high moisture content, especially livestock waste and urban sewage sludge.

The first stage of DA is called hydrolysis or liquefaction. Hydrolytic and fermentative bacteria break down carbohydrates, proteins and fats contained in the biomass feedstock. These substances are split into fatty acids, alcohol, C02, hydrogen, ammonia and sulfides. In the next step, the acidogenic, decomposing bacteria continue hydrolysis products and convert them into acetic acid, hydrogen and C02. In the final stage, these products are converted into biogas by methanogenic bacteria.

This is the most promising method for treating the organic fraction of municipal solid waste and other organic waste. Anaerobic bacteria convert biomass into biogas and landfill gas, which can be used to generate energy. However, if left on its own, most biogas would escape and mix with the other greenhouse gases in the atmosphere. So instead of being released into the atmosphere, biogas can be used constructively for the benefit of society. Traditionally, this type of waste has been considered as a nuisance, associated with low value, but biogas technology can convert organic waste into a profitable source of renewable energy.

By DA process, biogas can be produced from various types of waste, including sewage, animal manure and litter. Sewage water comes from the water used for some purpose, as an industrial process, and is not suitable for consumption. Wastewater must be treated to remove pathogens that could threaten human or animal health. They are often accompanied by the solid waste material, which increases the overall volume of waste. This is evident in the case of municipal wastewater, containing a high volume of solid organic biomass. DA may reduce the volume of these solids, while eliminating harmful pathogens. There are over 30 industries producing adequate sewage treatment water using DA. This includes beverage processing plants, chemicals, food, meat, milk, pulp and paper, and pharmaceutical products.

Animal waste (manure) is an excellent source of biogas. When manure is anaerobically digested, it produces biogas. In fact, this is the most common technology used in DA. In addition, you also get biogas fertilizer from manure.

Also, garbage transported to a dump produces biogas when the organic material begins to deteriorate through the DA process. Industrial and municipal solid wastes contain cellulose, one of the raw materials used in various manufactured products, such as paper, rayon and cellophane. Cellulose is decomposed in this process, and produces landfill gas. This DA process is uncontrolled, unlike the control process used to digest animal manure in digesters.

Different types of anaerobic digesters can be used to produce biogas. These include covered lagoon digesters, complete mix and capping flow, among others. Digesters that use multiple stages, multiple tanks, fixed film or induced "blanket", are successful in the digestion of organic waste. Each of these technologies revolves around the use of a deposit-tight digester which may cause the waste material to digest in the absence of oxygen. The digester temperature should be at least 68° F to facilitate bacterial activity.

Covered lagoon digesters are ideal for liquid manure digestion containing at least 3% solids. They are often used on dairy or pig farms, and are installed primarily to reduce odor. Complete mix digesters are suitable for large volumes of manure, with between 3% and 10% solid concentration, and are typically used in industrial environments. Although they are more flexible to work with a wide range of solids, the construction and operation of this technology is more expensive and requires more maintenance, compared with complete mix or plugged flow ones. The latter are ideal for processing ruminant manure with a high concentration of solids (between 11% and

14%). Although its construction cost is lower than complete mix digesters, its efficiency is lower.

While anaerobic digestion is the main way to generate biogas for use, there are other ways that can be used. One is the use of biogas in municipal dumps (landfills), where it must be removed (AD occurs naturally in certain conditions) to avoid any environmental impact. If the extraction volume is sufficient, it can serve as a source of electrical energy or heat. The practical application begins with the capture and transport of biogas to the treatment plant, which is carried out through a network of perforations, holes or trenches that covers the surface of the landfill. These perforations are responsible for capturing the gas, and later, through a network of pipes, sending it to a general collector for treatment.

There are many models to estimate the extraction of biogas from landfills, including the Mexico LFG Model, developed by SCS Engineers under a contract with the program Landfill Methane Outreach Program (LMOP), the Environmental Protection Agency (EPA) of the United States. This is another alternative for the use of biogas and was launched at least in two large-scale projects in Mexico, in Salinas Victoria dump, and in the outskirts of Monterrey, Nuevo León.

5.3.3 Current and potential use

Biogas can have the same uses as natural gas. Practically you can adjust all gas appliances (natural or LP) to the calorific value of biogas. This could be used for heating water and steam boilers, for combined heat and power (CHP) and micro-turbines or hot fuel cells (solid oxide fuel cells, or molten carbonate fuel cells). After a conversion and storage process , biogas is also used as a vehicle fuel. However, most applications require some type of cleaning improvement. This is to reduce the amount of water vapor and removing sulfides.

Methane, in its purest form, has a calorific value of 9,100 kcal/m^3, at a temperature of 15.5 C and at atmospheric pressure. The calorific value of biogas varies between 4.800 and 6.900 kcal/m^3. In terms of energy equivalence, between 1.33 and 1.87 m^3 equals one liter of gasoline, and between 1.5 m^3 and 2.1 m^3 equals one liter of diesel. Biogas has, approximately, a specific gravity of 0.86 and a flame speed factor of 11.1 (low), which causes the flame to get “off” the point of combustion, and in poorly designed burners

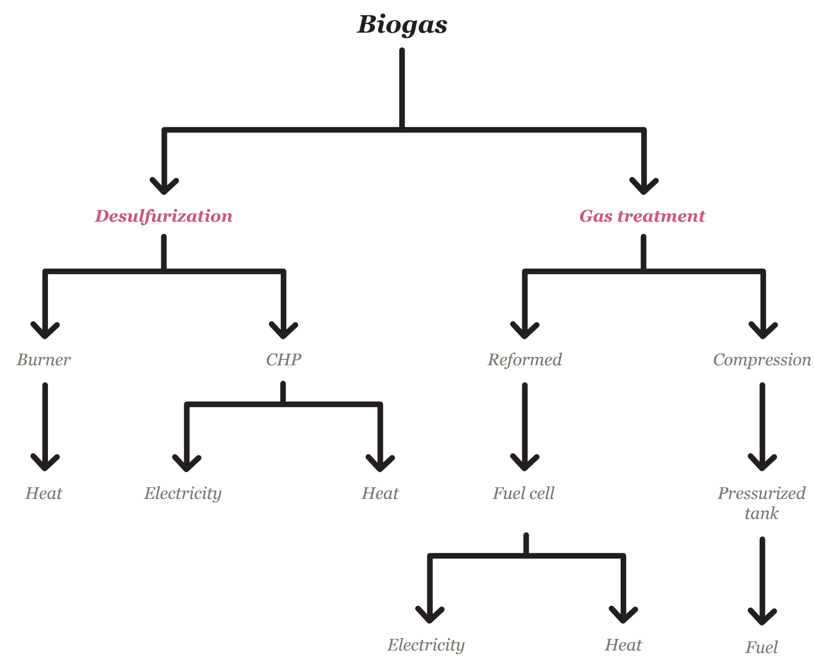

Figure 5.3
Main uses of Biogas.

Source: Own elaboration.

it may become unstable if the distance to the burner is considerable (ESCAR 1980). The energy content of biogas derived from DA processes have, on average, between 20 and 25 MJ per m^3, while for every ton of municipal solid waste between 167 and 373 MJ can be drawn through the recovered methane. Generally, there are between 100 m^3 and 200 m^3 of total gas for each ton of total municipal solid waste digested (RISE-AT, 1998).

There is a significant difference among stationary and fuel gas applications, i.e. the gas is distributed through the grid. Gas burners (boilers), however, have minimum requirements regarding the quality or purity of the gas. Gas pressure must be between 8 mbar and 25 mbar for normal use. It is recommended that H2S concentrations be always below 500 ppm.

It is estimated that there are about two thousand five hundred waste concentration sites, from which, about 120 are controlled landfills and sites. 53% of the 84 thousand 200 tons generated per day in Mexico are deposited at 51 sites, according to SEDESOL information. During 1994-2004 period, the generation of waste in the country rose almost 17%, from 29.5 million tons per year in average to 34.6 million, in 2004. According to a 2003 study by SEISA, it is estimated that a total of 88 MW from municipal solid waste could be obtained in Mexico in places like Tijuana (5 MW), Juarez (4 MW), Torreon (2 MW), Aguascalientes (2 MW), Querétaro (3 MW), Puebla (3 MW), Leon (8 MW), Guadalajara (9 MW), Culiacan (2 MW) and the metropolitan area of Mexico City (45 MW). This amounts to 95.4 MW generated from municipal solid waste, considering the plant already operating in Monterrey. According to data from the Institute of Mexico's Electrical Research (IIE), if all the generated waste was deposited in confined municipal landfills, it could reach a national capacity of 400 MW.

By the end of 2006, the IIE estimated that the total potential of biogas extracted from solid municipal waste was 165 MW. As for the biogas generated from DA in the livestock sector, IIE gave the following values: potential biogas from dairy cattle, 138 MW; beef cattle, 123 MW, and pigs, 223 MW. This makes a total of 484 MW for the livestock sector. These numbers do not include solid waste incineration (2,415 MW) nor the potential energy that could be extracted from the forest sector through the gasification process (12.528 MW). In summary, it can easily reach a total of 649 MW across the country from biogas technologies. This would represent approximately 1.3% of the national installed capacity.

5.3.4 Impacts resulting from the use of biogas

As natural, commercial, and industrial waste, and those resulting from domestic processes arising from residential and industrial activity are constantly produced, there will always be a source of renewable energy in the form of biogas. From an energy standpoint, this acts as a source of fuel for power generation and is significantly cleaner than coal. DA is a "process of net energy production." Excess energy produced by biogas can be sold to local utilities or industrial customers. Biogas production also helps farmers to reduce energy costs. All electricity generated by biogas can offset payment for traditional electricity providers.

Although biogas, particularly methane, is a greenhouse gas with a high potential to contribute to global warming, this can be recovered and used to benefit the environment. The DA process allows building waste disposal facilities to mitigate the odor of waste for the recovery of nutrients and, in turn, to convert the biogas in a fuel to generate electricity and heat.

Some environmental benefits arising from the production and the use of biogas are renewable energy generation from biomass, the reduction of

CH4 generated by the decomposition of manure, gas substitution or diesel when used as fuel for vehicles and producing an effluent that can be used as bio-fertilizer.

Chart 5.7 summarizes the benefits associated with the generation and use of biogas. This resource and its technologies are a viable and sustainable power generation in Mexico today. The path to be followed was drawn up by countries that have used this technology for years and have launched, successfully, mechanisms, laws and incentives for their development and growth. This renewable energy source can achieve, a total of 649 MW in the short term by taking advantage of existing resources.

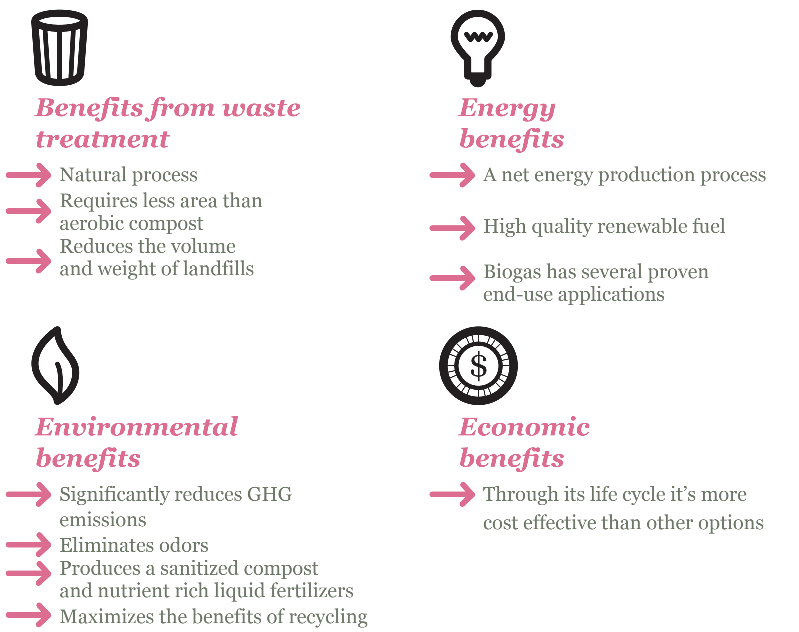

Chart 5.7 Benefits associated with the generation and use of biogas

Source: Own elaboration.

5.4 Conclusions

To increase generation by means of this technology, it is necessary to have a legal and institutional framework that integrates, in an agile and well supported way, the various organizations involved. Currently, the delay in administrative proceedings is one factor that works against such projects. To illustrate this point, it is worth examining the project in Salinas Victoria, Nuevo Leon, where the construction took just under eight months, while negotiations and paperwork spread across just over four years. With these conditions, few projects will be able to survive a widespread development time.

It is essential to promote litter control to avoid generating toxic waste and thus, benefit technologies as biogas. Good control, classification and separation of waste, both solid and liquid, industrial or residential, will translate into increased opportunities for generation. Moreover, it is important to acquire the skills relating to this technology and start investing in research and development. By now, large scale biogas projects in our country depend on foreign consultants, who, in many cases, limit the scope and are very costly. In this regard, having the knowledge and techniques in the country will quantify, design and build a more efficient way to exploit this resource at a lower cost.

Recent initiatives in Mexico, as well as recent changes in legislation on renewable energy, are a first step, but there is a long way to go to keep up with the more developed countries.

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6.
Bioenergy, part II: liquid biofuels

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6.1 Introduction

Liquid biofuels, although to a lesser degree than solid biomass, are one of the most important sources of energy, mainly due to their use in transportation systems worldwide and their oxygenating properties. Although dozens of countries have adopted the use of biofuels in their transport systems, there are really only two major global players: the United States and Brazil. Chart 6.1 shows that these two countries produce significantly more than the rest of the world put together. This is due to aggressive promotion policies and biofuel subsidies (in the case of the U.S.) and the early commitment to the use of this input for several decades (in the case of Brazil).

Biofuel regional production, 2008.

	Country	Fuel Ethanol (billion liters)	Biodiesel (billion liters)
1	United States	34	2
2	Brazil	27	1.2
3	France	1.2	1.6
4	Germany	0.5	2.2
5	China	1.9	0.1
6	Argentina		1.2
7	Canada	0.9	0.1
8	Spain	0.4	0.3
9	Thailand	0.3	0.4
10	Colombia	0.3	0.2
11	Italy	0.13	0.3
12	India	0.3	0.02
13	Sweden	0.14	0.1
14	Poland	0.12	0.1
15	United Kingdom		0.2
	EU Total	2.8	8
	World Total	67	12

Chart 6.1
Biofuel regional production, 2008.

Source: REN21, 2009.
Note: The values for ethanol produced correspond to the quantity of liquid fuel that is used in transportation.

According to the latest report issued by REN21, applicable policies to new biofuels, tax exemptions and adoption goals received a major boost in the period 2006-2007. However, they did not receive the same impulse in 2008, although it was a transcendent year in terms of sustainability provisions adopted by the European Union (EU) as part of their energy goals associated with transport. All EU countries have a goal regarding the proportion of biofuels to be used, which is around 5.75% of the energy supply. Other countries that have recently adopted new targets for biofuels are Australia (350 million liters in 2010), Indonesia (5% of supply by 2015) and Japan (500 million liters in 2012).

The need to expand energy sources to offset the fall in accessible and affordable oil reserves, and to contribute to the energy security of the country, led to the use and exploitation of various liquid fuels like ethanol and biodiesel.

Most of the documents for decision making relate specifically to Brazil and the United States. For several decades, these countries began to produce ethanol from various inputs such as sugar cane and corn, respectively, and used it as biofuel in combination with gasoline. However, the implications of the production and consumption of ethanol are different, depending on the geographical and cultural conditions of each country, among other factors. For this reason, it is necessary to be certain of the energy balance and the environmental, economic and social implications the use of ethanol and biodiesel would have in Mexico.

This chapter presents a summary and analysis of the main results of a multidisciplinary study sponsored by SENER, the Inter-American Development Bank and the German Cooperation Agency. Also considered is a study sponsored by the Autonomous Technological Institute of Mexico (ITAM) and a summary of official citations and publications including interviews and studies by researchers in various countries addressing the life cycle of biofuels in Mexico.

6.2 Overview of ethanol and biodiesel

Ethanol is a compound obtained from the fermentation of organic material, particularly of crops. This section presents some aspects related to five crops, classified as first-generation biofuels precursors: sugarcane, maize, sorghum, cassava and sugar beet. Among other features, the product of these crops can be used for the production of food or fuel. The opposite is the precursor of the second generation (eg lignocellulosic residues), used exclusively as fuels and discussed in a later section.

Ethanol production processes are derived from two sources. Most of the ethanol produced in the world is obtained from biological material processing, this type of fuel is also known as bioethanol. The other source of ethanol production is based on ethylene chemical modification through a hydration process.

Ethanol can be produced from various kinds of plants and agricultural products used as precursors. According to their obtaining source, its production involves basically the separation process of sugars, fermentation and distillation. Chart 6.1 lists some of these precursors.

Overall, ethanol production process involves crushing the precursor (sugar, amylase or cellulose), and thus increases the total contact surface area of amylase enzymes that convert cellulose or a sugar into a fermentable solution. This solution is often the result of a process of saccharification, wherein the sugars are converted into simple sugars. Subsequently, a fermentation

Precursors used in biofuels production

Ethanol precursor	Precursor examples
Sugar	• *Saccharides sucrose crops: sugar cane, sweet sorghum, sugar beet* • *Invert sugars and glucose: molasses and other agro-industrial residues as lactose*
Starch	• *Cereal grains: corn, sorghum, wheat, barley* • *Processed products: wheat flour, corn husk* • *Starchy roots: cassava, potato, potato, artichoke*
Cellulose	• *Lignocellulosic waste: sawdust, straw, residups forested, agricultural residues* • *Industrial urban waste: paper, cellulose fractions*

Chart 6.2
Precursors used in biofuels production

Source: Own elaboration.

process takes place, in which sugars are converted into ethanol and other products such as water, carbon dioxide or dry distillers grains. Finally, the fermented solution is integrated into a distillation process which seeks to separate the fermentation byproducts and obtain ethanol with an appropriate purity level for its end use.

Meanwhile, biodiesel can be produced from a variety of oil crops, animal fats and recycled oils and fats. To date, rapeseed, soybeans, jatropha, sunflower and safflower have been studied to be used as inputs for this fuel. The use of animal fat and recycled oil for biodiesel production has also been considered in plants dedicated exclusively to the fuel, or as annexes to existing plants for edible oil extraction.

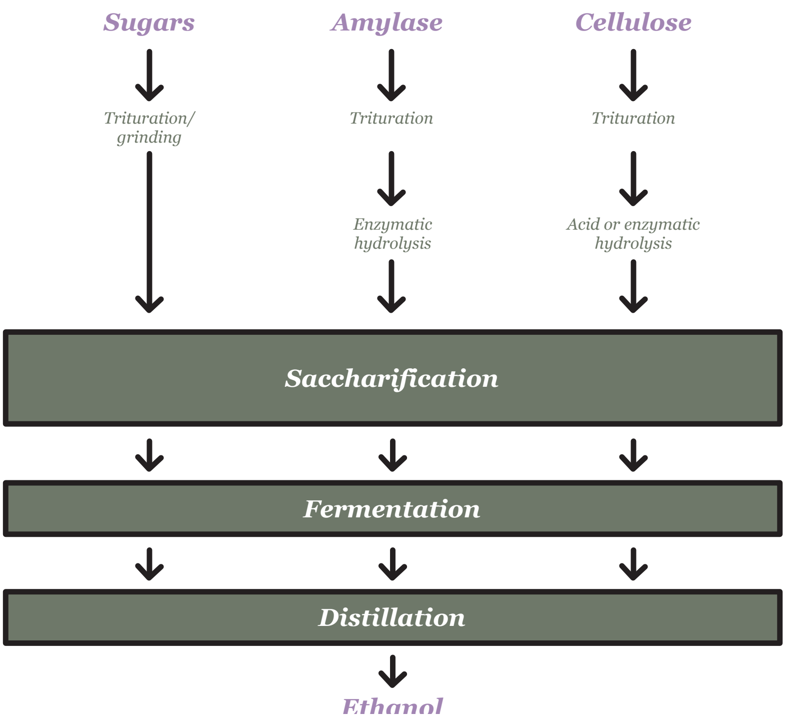

Figure 6.1
Synthesis of the processes and technologies used in ethanol production from different precursor inputs.

Source: Own elaboration.

For ethanol production in Mexico five crops have been extensively used : sugar cane, maize, sorghum, cassava and sugar beet (SENER-BID-GTZ, 2006). There are already mature technologies available for the use of cane and corn, while those related to the use of other crops are still in an early stage of development. Economic, environmental and energy yield in this process varies depending on the type of precursor and the specific process of ethanol production. The following sections provide an overview of these implications and in particular, they are illustrated by a specific and applicable example in Mexico: the use of ethanol from corn.

6.3 Socioeconomic impact

Biofuels represent an important opportunity for the development of rural communities, increasing the wealth generated in the country to reduce dependence on oil resources and stimulate scientific and technological development in Mexico, among other benefits. In that sense, the opportunity to have an additional market for the use of agricultural products is important because it promotes sustainability in rural communities through a new value chain, in which the crop product would find a more attractive alternative, economically speaking, than traditional food sales. However, this can also have side effects.

These statements coincide with some of the results of the feasibility study of biofuels (SENER-BID-GTZ, 2006) indicating that Mexico would benefit from the introduction of ethanol as fuel. These benefits include job creation, development of the rural economy, the expansion of social infrastructure in rural areas, increased energy security, the expansion of agriculture into drier lands where resistant crops are harvested, for example, multiple annual crops, such as sweet sorghum-, stimuli to the scientific and technological community, and incentives for production goods industry.

For some inputs, expectations are higher. From the technological point of view and availability of precursors, it is observed that the projects for manufacturing ethanol and combined heat and power-in the case of bagasse-could have a nationalization index of nearly 100 % in Mexico, which would create good jobs and strengthen the industry.

Furthermore, the reduction in imports of gasoline and MTBE, in a scenario where all gasoline in Mexico were mixtures of 10% ethanol-would represent savings in the balance of payments of up to $ 2,000 million USD (SENER-BID-GTZ, 2006).

6.3.1 Impact of ethanol on land use and water

Increasing resource consumption for ethanol production requires a larger agricultural area to meet the demand of both food and biofuels. It is believed that by 2050, the land exclusively dedicated to meeting the need for food will grow 18% (Sexton, 2007), and that there will also be an increase in the demand for land required for growing biofuel inputs.

The latter can also be seen in a 2008 study, which estimated that the potential area for growing corn was about 4.5 million hectares (SEMARNAT, INE, UNAM, CEJCO, 2008). To reach this figure, direct or indirect conversion is needed. Direct conversion occurs as part of the specific supply chain in a biofuel production. Indirect conversion occurs when market forces influence the conversion of the lands that are not part of the supply chain of some biofuel (Hyungtae et al., 2008).

This conversion of land results in an alteration of carbon sequestration in the soil and in biomass surface. A recent study concluded that, to change the use of land through deforestation or conversion of grasslands, from 17 to 420 times more greenhouse gases (GHG) are emitted than those not emitted if the use of fossil fuels were suspended (Rajagopal and Zilberman, 2008). Furthermore, the increase in cropland would imply a loss of biodiversity, destruction of natural habitat of various species and gradual extinction. This loss of biodiversity will affect, in the long term, water cleaning, restoring soil nutrients and carbon sequestration.

The growth in ethanol production also involves the increased use of fertilizers, herbicides, pesticides and water. It is known that intensive biofuels use water intensively, particularly during the precursors cultivation and in the bio-refining process (The National Academy of Sciences, 2007). The amount of water will be affected by this productivity growth so to meet the water demand of irrigation systems used for energy extraction, desalination and transport. With increasing demand, energy prices will increase and this will make the price of water go up. In addition, water for energy crops will compete directly with drinking water, causing great pressure on water resources that will have a negative impact on the conservation of these resources (McCormick, 2007). Water quality will also decrease due to the use of fertilizers, which contain large amounts of nitrogen and phosphorus, herbicides, pesticides and eroded land, as they may seep into underground reservoirs. Another element to consider is the use of technically advanced irrigation systems, which will have a direct impact on water supply, soil erosion, salinization and potential water pollution in the subsoil.

6.3.2 Impact of ethanol in the Mexican food industry

Food and energy sectors have been independent throughout history, but today are closely related because of the use of certain crops to produce ethanol. This could lead to a destabilization of food prices, as it would be transmitting the volatility of the energy sector to the food industry.

Between 2006 and 2007, the price of food increased worldwide, and in Mexico this was reflected in the price of tortillas increase. Since then, there has been an increase in the international price of corn of up to 60%. It is believed that this result is basically the actual use as a biofuel maize (Brown 2008). According to neoclassical economic theory, there is an increase in prices of both corn and foods made from it, because it creates additional demand, as corn is a *commodity*.

However, the increase in food prices is not only due to the use of crops to produce biofuels. It is estimated that biofuels are responsible for 10% to 15% of the increase in prices (Zilberman and Wiebe, 2008), while economic models consider that ethanol is responsible for 15% to 20% of this increase (Perrin, 2008).

Population growth, per capita income rising, dollar depreciation, speculation and some weather conditions, such as droughts and floods, are contributing factors to the increase in grain prices. At the same time this increase, spread to the prices of fuel and other inputs, influences the price of food. Population growth and per capita income increase are factors that trigger a change in the power of the people, as there is a greater demand for meat. Thus, the agricultural sector requires a greater amount of grains and seeds to feed livestock and to meet the demand for food.

Some climatic phenomena dwindle grain production to be used as food. By reducing the global supply of grains and seeds and increasing demand due to population growth, prices soar. This creates a great concern and speculation on grain availability in the next crop year, so some importers decide to make their purchases in advance to ensure food production.

In recent years, energy prices have risen dramatically, as they are an important input in the production and distribution process of both, food and grains. This, invariably, is resented by the final consumer. For this reason, it is critical to have some food security in the country to use corn and other precursors and produce ethanol. Achieving this security requires an analysis of the availability, accessibility, stability and food utilization.

6.4 Environmental Impact

Besides their impact on land use and water consumption, biofuels are part of an intense discussion regarding energy balance, as well as the amount and type of emissions generated throughout its life cycle. For example, some studies point to the ambivalence of ethanol in terms of their energy and environmental effects. The results depend, to a large extent, on the geographic area being analyzed.

It is believed that, under certain conditions, producing one ton of ethanol requires a greater amount of energy than that available during consumption. To illustrate this, some results of a life cycle analysis are included, to achieve a better understanding of the effects of ethanol at each stage of its life cycle, from grain sowing to its final combustion, including processing of grain into fuel, transport and distribution.

6.4.1 Life Cycle Analysis. System Definition

The life cycle analysis of ethanol (LCA, for its acronym in English) allows calculating emissions and energy requirements associated with a system divided into three main stages: (i) maize production, (ii) production of ethanol, (iii) consumption of ethanol (Figure 6.2).

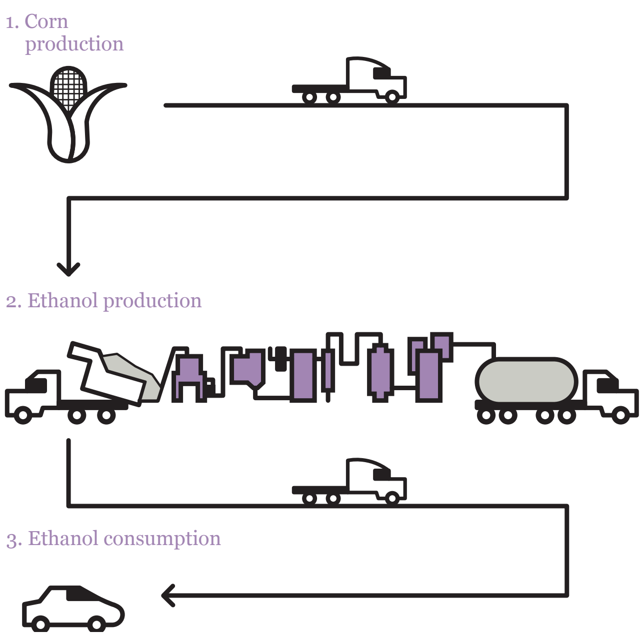

Figure 6.2
Ethanol life cycle.

Source: Own elaboration.

The detailed study is available and can be obtained in the Technology Development Centre of ITAM. The methodology used in this project was based on the international standards family ISO 14040, designed for the development of life cycle assessments. The study includes an estimate of the energy requirements and emissions from ethanol by mass and energy balances, information analysis, interviews and a program called Greet. The latter contains information about all the stages through which ethanol goes through, and information about the processes that necessary inputs undergo at every stage of their life. Through this software, necessary information entries were modified in accordance with the conditions in Mexico, particularly in the corn production stage and transport activities.

Step 1 of 3: corn production

Corn sowing, ethanol production and fuel consumption were carried out in the state of Sinaloa, and in general, in the Mexican Pacific. Meanwhile, the inputs used in the production process were maize, fertilizers and herbicides. The types of fertilizers and herbicides and the quantities in which they were used, were defined according to SAGARPA recommendations for the state of Sinaloa. Regarding transport, it was assumed that imported fertilizers, herbicides and insecticides arrive at the Port of Manzanillo on a ship, and then they are transported to their destination in a smaller boat or through gas pipes.

During the inventory of corn production emissions, it was found that the processes with the most significant emissions are corn planting and nitrogen fertilizer production. On the other hand, the amount of CO2 absorbed during maize planting was considered as a credit in the calculation of total emissions generated during corn production process. Thereby, the total CO2 emissions per mile traveled by a car that runs on a fuel composed by 85% ethanol and 15% gasoline (E85) were calculated.

Step 2 of 3: ethanol production

Ethanol is generated by breaking the large amount of starch present in the grain of corn (62.6%) into simple sugars (glucose). This, through the activity of yeast during the fermentation process, will enable the production of ethanol. Carbon dioxide and distiller grains are recovered as byproducts. The grains are used as cattle feed.

The process comprises the steps seen in Figure 6.3

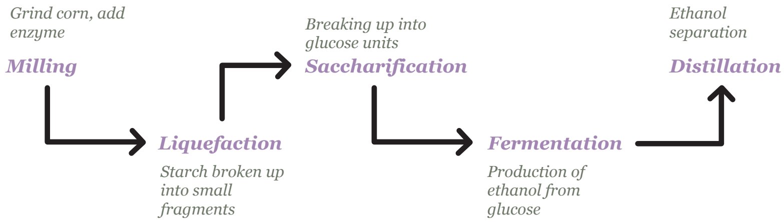

Figure 6.3
Ethanol production process.

Source: Own elaboration.

Various sources indicate that ethanol production process has a yield, per each transformed corn ton, of 400 liters of ethanol, 333 kg of distillers grains and 285 kg of carbon dioxide. For practical results of process performance, experiments were conducted at the Laboratory of Basic Sciences and Engineering of ITAM, where the ethanol production process that takes place in plants production, was replicated in smaller quantities and with simpler instruments. Transport conditions and transported distance were changed for energy estimation.

Stage 3 of 3: ethanol consumption

In order to estimate the energy requirement during the stage of ethanol consumption, the whole distribution process was considered, from the production plant to the bunkering center. Likewise, the emission calculation at this stage required considering those generated during the distribution of ethanol for fuel supply and during consumption as fuel for vehicles. Finally, adjusting the assumptions of ethanol consumption in Mexico involved modifying transport conditions and the corresponding distances to transport ethanol from the plant to the place of consumption

6.4.2 LCA: results

Overall energy requirement

Energy requirements in ethanol´s life can be observed, in aggregate, in Figure 6.4. The greater demand stage is the production of ethanol, which causes the total energy balance to be negative. This indicates that for every unit of electricity from ethanol as a fuel, 1.7 units of energy are required to produce it. This result is an indicator of the negative impact a project of this kind would have, in terms of energy. He also reflects the need to seek other alternatives in terms of production and consumption of ethanol that yield a positive balance for the greater benefit of society and the environment.

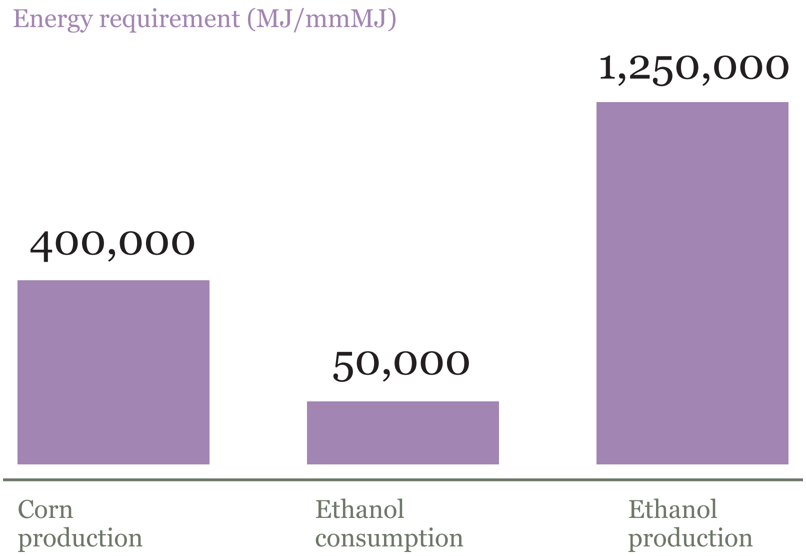

Figure 6.4
Energy requirements in ethanol lifecycle.

Source: Own elaboration.

Sensitivity analysis of energy requirement

In order to calculate energy requirements, it was necessary to have some input data, adapted to the current conditions of Mexico, except those involving internationally standardized processes. Additionally, a sensitivity analysis was carried out to verify the extent of the changes in energy requirements, taking into consideration that input data are not standardized in practice and that, therefore, may vary. Taking the data of this study, in addition to the maximum and the minimum value of each entry found in various sources, three scenarios were created: the pessimist, the optimist and the used. The three scenarios led to the same conclusion: the energy balance of corn ethanol is negative.

Global emissions inventory

To observe the total of each emission during the life cycle of ethanol, a global inventory of emissions was carried out, adding all grams emitted per compound, per kilometer, using E85 fuel. Emissions inventory includes carbon dioxide atmospheric emissions, carbon monoxide, methane, nitrogen oxides, sulfur oxides, volatile organic compounds, among others.

CO2 is the most important compound emitted during ethanol lifecycle, as a great quantity of this is generated at different stages. Figure 6.5 shows the distribution of total emissions in the three stages of the life cycle of ethanol. Although emissions for corn production were negative due to the absorption of CO2 during the corn plant growth, this is not sufficient to fully offset the emissions generated during the production and consumption of ethanol. This is even more remarkable in the consumption stage. However, the absorption of CO2 during production of maize is an advantage over other energy sources, such as gasoline, since corn absorbs much of the carbon and contributes to the reduction of GHG.

The amount of CO2 emissions is the most significant in ethanol lifecycle, as occurs in the gasoline lifecycle. Data about gasoline comes directly from the Department of Transportation of the United States. The results of the

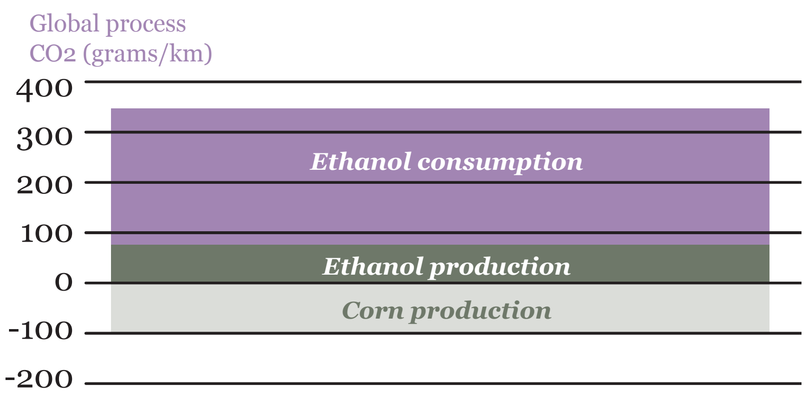

Figure 6.5
Source: Own elaboration.

comparison show that ethanol would provide a benefit compared with gasoline, in terms of the amount of CO2 emissions generated during their life cycle. Figure 6.6 shows the difference between the total emissions that both types of fuel produce. Thus, a potentially beneficial aspect of the use of ethanol as fuel was found, instead of gasoline. This analysis was also conducted with all GHG emissions precursors, assessed by the category of Global Warming Potential (GWR for its acronym in English). The results are similar, as aggregate emissions of ethanol and expressed in terms of GWR are, on average, 12% lower than those estimated for gasoline.

In another study commissioned by SENER, they include some preliminary estimates of greenhouse gases emissions, in a scenario in which 10%

CO2 (grams/km)

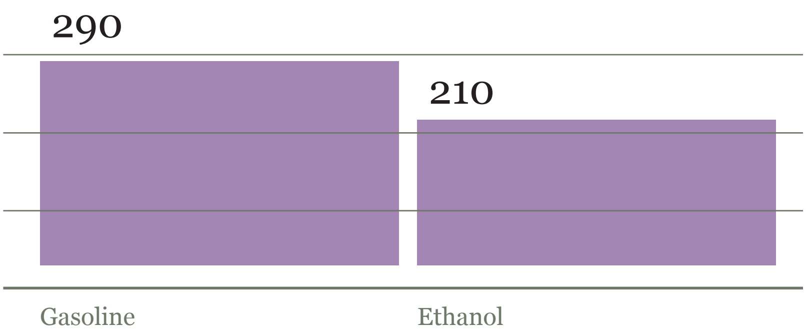

Figure 6.6
Comparison of CO2 emissions between ethanol and gasoline

Source: Own elaboration.

ethanol in the country´s gasoline is adopted. (SENER-BID-GTZ, 2006). A variety of precursors was used, and 2004 was considered as the reference year.

Percentage of change in greenhouse gas (GHG) emissions in a range of 1st and 2nd generation biofuels.

		GHG Emissions		**GHG emissions mitigation**
		kg CO2 eq./1 kg anhydrous ethanol		***10^6 tCO2 eq./year***
	Fossil energy ratio	*Ethanol production*	*Net emissions avoided (1)*	
Corn	1.3	1.8	1	3.9
Sugar cane (2)	10	0.43	2.72	10.6
White beets	2	1.4	1.4	5.4
Sweet sorghum	4	0.7	2.1	8.2
Wheat	2	1.8	1	3.9
Yucca (3)	1	—	~ 0	—

Chart 6.3
Expected effects of GEI emissions when adopting ethanol production from various precursors

Source: SENER-BID-GTZ, 2006.
(1) Considering gas emissions of 2.8 kg CO2 eq. / L gasoline, and equivalence (by volume) of the two fuels, using a mixture of 10% ethanol.
(2) Emissions avoided with ethanol and a surplus in the use of electricity from sugar cane
(3) Modern technologies and commercial use will improve the relationship in the use of fossil fuels to reach magnitudes similar to those of other systems.

Some studies indicate that one of the concerns associated with first-generation biofuels is that they provide limited benefits in reducing GHG (with the exception of ethanol produced from sugar cane) and a relatively high cost in terms of dollars per each CO2 ton avoided. Figure 6.7 summarizes the results of 60 other life cycle analysis for various precursors of first and second generation biofuels. The same figure illustrates the percentage change in total GHG emissions (excluding the change in land use) with respect to emissions from a system based on the consumption of petrol and mineral diesel. The bottom and top of each bar illustrates the minimum and maximum values that were derived from each study. This shows the need for continued research and development of other technologies and other precursors, in particular the so-called second-generation precursors.

Percentage of change in greenhouse gas (GHG) emissions in a range of 1st and 2nd generation biofuels

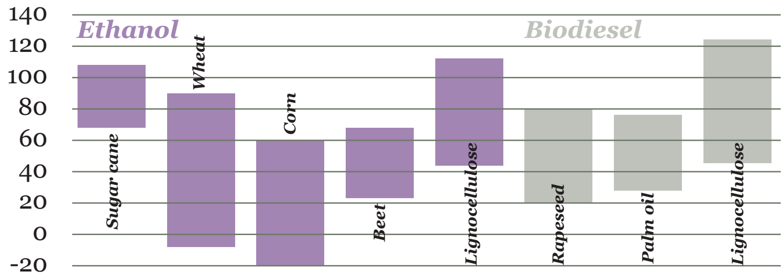

Figure 6.7
Change percentage in greenhouse gases emissions (GHG) in a range of 1st and 2nd generation biofuels.

Source: OCDE, 2008. Study based on an analysis of the IEA and the UNEO over a spectrum of sixty LCA.

6.5 Second generation biofuels

Although first-generation biofuels are used with ever greater frequency, the use of second-generation biofuels is also becoming more important and its future looks most promising. Second generation biofuels are those from cellulose such as wood, grasses, crop residues and algae. It is expected that this generation of biofuels is higher than the first, since they do not compete with food, energy balances are better, do not compete for land or water, do not increase the use of fertilizers and help decrease the emission of greenhouse gases into the atmosphere,- between 70% and 90% reduction, compared to fossil fuels (Science Council, 2008) -. In addition, they offer higher productivity per hectare, in terms of energy content per biofuel per year (IEA, 2008).

The production of ethanol from these materials has a global potential production of 491.1 GL / year (Petrou and Pappis, 2009). Some advantages of using corn stover are the decrease in the rate of global warming and the impact reduction on natural resources and on ozone. This is expected to expand the range of inputs to produce biofuels and improve their quality. It is estimated that they will be available for commercial use in 2015 (IEA, 2008).

However, it is also believed that the use of crop residues could have negative effects, as this is used to fertilize the fields, keep the texture and prevent soil erosion. Since waste as natural fertilizers would not be fully exploited, , a larger amount of chemical fertilizers would have to be used, which would significantly increase the proportion of both nitrogen and phosphorus in the soil and aquifers, and also cause environmental degradation . It is also thought that the use of this raw material would have a negative impact on GHG emissions due to the fact that fossil fuel is used during the distribution stage, specifically during collection and transport.

This biomass cellulose has a much greater tensile strength than that of first generation inputs, which makes it more difficult to break it to form liquid fuels. It requires more sophisticated technology which, in turn, implies greater investment. However, this property of lignocellulose also has certain advantages: easier handling, reduced management costs, storage and quality control required by other crops, and storage is less complicated.

In turn, second generation biofuels can be classified, according to their treatment, in biochemical and thermochemical conversion. Biochemical conversion biofuels are best known for their resemblance to first-generation biofuels. Biochemical conversion process involves pretreatment, saccharification, fermentation and distillation. The pretreatment step is carried out to separate the cellulose, hemicellulose and lignin and subsequently break the complex molecules of cellulose and hemicellulose into simple sugar molecules, through hydrolysis. In the case of lignin, it may be recovered and used as fuel to generate heat and electricity in the alcohol production plant (UNCTAD, 2008).

In turn, thermochemical conversion begins with gasification or pyrolysis. In gasification, biomass is converted into synthesis gas containing carbon monoxide and dioxide, hydrogen and methane, and then becomes bioethanol (GBER 2008). Biomass is heated by means of pyrolisis, in the absence of oxygen conditions, this process can be fast and an oil called bio-oil is obtained, which can be transported and stored immediately (GBEP, 2008). The latter technique requires more capital and is optimal for large-scale production, as its finished product is a clean fuel that can be used directly in engines (UNCTAD, 2008)..

Despite the substantial benefits second-generation biofuels have, they face a number of barriers that must be researched and overcome to achieve their full development (IEA, 2008):

- It is necessary to eliminate high costs of production and the reluctance of some producers to reinvest in new technology to displace first-generation fuels in order to prevent loss of the experience curve.
- It requires changes in logistics and the supply chain, as today, the process of cultivation, storage and transportation of biomass is unsuitable for production and distribution of large scale.
- It should get quality acceptance, both by industry and by consumers, and this is only possible if bioenergetics characteristics and performance are very similar to those of fossil fuels, which currently dominate the market. For this reason, it is necessary to develop new technologies to achieve the value, quality and security desired.
- It requires the removal of financial barriers in terms of risk and uncertainty. The government should be involved in this sector to reduce risk and demonstrate that second-generation biofuels can be commercially successful.
- Changes in forestry and agriculture must be made, to be able to supply the raw material needed to create bioenergy.

Mexico is a country with great opportunities in the production of second generation biofuels. This is because “geographical and climatic characteristics make it a suitable place for the cultivation of useful vegetal species for generating these fuels” as both algae and jatropha could be cutivated without any trouble (Excelsior, 2009). Jatropha is a shrub native to Mexico and Central America that grows in arid land and requires very little water for cultivation. When processed, you get an oil used to produce biodiesel. Recently, an agreement between Mexico and Colombia was reached for the cultivation and production of biofuel in Chiapas.

Meanwhile, algae are suitable for cultivations with a variety of conditions: on dry land, in salt water and contaminated aquifers. They can also grow in open ponds or photobioreactors. The former are more economical. However, they use a greater amount of soil and water than photobioreactors, and also require controlled climatic conditions. Instead, photobioreactors are much safer in health issues and their temperature can be controlled, even if it means that the cost of the technology required is much higher (Morrison, 2008). Microalgae production requires carbon dioxide, nitrous oxide and light (GBEP, 2008). One problem associated with the use of algae for energy production comes from its water content and that, to remove them, they should use energy-intensive methods, so this alternative is less attractive to investors in economic terms (Morrison , 2008).

In the case of ethanol production using algae, there is currently a project in the state of Sonora developed by BioFiels company, through which 100 million gallons of ethanol could be produced annually in the first plant, and then reach a billion gallons in 2012 (Excelsior, 2009). On the other hand, cob and corn husks, which are obtained as waste from those plants that produce food to produce biofuels from cellulose , could be used.

6.6 Legislative aspects

In February 2008 the Law on Promotion and Development of Bioenergy came into force. The Act seeks to contribute to energy diversification and to improve life in the countryside. It lays the groundwork for “promoting the production of inputs for bioenergy from agricultural activities, forestry, algae, biotechnological and enzymatic processes in the Mexican countryside, without compromising safety and country’s food sovereignty, develop production, marketing and efficient use of bioenergy to contribute to the revival of the rural sector, job creation and a better quality of life for the population, particularly the high and very high marginalized, seek reducing emissions to the atmosphere and greenhouse gases; coordinate actions among federal, state, municipal and Federal District, and the competition with the social and private sectors, for the development of Bioenergy “(Act Bioenergy Promotion and Development, 2008).

On the other hand, it set as a mandate the use of a maximum concentration of 10% bioethanol in gasoline blending for productive infrastructure. (SENER-BID-GTZ, 2006).

This Act also provides for the creation of the Commission on Biofuels, made up by the Secretary of Energy (SENER), the Ministry of Finance and Public Credit (SHCP), the Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA), the Secretariat of Environment and Natural Resources (SEMARNAT) and the Secretariat of Economy (SE). Its tasks are to develop programs for the production and marketing of inputs and the production, storage, transportation, distribution, marketing and efficient use of bioenergy. In short, it is responsible for coordinating the entire supply chain of biofuels. It also encourages investment in infrastructure and technology to streamline the supply chain (Act Bioenergy Promotion and Development, 2008).

Meanwhile, SENER established the Bioenergy Program Introduction, in which it is intended that, by 2012, bioenergy meet the requirements of national and international quality, contribute to sustainable development in the country and, through the application of high technology, help eliminate concerns over food security, biodiversity, pollution, water use and land conversion. It is expected to achieve this through the promotion of information, research, partnerships for the development of biofuels, generating certainty in the market that allows for increased investment and boosting implementation, capacity building and bioenergy production (SENER, 2006).

Furthermore, the Interministerial Commission for the Development of Biofuels Production created the Program for Sustainable Production of Biofuels Supplies and Scientific and Technological Development. Its main objectives are: "To encourage the production of inputs for Bioenergy, promoting scientific and technological development of potential crops, encouraging the use of integrated technology packages; assist producers in creating companies that produce inputs for bioenergy; promote coordination and ongoing cooperation with authorities, levels of government, political, economic, academic and social actors "(Interministerial Commission for the Development of Bioenergy, 2008).

These two programs ensure coordination, unity of effort and multisectoral resources to achieve sustainable production inputs needed to generate bioenergy. It also seeks to increase investments in research and development to improve the production process, so as to achieve the goals set by the Law for the Promotion and Development of Bioenergy.

In November 2008, the Law on the Use of Renewable Energy and Energy Transition Financing was published, which aims to encourage research, production and use of bioenergy, through "policies, programs, actions and projects to achieve greater use and development of renewable energy sources and clean technologies "(Bernal et al., 2008).

6.7 Other barriers and incentives

According to an economic analysis conducted in Mexico on the introduction of biodiesel from different precursors, it was found that, in all cases, the prices of biodiesel production are greater than the opportunity cost of diesel sold by PEMEX. However, it is important to note that the situation in Mexico is not very different from other countries, although it is more evident, given the low cost of diesel oil, which relies on special subsidies within the agricultural sector. Biodiesel production costs have a range of between $ 5.3 and $ 12.4 per equivalent liter. The most competitive crops are palm, sunflower and soy.

Biodiesel production from rapeseed and soy is a mature process worldwide. The biodiesel produced from jatropha is technically feasible, but they do not have much experience in its use internationally. Finally, palm biodiesel has the disadvantage of not allowing esters to satisfy the requirements of cold flow in temperate regions.

Jatropha is promising, but still the problem of possible toxins in the glycerin and other by-products that are generated in the process must be solved. Agricultural input costs represent between 59% and 91% of production costs of biodiesel. In many cases, such as soybean, these depend greatly on the ability to sell agricultural byproducts.

Some studies indicate that the major bottlenecks for the successful introduction of biodiesel in Mexico are in the agricultural sector. For this reason, there is a proposal to establish a comprehensive plan to support agriculture for domestic supply of inputs (SENER-BID-GTZ, 2006). The study notes that the following incentives should be offered in order to have a more dynamic rural economy:

- Support of small scale oil crops, which increase the added value of rural agriculture and contribute to biodiversity. A specific promotion plan should be started (for example, the Brazilian program of biodiesel).
- More knowledge on some oil crops such as jatropha. The knowledge resulting from these research activities will be transferred to the rural population through educational programs.
- The formation of specialized cooperatives will create synergies through joint use of machinery. Access to financing and technical assistance should be encouraged.
- Financing agencies such as FIRA, would be able to create special programs for biodiesel production at preferential interest rates.
- We must promote the integration of the production of oilseeds and seed pressing, oil refining and biodiesel production (as it is economically feasible) to retain added value in rural areas.

6.8 Conclusions

The development and implementation of first-generation biofuels, with strict sustainability criteria, represents a starting point for diversifying energy supply in the country and promoting regional development. As presented throughout this chapter, the decision on which crops to promote, where and how agronomic packages will be established and what kind of technology will be used in processing is crucial.

In the case of ethanol, there are several alternative technologies to improve the production of precursor crops and ethanol process: The construction of closed loop refineries, the promotion of alternative uses of sub-products generated during bioethanol production (including, for example electricity cogeneration in sugar refineries). Taking into account Mexico´s outlook and the current state of refineries, a significant investment, both public and private, and seed grants are required. The goal is that bioethanol is competitive and generates a positive impact on environment.

Potential impacts of biofuels are diverse. For example, the selection of the precursor seed to be used in the production of ethanol or biodiesel must take into account the level of agronomic knowledge, energy balance (expressing the relationship between demand and energy production for a given combination of raw material and conversion process), the availability of economic value by-products, environmental impacts (of agricultural and industrial production and global type, such as emissions of greenhouse gases) and competition with food production.

In a first analysis, and taking into account these criteria, cane stands out as the best option to promote ethanol production in Mexico in the short term, as it has much experience in the use of the crop. However, major changes are needed in policy issues and subsidies, more electric cogeneration possibilities and modernization of the mills used for this purpose.

We also consider that corn should not be promoted as a feedstock for ethanol production, as this is a staple Mexican food. In addition, Mexico is not self-sufficient in growing and has very low rates, or zero, substitution of fossil fuels or emissions of greenhouse gases.

In Mexico, a tender was published so that private companies can supply PEMEX Refining with the amount of 176 million liters of ethanol annually. The purchase price of ethanol is fixed at $ 8.20 per liter for five years, leaving on the product side the risk of an increase in inputs and precursor materials price. On the other hand, domestic corn use is prohibited, limiting inputs for the manufacture of ethanol, practically sugarcane. In addition, preference will be given to those companies with production facilities (Reform, 2009). Initially, these rules relate to some of the concerns raised throughout this chapter, so it will be important to follow up on this bid and verify that the biofuel program will actually continue to align itself with economic, social and environmental principles required for any sustainable project .

From 2008, there are also laws regulating the research and development of bioenergy, such as the Law for the Promotion and Development of Biofuels and the Law on the Use of Renewable Energy and Energy Transition Financing. Mexico is at the initial stage of the regulatory framework for this new industry and still has a long way to go in order to have a strong legal system upon which to rely and develop this industry.

Furthermore, second-generation biofuels are a better choice for Mexico, because they do not compete with food, their cultivation is at lower cost and both their energy and gas emissions balance is positive. Today it is known that second generation crops have a 50% higher efficiency on soil use than those of first generation, measured in terms of how far a transport unit can travel with that generated by one hectare of cultivation. Moreover, they are not intended exclusively for transport but can be used as fuel for cooking or small industry, especially in those rural areas where there are processing plants. This would prevent the increase in GHG emissions and transportation costs.

This type of biofuels is still in research and development stage, so its commercial availability could take a decade. If so, Mexico would be ready to participate actively in the market, as it has a wide variety of climates, supply of rural workforce and research centers of international prestige that could eventually develop technology in line with national conditions.

In synthesis, it requires a large technological system, innovative and informative, where each of the links that make the supply chain are interconnected and actively participate, to be able to fully integrate biofuels into the national consumption pattern (for example, by mixing them with fuels) and not simply produce inputs for export to other countries.

To achieve this, it is necessary that the fossil fuel market shares its well established distribution channels and mixing facilities with this new form of fuel, as biofuels are not perfect substitutes for gasoline in the immediate future, but simply represent a method of transition to cleaner fuels.

It is also necessary to involve other countries, either to initiate research projects jointly, to invest in opening plants producing ethanol and flexible fuel cars (flex-fuel) and to transfer technological advances and set standards or treaties governing the international use of bioenergy and international trade. In this sense, Mexico is on track, as it is already working with countries like the U.S. and Canada, sharing information between corresponding Bioenergy Commissions.

Increasing knowledge of second-generation biofuels would reduce the environmental impact and allow the formation of a more comprehensive regulatory framework for the entire supply chain. This would establish the conditions for investment in research and development, and the opening and regulation of bioenergy production plants.

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7. Elements for the promotion of wind power in Mexico[1]

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7.1 Introduction

[1]Chapter based on the documents Arturo Romero Paredes, Ana Delia Córdova, Rubén Guízar, Moisés Lino, Manuel Luengo and Mark Oven, 2009. Elementos para la promoción de la energía eólica en México. USAID. http://www.amdee.org/ LiteratureRetrieve.aspx?ID=44031 and Manuel Luengo and Mark Oven, 2009. Análisis comparativo del marco eléctrico legal y regulatorio de EE. UU. y México para la promoción de la energía eólica. USAID. http://www.amdee.org/ LiteratureRetrieve.aspx?ID=44032.

The worldwide capacity of wind power generation has doubled every 3.5 years since 1990. Currently, the wind industry captures 43% of investment in the electricity sector worldwide, growing at a rate of between 20% and 30% each year. Projections of the World Wind Energy Association (WWEA, for its acronym in English) show that installed capacity will reach 190.000 MW in 2010.

Incentives to encourage the creation of alternative power plants as public policy have proved, in many countries, the catalyst of growth in generating capacity from unconventional sources. With these stimuli as part of the energy policy in different countries, entrepreneurs are attracted to invest, thereby generating employment and sources of energy, promoting regional development, creating industries different from conventional industries and driving the existing industries, such as cement, electrical and heavy machinery, among others.

In recent years, Mexico has played an important role in the wind energy issue, being Oaxaca the protagonist. In this state there was no law to support or promote wind power, just some reliable data about its potential, and only a few companies had the ability to generate such energy. However, the state government had the political will to promote this industry, which represents a very important lesson for Mexico and the world.

Nationally, the sites that have a prominent wind potential are in the states of Baja California, Baja California Sur, Zacatecas, Tamaulipas, Campeche and Yucatan. However, it is known that much of the Mexican coast has exploitable wind resources. According to calculations by the Renewable Energy Laboratory USA (NREL, for its acronym in English), the Isthmus of Tehuantepec has a usable potential of up to 35,000 MW, although the Institute of Electrical Research (IER) has calculated, conservatively, a potential of 5,000 MW.

This chapter presents economic indicators that show that any area with plant factors above 30% is economically profitable. In Mexico there are sites that exceed that value, at least in states with more advanced projects. The network capacity and portage costs are still pending issues on the agendas of main stakeholders. Oaxaca´s Open Season Project is not enough, and most worrying is that few works of this kind are foreseen for the next few years.

Finally, while generation from wind resource has clear environmental benefits, the definition of the projects should consider the environmental impact. In the case of wind energy, the main concern is the effect of wind turbines on migratory birds. In this regard, in 2007, the National Council of Science and Technology (CONACYT) conducted a research program and, using radar manage to evaluate the passing of twelve million birds of 130 species each season at the Isthmus of Tehuantepec. The resulting information is intended to implement protection and mitigation measures based on international best practices.

7.2 Global overview of the wind industry

The wind industry in the world has made significant progress since the first wind farms were installed in the eighties, until those with the latest technology. This growth is due to the global energy situation and the strategic response from governments, businesses and communities. Technological development and success of these pioneering efforts led to a multiplier effect.

Many countries of Western Europe live under constant pressure because their domestic oil or coal supplies are not sufficient to meet the growing demand of their economies, especially in electricity generation. Also, the traditional problems with the main producers of the Middle East, from the time of the oil embargo, coupled with the increase in oil prices, forced countries like Germany, Spain, Denmark, Norway and the United Kingdom, among others, to use their natural resources to satisfy much of their energy needs.

Today, these nations have a significant installed power generation capacity based on alternative sources, thanks to reformed laws, granted tax incentives and government support, and to the implementation of favorable regulations, subsidies, norms and laws. Eventually they also became generators of increasingly efficient technologies coming in direct competition with fossil fuels, especially in a context of global concern for the environment. The phenomenon undoubtedly favored the emergence of markets for carbon credits under the agreements and obligations derived from the Kyoto Protocol.

7.2.1 Current Situation

In the past 10 years, worldwide installed capacity of wind power grew in a unprecedented manner, from 7.480 MW in 1997 to over 120,000 MW in 2008, as shown in Figure 7.1 (WWEA, 2009). The increase in added wind generation capacity, since the beginning of its industrial use until 2003, is similar to what occurred between that year and 2007.

The WWEA expects installed capacity to reach 190,000 MW in 2010, due to the accelerated development of this industry, especially in recent years.

Wind power: world installed capacity (GW)

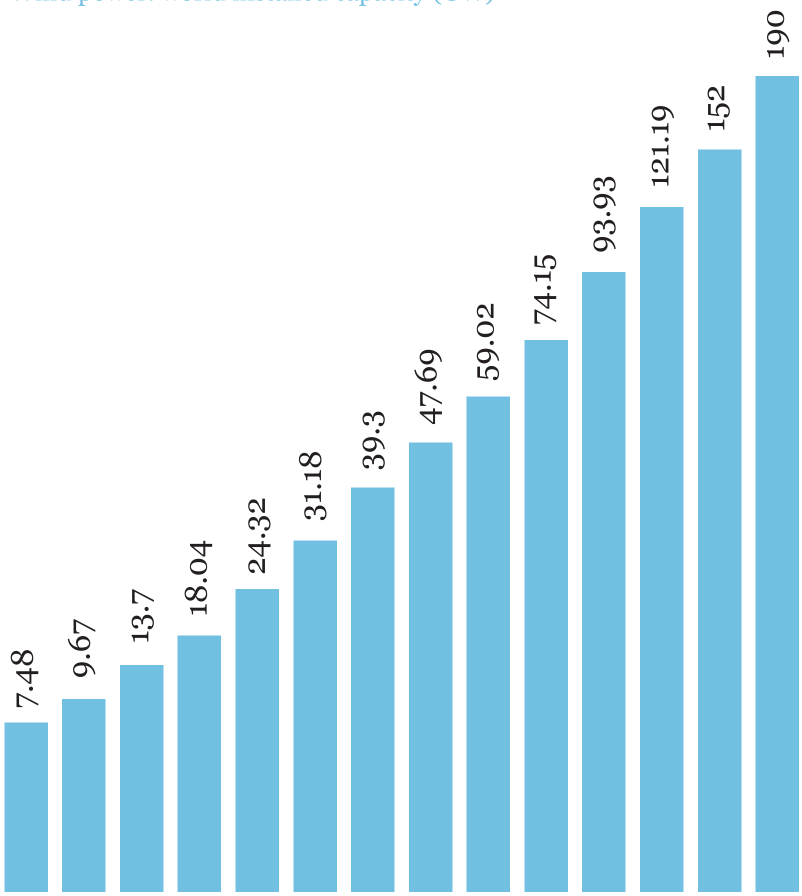

Figure 7.1
Wind power: world installed capacity (GW).

For example, China grew 106.5%, from 5,912 MW in 2007 to 12.210 MW by the end of 2008-using 2006 as a base year, with a growth of 127% -. Meanwhile, the United States grew by 49.7%, as in 2007 it had 16.819 installed MW, and by the end of 2008 it had increased to 25.170 MW, standing in first place in installed capacity (place that previously was held by Germany) -. On the other hand, Australia increased its national wind energy capacity by 82.8%, moving from 817 MW in 2007 to 1.494 MW in 2008, while India did the same growing 22%. Ireland, in turn, grew 54.6% in this period, Poland, 71%, and Belgium, 33.7%. Italy, France and the UK increased between 37% and 38%. Turkey did so by 61.2% (WWEA, 2009). Figure 7.1 presents the most outstanding growth in wind capacity generation in the period 2005-2008.

Rank (2008)	Country	Total Installed Capacity (2008)	Added Capacity (2008)	Increase rate (2008)	Total Installed Capacity (2007)	Total Installed Capacity (2006)	Total Installed Capacity (2005)
			MW	*%*	*MW*	*MW*	*MW*
1	United States	25,170.00	8,351.20	49.7	16,818.80	11,603.30	9,149.00
4	China	12,210.00	6,298.00	106.5	5,912.00	2,599.00	1,266.00
6	Italy	3,736.00	1,009.90	37	2,726.10	2,123.40	1,718.30
7	France	3,404.00	949	38.7	2,455.00	1,567.00	757.2
8	United Kingdom	3,287.90	898.9	37.6	2,389.00	1,962.90	1,353.00
10	Portugal	2,862.00	732	34.4	2,130.00	1,716.00	1,022.00
14	Australia	1,494.00	676.7	82.8	817.3	817.3	579
15	Ireland	1,244.70	439.7	54.6	805	746	495.2
19	Poland	472	196	71	276	153	73
22	Belgium	383.6	96.7	33.7	286.9	194.3	167.4
24	Brazil	338.5	91.5	37	247.1	236.9	28.6
25	Turkey	333.4	126.6	61.2	206.8	64.6	20.1
27	South Korea	278	85.9	44.7	192.1	176.3	119.1
28	Bulgaria	157.5	100.6	176.7	56.9	36	14
31	Hungary	127	62	95.4	65	60.9	17.5
36	Estonia	78.3	19.7	33.6	58.6	33	33
43	South Africa	21.8	5.2	31.4	16.6	16.6	16.6
46	Uruguay	20.5	19.9	3308.3	0.6	0.2	0.2
60	Cuba	7.2	5.1	242.9	2.42.9	0.5	0.5
61	Ecuador	4	0.9	30.7	3.1	0	0
	76 registered countries						
	World Total	**121,187.90**	**27,261**	**29**	**93,926.80**	**74,150.80**	**59,024.10**

Chart 7.1
Installed wind generation growth in target countries 2005-2008.

Source: Own elaboration based on WWEA, 2009 data.

It can be clearly seen that all the studied countries (of the 76 registered) grew at a faster rate than the total world average, which was 29% between 2007 and 2008. Probably what has motivated them to develop their installed wind capacity is the interest in experimenting with other electricity generation technologies. Moreover, these countries have vast experience in this type of systems after 20 years of operation, since the first wind energy generation parks were built, when the capacity of the air turbines were only 50 kW, mounted on towers no more than 25 meters high, and with rotor diameters of 14 meters, to reach the impressive turboprop manufactured by Enercon, with a capacity of 4.5 MW, rotor diameters near 120 meters mounted on towers of 124 meters.

7.2.2 Overview of the wind industry in Mexico

In the eighties, when renewable energy began to develop in Mexico, the conditions in the states of Oaxaca and Hidalgo were studied, with the available tools. The share of external funding, as well as the collaboration among countries, allowed for the application of systematic measurements with more reliable methodology. Subsequently, technology allowed for approximations with data from airports, boats, weather station images overlaid on aerial photograph maps, and later, with satellite data. The technology for wind measurement has evolved and Mexico continues to benefit from interest in its wind current sites.

Currently, the country has anemometric information through the work of the Federal Electricity Commission (CFE), the Institute of Electrical Research (IIE) (Chart 7.2), and the work performed at the National Renewable Energy Laboratory in the United States of America (NREL, for its acronym in English) (Jaramillo, 2008).

State	Sites with measurement
Baja California	Laguneros and Vizcaíno (CFE)
Baja California Sur	Región Pacífico Norte, San Bartolo, Rancho Mar Azul and Bahía Magdalena (IIE+SNL), San Carlos e Isla Margarita (CFE)
Campeche	Isla del Carmen (IIE)
Coahuila	Valle del Hundido and Valle de Acatitla (IIE)
Estado de México	Valle de México (IIE)
Hidalgo	El Gavillero y Pachuca (IIE)
Oaxaca	La Ventosa (CFE, IIE)
Quintana Roo	Puerto Juárez, Cancún, Cozumel, Puerto Morelos, Chemuyil, Cobá and Xcalak (IIE + SNL)
Veracruz	Laguna Verde (IIE, CFE), Lerdo and Acayucan (CFE)
Zacatecas	Cerro de la Virgen (IIE)

Chart 7.2
Places in Mexico where anemometric measurement has taken place.

Source: Jaramillo, 2008.

Wind potential sites in Mexico

The estimated potential resource varies according to the source. NREL estimates that only in the Isthmus of Tehuantepec there is a usable capacity potential close to 35,000 MW, while the IIE, with a more moderate view, says the capacity in this area is 5,000 MW. Meanwhile, the Energy Research Center of the National Autonomous University of Mexico (UNAM ICD) states that the potential is 2,000 MW (Jaramillo, 2008), while the Energy Regulatory Commission (CRE) suggests that the potential in that region is over 10,000 MW (Barnes de Castro, 2006).

Sites that have an outstanding wind resource potential are the following: The Rumorosa in Baja California, the Guerrero Negro´s area in Baja California Sur, the Cerro of the Virgin in Zacatecas, the Tamaulipas coast, and the area of Campeche, the Isthmus of Tehuantepec and the Yucatan Peninsula. However, it is known that much of the Mexican coast holds exploitable wind resource. In this regard, the NREL developed a series of wind maps for some states. The most complete, undoubtedly, is Oaxaca´s, although it also has those for Yucatan, Quintana Roo, Campeche and Baja California (NREL, 2003).

History of Renewable Energy in Mexico

The use and development of renewable energies in Mexico are related to the needs of electricity supply in the country. The vastness of the country and the fact that there are thousands of villages in remote areas with limited access and communication means have made it difficult and expensive to expand the national grid. This situation led various federal, state and local governments, especially in the late eighties, to seek other options for electricity generation on-site.

Some programs such as Solidarity, created under President Carlos Salinas de Gortari, and Progresa, established during the administration of Ernesto Zedillo, were drivers of renewable energy use in communities and remote areas. However, wind power remained limited to small systems.

As a result, renewable energy, mainly photovoltaic energy, found important niches in parts of Mexico where there is no access to electricity networks. These energies are used to provide electricity to ecotourism camps, pumping and purifying water, in productive projects in fishing areas and villages, in areas of research and international cooperation, and protected natural areas. Other applications that emerged in the early nineties were the power projects for telephone systems and telecommunications networks.

All these mechanisms have driven the development of small enclaves of alternative generation, whether solar, hybrid, mini-hydro or wind. However, these sites have very limited dimensions and results when they are not in institutional hands. Mexico's experience shows that if there is no prior social work, careful planning, constant monitoring, basic training, in addition to financial support and a provision for appropriate spare parts, this kind of development will fail.

In an investigation by the IIE over the use of alternative energy sources in rural areas in Mexico, it was noted that at least 50% of the projects were abandoned or vandalized because they were not given follow-up, maintenance activities, and parts or supplies were rarely provided for their proper operation. In other cases, such initiatives were inconclusive or user mismanagement caused a rapid deterioration (IIE, 2006).

In another study on lessons learned from development projects to generate electricity from alternative sources it is stressed that, in wind energy, the first ones were small, productive developments in rural areas where there was no electric service. They were also used to provide electricity to some productive projects, for example, small ice plants needing power to preserve perishables. Basically they were hybrid initiatives, and most of them failed for lack of monitoring, maintenance and training. (Romero, 2005).

Exclusively with regard to wind energy, important projects have been undertaken, which have been pioneers in this type of generation. Most of them are linked to productive activities. Some of the most well-known are in Chart 7.3.

Year	Proyect	Installed capacity (kW)
1992	Xcalack, Quintana Roo	60
1993	Rancho Salinas, Oaxaca	10
1993	Isla Arenas, Campeche	3
1994	Central Eólica La Venta I, Oaxaca	1,575
1995	El Gavillero, Hidalgo	2
1993-95	Ejido Santo Domingo, Oaxaca	n.d.
1996	Rancho Minerva, Oaxaca	1.5
1996	Costa de Cocos, Quintana Roo	7.5
1997	Puerto Alcatraz, Isla Santa Margarita, BCS	10
1998	Central Eólica Guerrero Negro, BCS	600
1999	San Juanico, BCS	100
2007	Central Eólica La Venta II	85,000.00

Chart 7.3
Chronology of the main wind projects in Mexico (1992-2007).

Source: Own elaboration.

7.2.3 Analysis of wind power generation capacity

Despite being a member of the Organization for Economic Cooperation and Development (OECD), Mexico has a considerable lag in the field of utilization of alternative energy sources. Energy balance in 2008 shows that these occupy a marginal place in generating capacity since, excluding the large-scale hydroelectric plants, installed capacity represents only 2.05% (1,050 MW) of the total reported of 51,105 MW, as it can be seen in Chart 7.4 and Figure 7.2.

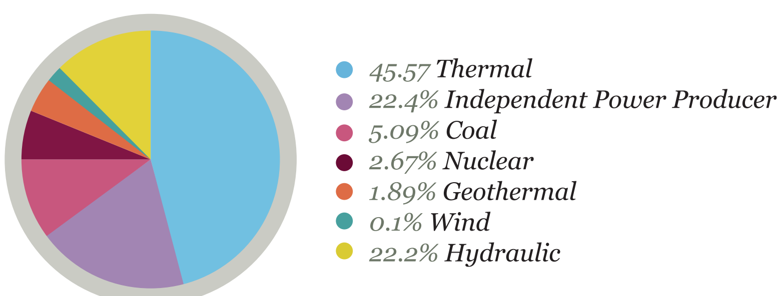

Figure 7.2
Installed power generation capacity in Mexico, 2008.

Source: Own elaboration.

Years	Hidro-eléctrica	Termo-eléctrica	Productor externo de energía	Carbo-eléctrica	Nucleo-eléctrica	Geotermo-eléctrica	Eolo-eléctrica	Total
1999	9,618	21,327	0	2,600	1,368	750	2	35,665
2000	9,619	21,772	484	2,600	1,365	855	2	36,697
2001	9,619	22,639	1,455	2,600	1,365	838	2	38,518
2002	9,615	23,264	3,495	2,600	1,365	843	2	41,184
2003	9,615	23,264	6,756	2,600	1,365	960	2	44,562
2004	10,530	23,830	7,265	2,600	1,365	960	2	46,552
2005	10,536	22,820	8,251	2,600	1,365	960	2	46,534
2006	10,566	23,017	10,387	2,600	1,365	960	2	48,897
2007	11,343	23,218	11,457	2,600	1,365	960	85	51,028
2008	11,343	23,291	11,457	2,600	1,365	965	85	51,106

Chart 7.4
Installed power generation capacity by energy source in Mexico, 1999-2008 (MW).

Source: SENER, 2009.

With regard to wind energy as a source of electricity generation, the figure is minimized because an installed capacity of 2 MW was kept for nearly 10 years. It was in 2007 when this capacity was expanded to 85 MW through projects at La Venta in Oaxaca.

According to data issued by the SENER, during the period 1999-2008, wind generation grew significantly, from 6 GWh recorded in 1999 to 255 GWh in 2008, that is, there was an increase of 4000% (Chart 7.5 .) However, this growth is not significant compared with the participation of other sources,

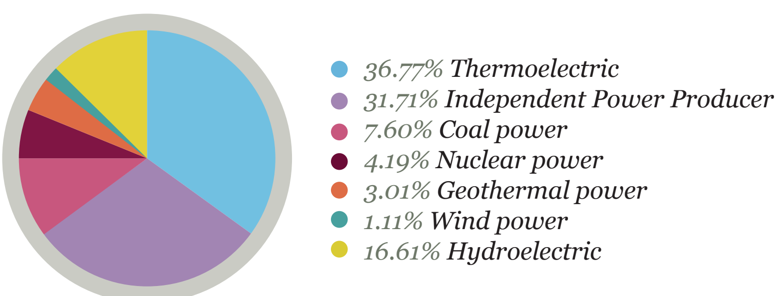

Figure 7.3
Gross electricity generation by energy source in Mexico, 2008.

Source: SENER, 2009.

as in 2008, it represented only 0.11% of the total generated (Figure 7.3), although, with respect to the installed generating capacity, this source accounted for 0.16%.

Chart 7.5
Gross electricity generation by energy source in Mexico, 1999-2008 (MW).

Years	Hydro electric	Thermo electric	Independent Power Producer	Coal	Nuclear	Geothermal	Wind	Total
1999	32,712	114,322	0	18,251	10,002	5,623	6	180,916
2000	33,075	125,525	1,295	18,696	8,221	5,901	8	192,721
2001	28,435	131,215	4,590	18,567	8,726	5,567	7	197,107
2002	24,862	122,345	21,852	16,152	9,747	5,398	7	200,363
2003	19,753	117,722	31,645	16,681	10,502	6,282	5	202,590
2004	25,076	102,428	45,855	17,883	9,194	6,577	6	207,019
2005	27,611	107,501	45,559	18,380	10,805	7,299	5	217,160
2006	30,305	98,308	59,428	17,931	10,866	6,685	45	223,568
2007	27,042	96,729	70,982	18,101	10,421	7,404	248	230,927
2008	38,892	86,069	74,232	17,789	9,804	7,056	255	234,097

Source: SENER, 2009.

The CFE is planning to install six generation plants with a total capacity of 585 MW. Up to 2006, the CRE had granted self-supply permits for a total of 700 MW, more than 360 MW, in the area of La Rumorosa in Baja California. The Mexican Wind Energy Association (AMDEE) has shown interest in installing a total of 3.200 MW over the next 10 years in Oaxaca (Barnes de Castro, 2006). Once the first phase of the Open Season Project was decreed, whose main aim is to secure commitments from companies interested in expanding the transmission capacity in the area and to distribute the energy, commitments were made for about of 2,000 MW. This result clearly indicates that the estimate made by UNAM was already fulfilled and that the estimate by the IIE will be covered soon, suggesting that both institutions were very conservative.

7.3
Legal and economic aspects of wind energy in Mexico

7.3.1 Barriers to wind energy development by the private sector

Currently, the three main alternatives for private participation in the development of wind energy in Mexico are the independent power production (IPP), remote self-supply and export. The export market has characteristics that are not discussed in this chapter (Then and Oven, 2009). However, this section will cover the barriers to participation in other forms.

Independent Power Production (IPP)

Planning for the expansion of wind energy for public service is mainly the responsibility of the CFE according to SENER´s guidelines. Consistent with the Public Service Electric Energy Act (LSPEE, initials in Spanish), the CFE decides capacity additions, technology and financing scheme. As a result, companies interested in participating depend on the new tenders put out by the CFE.

The biggest limitation of wind energy in the IPP scheme is the energy planning methodology used by the CFE, which is based on the evaluation of projects based solely on short-term economic cost of power generation. The lack of appreciation of other benefits that could eventually provide renewable energy, such as greater price stability and better security in the generation of energy, together with the goal of the CFE to expand natural gas generation, have prevented non-hydro renewables from developing to the fullest. In the case of wind energy and with a class I and II potential of approximately 10,000 MW, the CFE plans to only develop 500 MW (5%) by 2017.

Remote self-supply

In the case of the remote self-supply mode, the planning of the project is outside the domain of the CFE. However, since it depends on the CFE transmission grids, a limiting factor is the procedure to give network access to the licensees. The Open Season project in Oaxaca has tried to be a meeting point between developers and the CFE for the planning and joint funding of the new transmission line.

Another potential barrier to the development of this mode is the charge for transmission service. Although the CRE publishes the calculation methodology, it involves a power flow model that cannot be developed by the CRE, but by the CFE. Therefore, the establishment of transmission charges is not in an independent or transparent procedure, thus resulting in a position of market power in favor of CFE.

The fact that the CFE controls both, access to third parties and the establishment of the transmission charges can represent a significant barrier to the development of wind energy. While it is true that much of the development of remote self-supply aims to get a supply of cheaper electricity to the industrial sector, it is also true that it decreases the market share of the commission and threatens it’s cross-subsidy scheme. If residential fee levels are not substantially modified to avoid the need for higher subsidies, the CFE will have a big incentive to exert a powerful position in the market and prevent the development of remote self-supply.

7.3.2 Economic aspects

Below is an economic analysis of wind farms that use large-scale machines (above 50 kW). The aim is to understand the main factors affecting the profitability of these investments. This information is the result of various investigations and reports of wind associations, universities and research centers in the U.S., Canada and Europe.

The costs of wind energy have changed dramatically over the past 20 years. To get an idea of the the change, the cost of wind energy fell 90% in this period. Despite technological improvements, some experts say that this generation source is still in process of maturation. The current production volumes are minimal compared with those estimated to be in the next 20 years.

There are several factors that determine the costs of projects and their competitiveness in the energy market:

- Maturity of the technology.
- Size of the project.
- Selected team.
- Geographical and topographical conditions of the project site.
- Political, regulatory and social issues.
- Financial parameters.
- Wind speed.

Investment costs

Before installing a wind farm, we must consider feasibility studies, the evaluation of its potential and the basic engineering of the early phases of the project as part of the investment costs. An analysis by the European Wind Energy Association estimates that the cost structure for a typical 2 MW turbine is distributed as shown in Chart 7.6.

Concept	% of total cost
Generator	75.6
Interconnection	8.9
Founding	6.5
Land rent	3.9
Electric instalation	1.5
Consulting	1.2
Road construction	0.9
Control systems	0.3

Chart 7.6
Source: Khron, 2009.

In the case of Mexico, where there are few wind farms, the labor is cheaper than in other countries, but lacks the experience and skills required. Investment costs in U.S. $ / kW influence the price of energy; hence, low costs of implementation must be searched, so that the project as a whole becomes profitable.

Optimization of the project

To optimize the project area, factors such as soil type, which determines the system configuration, should be considered. This is because the type of terrain and conditions of a wind farm are not the same for La Venta in Oaxaca and La Rumorosa in Baja California. Oaxaca ranks first in wind energy potential and La Rumorosa second. Moreover, in the case of the first-mentioned State, machines can be aligned, while in the California Mountains, this is complicated because of the rugged terrain.

Land requirements are also important, as shown in Chart 7.7, which compares Oaxaca and Baja California. While for the former 7.7 ha / MW must be acquired, Baja California requires a minimum of 38 Ha / MW, but may require up to 77 Ha / MW.

Chart 7.7
Land requirements to install a wind farm.

Source: GEC, 2003. Exemplified for 48 m rotor diameters and 900 kW generators.

Wind direction and terrain	Turbine spacing (# rotor diameters)	Spacing between rows (# of rotor diameters)	Hectare per MW	Hectare per turbine
Multidirectional / ground plane	8	10	20.5	18.4
Multidirectional/ low hills	10	15	38.4	34.6
Multidirectional/ mountainous	15	20	76.8	69.1
Unidirectional / ground plane	from 3 to 8	10	7.7	6.9
Unidirectional / low hills	from 4 to 10	15	15.4	13.8
Unidirectional/ mountainous	from 4 to 15	20	20.5	18.4
	BAJA CALIFORNIA		***OAXACA***	

Power generation costs

Energy generation costs obey several factors. The following are among the most relevant:

- Wind speed (wind potential of the site and it's profile).
- Characteristics of the wind generator (aspects that have to do with technology).
- Size of the wind farm.
- Optimization of the project area (aspects associated with land conditions).
- Financing Cost (national and global financial situation).
- Transmission costs (regulations and rates of the electricity company).
- Incentives.
- Other factors that may help improve the competitiveness of wind energy.

As the energy generated by the equipment is directly related to the speed of wind, its cost will be in inverse function of speed. The larger the potential, the lower the cost, since more energy is generated. This can be seen in Figure 7.4, which reflects values of a wind farm of 51 MW, with three wind speed scenarios. These prices include tax incentives.

Cost of energy vs. wind velocity

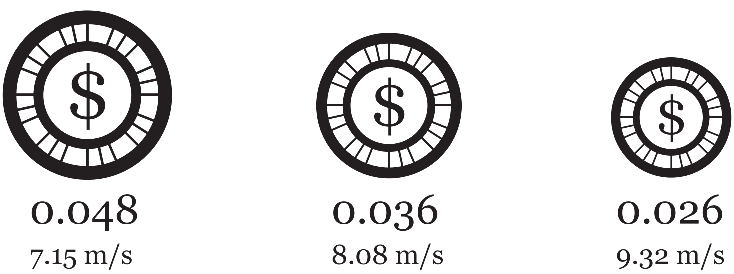

Figure 7.4
Cost of energy vs. wind velocity

Source: Own elaboration.

In parallel, the sweep area of a turbine rotor is a quadratic function of the blades´ length.That is, the higher the tower and the larger the blades, the larger the sweet diameter, thus costs are reduced considerably. For example, machines of 25 kW with 10 meters of rotor diameter were built in 1980. Currently the machines are at least 750 kW and 50 meters in diameter, that is an increase of 25 times the energy generated with substantial savings in economic terms, since they occur on the same site. Electric equipments have become more efficient because progress was made in the design of the blades, the towers and electrical systems-factor that contributed to wind systems becoming more economical. Chart 7.8 shows the major changes in the last 25 years.

Chart 7.8
Sequential change in prices in the last 25 years.

Source: AWEA, 2005.

Nominal power	1981: 25 kW	2006: 1650 kW
Diameter of the rotor (meters)	10	71
Cost (in thousands of dollars)	65	1,300
Costo per kW	2,600	790
Production kWh/year	45,000	5.6 millons

This type of industry allows the use of economies of scale. As an example, if one considers an average wind speed of 7 m/s, a 3 MW wind farm would produce energy at a price of USD$0.059kWh, while one of 51 MW would generate the same energy at USD $ 0.036/kWh, which implies a 40% reduction in cost. Any project has transaction costs that can be spread when the amount of kWh increases. Similarly, a farm will have, proportionally, lower operational and administrative costs by kWh, since administrative efficiencies are higher in larger parks. On average, the cost of operation and maintenance is $ 0.01/kWh (AWEA, 2008).

The financing costs of wind energy depend on a long list of variables. For various reasons, the financing of wind projects is one of the most expensive in order to generate electricity. Studies by the Lawrence Berkeley Laboratory (LBL) indicate that a 50 MW wind farm generates power at a cost of $ 0.05/kWh, whereas if it received funding as if it were a generation project based on natural gas, the energy cost would be USD $ 0.0369/kWh (Wiser and Khan, 1996).

Although the wind industry is growing steadily, and every time there are more wind farms in the world that demonstrate the advantages and that they are comparable with other forms of generation, many members of the financial community believe that wind electricity is still risky. This happens in the U.S., where European sources are used to get financing. In general, lenders offer less favorable financial conditions and demand high rates of return, compared with the rates for projects from other generation sources. Transmission costs and limits on market access can significantly impact energy costs. Because wind speed varies, it is not possible for the plant operator to accurately define the amount of electricity to be transmitted to the transmission lines at a specified time. Irregularities in the deliveries are penalized, regardless of whether it is possible to increase or reduce costs. In addition, interconnection procedures are not standardized. In the case of the U.S., there are instances when it is impossible to comply with the requirements of the electricity companies, reaching a point that stakeholders build their own transmission lines.

Undoubtedly, electricity markets are being restructured and therefore, they establish long-term energy purchasing agreements. Because of this, there is an opportunity to negotiate not only energy exchanges but also the conditions for market access and electricity transmission. This means a very important role in the wind industry.

In the case of Mexico, the simple calculation of the portage (carrying) cost, that is, to bring the energy from the generation to the consumption point is a complex algorithm that provides little transparency and predictability (Figure 7.9).

Finally, incentives are crucial when considering the economics of the project. They are a way to adjust market prices of traditional generation methods taking into account the variations and risks of new technologies.

Figure 7.9
Portage (wheeling) price ranges.

Source: Jaramillo, 2008.

For example, in the U.S., and according to what is reported by the American Wind Energy Association (AWEA, for its acronym in English), the federal tax code offers a great variety of temporary and permanent incentives for conventional energy sources. It also includes a "tax credit for wind energy production" (Production Tax Credit, PTC) and a five-year accelerated depreciation for wind machines: a PTC of USD $ 0.015/kWh is adjusted based on inflation (currently it begins at USD $ 0.018/kWh). It also provides, for the first 10 years of operation, support to wind farms producing electricity and electricity companies.

The first time that this incentive was adopted was in 1992, with breaks, changes and restarts, as well as modifications and adaptations afterwards. The PTC is a key incentive that helps level the economic playing field for wind projects in a market that subsidizes other means of energy generation.

7.4 Environmental aspects

It is clear that in any human activity there will always be an impact on the environment, however minimal. In the case of permanent structures, the shock is usually greater. The ecosystem will necessarily suffer some modifications and, in most cases, it will be impossible to predict its effects on mankind. In the case of wind farms, we have identified two vulnerable groups: birds and bats.

The preliminary draft of the Mexican standard to regulate the establishment of wind energy projects, NOM 151 SEMARNAT 2008, began in 2008. Currently, the standard is under review. Meanwhile, plans for the development of wind farms and machines in other locations outside of Oaxaca have not stopped.

7.4.1 Environmental regulations in Mexico

One cannot think of installing a wind farm if you do not have all permits and, if all economic and technical feasibility studies have not been carried out. It is impossible to imagine that technical data is changed so that the CRE authorizes a project or to achieve that the CFE allows energy to be transmitted through its networks. All approved projects are on the CRE website. However, similar lists were not found on SEMARNAT´s website, although this governmental agency states in a work meeting document dated March 20, 2009 that they are published. While completing this chapter, only one resolution was found that referred to a land use change that allows for a wind-generated electric project.

In Mexico, environmental regulations are lax. In that sense, you can modify the results of environmental studies because protecting the environment is not a priority, because perhaps energy is more important. There are many environmental legal loopholes that should be reviewed with the same speed with which the wind energy industry develops. Finally, it should be noted that this is not only a Mexican condition. For example, in the case of Spain, sanctions have been reported and applied that, in the medium term, were unsuccessful.

7.4.2 Environmental impacts of wind farms

The most worrisome aspects of this technology are its impacts on the wildlife. For this reason, it is necessary to analyze all aspects and seek solutions to potential environmental damage, even more so when dealing with a "renewables" technology industry.

Positive environmental impacts of wind farms

The positive impacts of wind farms have been widely disseminated, as they reduce fossil fuel consumption and prevent greenhouse gas emissions or other pollutants. These arguments, coupled with the need for energy from other sources than oil, mainly because of its high cost or low-local availability, have given place to a startling development of this industry.

For every 250 MW of wind power generated, the burning of 1 million barrels of oil is avoided and 700,000 tons of CO2 are not emitted into the atmosphere (AWEA, 2005). In Mexico, a capacity of 30,000 MW is projected by 2050, which means that the burning of 120 million barrels of oil would stop.

Negative environmental impacts of wind farms

The impacts of wind farms on natural resources have already been documented and evaluated in countries like Germany, Bulgaria, Canada, Denmark, Spain, USA and UK. Institutions like the Fish and Widlife Service (FWS) developed monitoring mechanisms put in place before, during and after installation of wind farms in places like Appalachia, Missouri and New

York (FWS, 2009). Mechanisms were also designed in Europe by the Norwegian Institute for Nature Research (NINA, for its acronym in English) with a program called RENERGI (Bevanger et al., 2008). NINA's research indicates that the main causes of the bird's death are:

- Birds do not detect the rotation of the blades of the turbines and are hurt when they fly into them.
- Birds are attracted by warning lights, get confused, extenuate and hit them.
- Birds are hurt with the cables connected to the stations.
- Each of these factors plays a different role, depending on the season and weather conditions.

Other environmental impacts are soil contamination by oil spills, fires due to faulty operation of wind turbines, noise pollution and changing land use for the location of wind turbines, which sets aside the role that pasture and surrounding vegetation play. This area attracts some bird species, as it is there where they find food.

7.4.3 Wind potential and migratory birds

The CONACYT announced through a newsletter in 2007, that through the use of a research program and radar, they managed to calculate that 12 million birds of 130 species fly by the Isthmus of Tehuantepec (Nava, 2007). The first CFE pilot project was installed in this region, launched in 1994 with a capacity of 1.575 MW. It was the first plant to be integrated into the electricity grid in Mexico and Latin America. This CFE pilot project has yielded a variety of lessons and experiences, which arguments to continue with them and to encourage private companies to generate power in this region of the world.

Records of affected birds at wind farms

Over many years of work and research, important conclusions about the negative impacts of wind farms on birds and bats were reached. It took the working group in Altamont Pass more than 20 years to show that the impact on birds was really alarming and that wind turbines should be stopped. Given this, part of the wind farm (Smallwood and Thelander, 2004) was dismantled. This wind farm was installed in 1982 with 5,400 wind turbines and has the highest record of birds killed worldwide, between 880 and 1,300 per year.

However, other studies record from 0.04 to 0.09 birds killed per turbine each day, giving an average of 23 birds per machine per year and approximately 500 birds during the life-span of the wind turbines. If there is little visibility or weather conditions are not favorable, accidents increase. It is estimated that in California, depending on the site, there may be from 0 to 37 dead birds per machine per year. Rates in Europe are not very different; no matter if it is a single machine or a wind farm, the numbers range from 0.04 to 0.09 birds killed per machine per day (Kingsley and Whittam 2001).

The studies also yielded data on the probable hours and seasons of the collision, the most probable circumstances for the accidents and weather conditions that favor the deaths. Therefore it is said that, somehow, the mishaps of the birds are predictable and controllable if their behavior is studied and monitored at least the first two years after the wind farm begins operating. These actions will lead to a suspension of generation for a few hours or days per year, but will also avoid killing many birds.

Radars and a early warning system to avoid the collision in a 50 MW wind farm may cost approximately USD$ 175,000 and can prevent the death of at least two thousand five hundred birds over the project´s life. Its operation is more useful the first four years, two before and two after construction. Later, dates, times and conditions about when and how machines must be stopped will be known. This investment is equivalent to life insurance for birds at a cost of USD$70 per bird (NERI, 2000).

7.4.4 Technology for mitigating the negative impacts

Currently, technology allows us to assess the risks of death in birds and bats, keep a real-time recording, and connect the tracking system to the control system of wind machines. These equipments are available for purchase or for rental. Radars are also commonly used in air navigation in order to prevent collisions between birds and airplanes.

Monitoring methodologies involve the measurement of the birds (size, weight and appearance), but also use other techniques such as:

- Transects at different distances from the turbines. The monitoring can be performed with daily or weekly visits during migration months.
- Equipment for telemetry studies, ultrasonic detectors with recordings, digital video cameras and acoustic monitoring with microphones to record the songs of the birds in order to identify them with the sound.

- Measurements with radar.
- Dogs trained to collect dead birds.
- DNA samples from adults and young first, second and other generation birds in order to study nest site fidelity, especially in the case of birds of prey.
- UV lights on the rotors (Bevanger et al., 2008).

7.5 Some recommendations for promoting wind power

Following is a series of recommendations that can help overcome barriers to wind energy development in Mexico.

7.5.1 Establish mandatory targets for renewable generation by CFE

The U.S. experience of establishing minimum renewable generation goals has proven effective in promoting and implementing them. These goals are accompanied by adequate flexibility mechanisms for compliance as well as for the application of non-compliance penalties. In the case of Mexico, this instrument would be even more significant because CFE controls all public sectors planning, including independent production. Thus, any incentive to production, likewise the green background of the La Venta III project, is conditioned on the Commission deciding or not to accelerate the development of new renewable energy capacity.

Currently, the CRE has no jurisdiction over the CFE in planning the expansion of the electrical system. In the planning cycle, CFE had to take into account, in an advisory capacity, the general outlines of the SENER. However, the development of a special program for the utilization of renewable energy is being contemplated in the new LAERFTE, and the SENER is charged with its definition. This program establishes participation goals for renewable energy in electricity generation, mandatory for institutions and agencies of the Federal Government, including the CFE.

In the definition of the regulation developed by LAERFTE, these must ensure that this instrument is designed properly and that it guarantees independence and transparency in the definition of minimum goals and appropriate mechanisms to comply with the law.

7.5.2 Ensure the availability of sufficient financing mechanisms and sustainable generation from renewable sources

Another lesson learned from the U.S. experience is that the minimum generation targets are accompanied by support instruments to finance the energy transition to renewable technologies. In the case of Mexico, since the CFE dominates generation and only limited private participation is allowed, these support instruments should take into account the characteristics of the Mexican electricity market.

In a scheme of a single-buyer electricity market, as in Mexico, establishing minimum renewable generation targets would only affect the CFE. Thus, it seems reasonable that the funding mechanisms of the energy transition help meet those goals. Since the CFE is a public company, the instrument cannot be a tax credit as in the U.S. case, but should take the form of a subsidy to the generation or “green fund”. This idea is being applied experimentally in the La Venta III wind project, in which the independent producer receives USD $ 11/MWh during the first five years. The single-buyer scheme mainly benefits the CFE, as it has to pay the independent producer a lower price for the energy generated.

The establishment of a stable green background covering all renewable energy is provided in the trust fund derived from the LAERFTE. However, we still need to develop the regulations that will determine the details for its implementation, and also the projects that are eligible to participate in the fund, what is their annual allocation, which part of this fund is earmarked to subsidize generation activities, how many years will be subsidized, who manages the fund and how it will be financed. Here are some suggestions on green background details:

- The generation subsidy must be sufficient and sustainable. To impact the development of renewable energy, it must have a stable level between at least $ 10 and $ 20 per MWh generated, and must be sustainable, with a guaranteed subsidy for five years and a total duration of five to 10 years.

- CFE and private actors should receive aid for renewables generation. Renewables generation projects in the export, self-supply, co-generation and small production patterns should be eligible for a subsidy, because, although they are not subject to renewables generation goals, they provide a range of environmental benefits to the overall generation system. Moreover, in case of exports, it will help improve the competitiveness of Mexican companies vis a vis American companies receiving the PTC.
- The management of the trust fund must be independent and transparent. To avoid control by the agents with greater market penetration, the control and monitoring of the fund should be in the hands of an independent institution that will set up clear and transparent mechanisms to assign the funds.
- The management of the trust fund must be stable and financially sustainable. The financing will be obtained from the federal budget, requested by the SENER and from other international support.

7.5.3 Promote the development of transmission lines to channel wind energy

By its nature, wind power is distributed in areas not necessarily close to where it is consumed. This creates problems for planning the transmission of wind-generated energy, which delays the development of wind generation capacity. In the case of Mexico, The Open Season program has proven to be a successful mechanism to coordinate the interests of potential developers of wind farms and the CFE, in charge of making the investment in transmission.

Based on the Texas and California initiatives, a more general transmission associated with renewable energies could be designed as they have their basis on a technical and economic analysis of renewable resources to define priority areas. The development of these areas will depend on electric transmission planning. There could be a committee with the participation of all stakeholders in the Mexican electricity market. It should also be able to analyze the potential of wind power developed in the country today as part of the Large Scale Renewable Energy Project, funded by the GEF.

7.5.4 Increase the transparency in the methodology used for calculating transmission costs

SENER´S look ahead on the electricity sector believes that most of the new wind power capacity planned for the next decade will be in the form of remote self-supply (2,600 MW, 65%). However, the transmission by the CFE grid provoked considerable uncertainties about the development of this additional generation capacity. Although the CRE developed and approved the calculation methodology, it involves freight flow models that only the CFE can develop. Given this, transmission charges cannot not be independently and transparently set, which opens the possibility for the CFE to assume a position of power in the market. Therefore, the CRE should have the technical capacity to establish the transmission charges to the national grid, in an independent and transparent manner.

7.5.5 Resolving the issue of electricity subsidies to ensure financial sustainability of the system

A cross-subsidy of the industrial and commercial sector to the residential and agricultural sectors, as well as the possibility of a remote area self-supply, has encouraged that the provision of electricity for the industrial sector shift from the public to the private sector, through a self-supply scheme. As a result, the financial sustainability of the subsidy scheme in Mexico deteriorated.

Although the wind energy development benefited from the remote self-supply mode, and although this represents a significant potential for future development, reforms in the subsidy scheme should be promoted. Otherwise, the financial sustainability of the electricity market would be at risk, as this mode is concentrated on the most profitable sector and permits losses to the public supplier. Therefore, sustainable development of renewable energies in Mexico must be accompanied by reforms to the CFE subsidy policies.

7.6 Conclusions

Although Mexico has one of the largest class I and class II wind energy potentials in the world, with over 10,000 MW, the development of such energy resource has been very limited, with less than 500 MW installed by 2009. In addition, medium-term prospects do not provide significant growth, as it plans to install less than 4,000 MW by 2017. The main reason behind such slow progress is the lack of government incentives that promote renewable energy and the absence of a clear regulatory framework to allow greater private sector participation in the development of wind farms.

Throughout this chapter we reviewed the status of wind industry in the world. Mexico is at an excellent moment to apply lessons learned in other countries, as it recently passed a law to promote renewable energy development and is ready is to define the details of the different mechanisms contained in it. This allows Mexico to be objectively evaluated and to conclude that there is a long way to go and that we are on the right path.

Other countries use different strategies to promote renewable energy, but Mexican incentives have low impact .The experience of California and Texas in the U.S. shows the relevance that some regulatory mechanisms may have in the development of the wind industry (Luengo and Oven, 2009). In particular, not only temporary subsidies to renewable generation have proven successful, but also the establishment of minimum generation goals with renewable sources.

In the environmental area, it cannot be denied that there is a pending task and the means, strategies and resources to do so are already available. There is no reason for not using protective and mitigation impact measures. Finally, from an economic point of view, there is evidence that with plant factors of less than 30%, companies can do business in other parts of the world. Mexico has sites with this and with a higher potential, which should be an incentive for job creation and the strengthening of local capacities.

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8. Geothermal Energy

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8.1 Introduction

Geothermal energy is generated from the heat inside the Earth that is continuously produced by radioactive decay of minerals such as uranium, thorium, and potassium. This heat is everywhere, but can only be exploited with current technology when it is concentrated in certain parts of the subsoil, known as systems or geothermal reservoirs. These usually appear on the surface as hot springs, hot soil, mud volcanoes, fumaroles, geysers and hydrothermal alteration zones. Geothermal resources can be used directly in resorts and spas, in agro-industrial facilities, in central heating, for aquaculture and greenhouse, or to generate electricity indirectly.

Geothermal energy has been used since prehistoric times. In Mexico many settlements were developed due to the existence of thermal sites in their vicinity, as evidenced by the use of the word “Atotonilco”, to name many people in various states of the center of the country (Suarez-Arriaga et al, 1999).

This word comes from Nahuatl and means “place of hot water”. It has the same meaning as that of Puruándiro, Michoacán, in Purepecha language, and Pathé, Hidalgo, in Otomi language (Hernández-Galán et al 1999).

However, early studies on the use of geothermal resources for electricity generation in Mexico were made from 1951 onwards, when Louis de Anda F, then Chief Engineer of the Federal Electricity Commission (CFE) presented a study on the feasibility of generating electric power using geothermy. In 1955, the Geothermal Energy Commission (GEC) was created, and shortly after, they began drilling the first geothermal well in the country in the field of Pathé, Hidalgo, located about 300 kilometers north of Mexico City. This well, called Pathé 1, produced steam in January 1956. That same year the first legal provisions relating to geothermal energy were issued. These gave preference to the CFE in the extraction of hot water and steam to generate electrical power (Quijano-León and Gutiérrez-Negrin, 2003). On November 20, 1959 a turbogenerator plant of 3.5 MW capacity was opened. It was the first geothermal plant in North and South America, and was partially in use until 1979, when its dismantling was ordered. It is currently on display as a museum piece in the geothermal field of Azufres in Michoacan.

The first geological reconnossaince activities were carried out in the field of Cerro Prieto, Baja California in 1958. On August 14, 1963, an M-3 well , drilled to a depth of 2.639 meters, began to produce a mixture of water and steam at high temperature and pressure. Between 1964 and 1969 about 20 exploration and producer wells were drilled and the construction of the first 2 units of 37.5 MW began in September 1969.

The first wells came into operation in April 1973 and the second in October of the same year (CFE 1998). By 1971 the Geothermal Energy Commission disappeared and its staff and equipment moved to the CFE, where 10 years later the Geothermal Project Management was created. This national decentralized management based in Morelia, Michoacan is now in charge of all aspects of geothermal energy in Mexico.

8.2 Geothermal systems

A typical geothermal system consists of a heat source, an aquifer and the so called seal layer. The heat source is usually a magma chamber or a bag of molten rock that is formed at great depth and near the boundaries between tectonic plates that form the outer layer of the planet, known as the lithosphere. The source is located at the boundaries where one plate is forced to slide beneath the other (a process known as subduction). These magma chambers come up to the surface through the lithosphere and sometimes cause volcanic phenomena. Chambers may be between 5 and 10 kilometers deep, and cool and solidify in a process that takes several thousands of years. In the surface, the existence of a magma chamber can only be inferred from indirect evidence, such as the presence of geologically young volcanoes, most of them formed less than 1 million years ago. Volcanism, seismicity and geothermal system formation are phenomena produced by the movement of these plates.

Meanwhile, the aquifer is any rock formation with primary or secondary permeability enough to lodge rainwater that infiltrates from the surface, or from other aquifer in their interstices. The seal coat is another rock formation, or any part thereof, with a lower permeability than the aquifer's. Its function is to prevent the geothermal fluid to dissipate fully on the surface. When the meteoric water contained in the aquifer is closer to the source of heat (which still has temperatures of 500 ° C or more) it is heated and mixed with magmatic fluids emitted by the source, thereby raising its temperature and pressure. These geothermal fluids tend to discharge at the surface, looking for areas of lower pressure, but cannot do so because the rocks of the seal layer prevent this; it is only possible to achieve this through narrow tubes that are generally fault and have fracture planes in those rocks . However, if an artificial duct is drilled like a geothermal well, fluids can reach the surface with virtually the same pressure and temperature they have in depth (Figure 8.1).

Geothermal systems can be of three types: hydrothermal , hot dry rock and geopressured or convective. The first ones stick to the model described above, as they include the natural presence of hot fluids or hydrothermal fluids, the heat source and the seal layer. At the same time they are subdivided into continental and submarine hydrothermal systems according to their location. Hot rock systems, also known as enhanced geothermal systems (Enhanced, or Engineered, Geothermal Systems, EGS) lack these fluids and consist only of the heat source. To exploit them, it is necessary to introduce water into the ground through an injection well where water warms as it descends and collects hot fluid through an additional producing well. Lastly, geopressured systems lack a single heat source. In them, the meteoric water infiltrated from the surface is heated by the geothermal gradient normal or slightly abnormal subsurface is approximately one degree Celsius for every 33 meters deep.

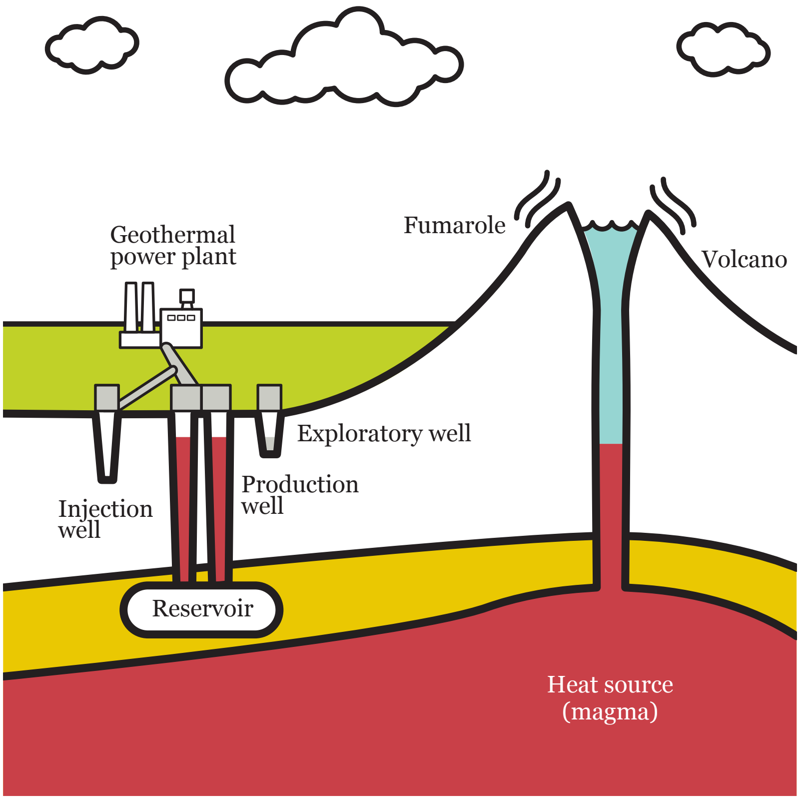


Figure 8.1
Schematic model of a geothermal reservoir.

Source: Own elaboration.

Geothermal systems that can be leveraged today are the continental hydrothermal. These systems are usually classified as continental liquid. These systems are usually classified as predominantly liquid, steam or dry steam dominant in terms of the proportion of water and steam contained therein. Systems are also classified as high temperature (over 180 ˚ C) intermediate (between 130 ˚ C and 180 ˚ C) and low (less than 130 ˚ C). The difference between a geothermal system and a geothermal reservoir is merely conventional, since the latter has a commercial connotation, as in the case of mineral deposits. Thus a geothermal reservoir is a commercially exploitable geothermal system to generate electricity or for other direct uses. If care is taken to remove a mass of fluid ,equivalent to that in the reservoir, by natural or artificial means, the resource is renewable for all purposes because although the magma chamber cools, the process will take thousands of years.

8.3
Geothermal power plants and geothermal wells

A conventional power plant, such as the ones that generate 3 quarters of the electricity consumed in Mexico, basically consists of 4 elements: a kettle to boil water and generate steam at high pressure and temperature, a turbine, with blades or vanes driven by the steam, a generator, which receives the movement of the blades of the turbine and converts mechanical energy into electrical energy, and an electrical substation transformer which raises the voltage of the energy produced by the generator to achieve the required voltage for its transmission. The differences between these power plants are based on the type of fuel used to heat the water in the hip, which may be oil (fuel oil, diesel, gas) coal or a nuclear reactor.

On the other hand, Geothermal power plants do not require a boiler to produce steam, but use the one produced by nature in geothermal reservoirs. Unlike other power plants, geothermal power plants do not require any fossil or nuclear fuel , but they do need geothermal wells to get not only the steam on the surface, but also the facilities to condition and drive it to from the well to the plant.

A typical geothermal well in Mexico is vertical, has an average depth of 2,000 meters and diameters are reduced with depth as shown in Chart 8.1

A slightly smaller diameter well casing is placed and cemented in each hole. The last section of pipe known as a liner, is not cemented, but installed with hangers of production tubing. It usually has a “blind” part, and a bottom, with slots to allow entry of fluid and stop possible rock fragments.

The depth of each diameter can vary depending on the characteristics of each geothermal field, the specific objectives and the total depth of each well. It can even be decided not to install the last part if the rocks are sufficiently compact. To construct a geothermal well, similar drilling rigs to those used to drill oil wells are used; they are deployed in an area known as a drilling platform and include cooling towers to reduce the temperature of the fluids. After some time, the so-called deviant or directional wells are also built , which deviate from the vertical at an angle previously scheduled

Depth (m)	Diameter (cm)		Functions	Diagram
	Whole	*Pipe*		
0 a ~50	91.4	76.2	This pipe insulates potential shallower aquifers.	
~50 a ~150	66.0	50.8	Isolates shallow aquifers and supports slightly compact formations.	
~150 a ~1,000	44.5	34.0	Protects the tubing and the header installation.	
~1,000 a ~1,600	31.1	24.4	Tubing leading the fluid to the surface.	
~1,600 a ~2,000	21.6	17.8	Hanging grooved pipe acts as a filter.	

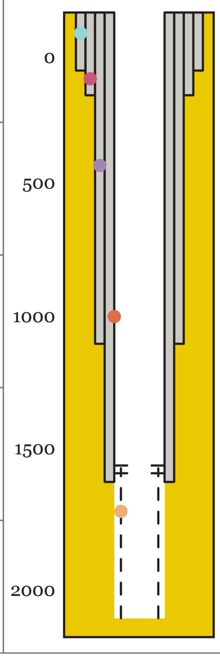


Chart 8.1
Characteristics of a typical geothermal well in Mexico.

Source: Own elaboration.

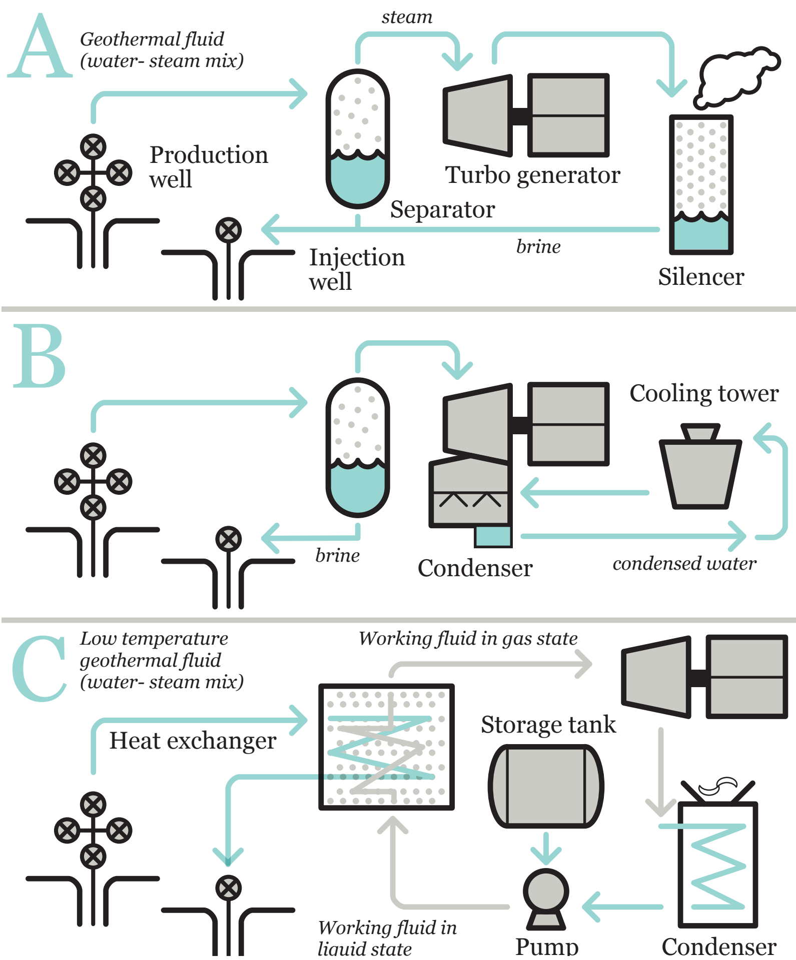
at a certain depth. This allows you to drill more than one vertical well over a single platform.

Except for the deposits of dry steam, the geothermal fluid produced by the wells is a mixture of water and steam to be separated by mechanical means. This is usually done in the platform of the shaft by a centrifugal separator: a closed cylindrical metal tank separating water from steam, due to their different density. Once separated, the steam is sent through a steel pipeline, known as steam duct towards the plants, so that when expanded, it rotates the turbine rotor. The separated water is a brine or water with dissolved salts. It is conducted through open channels or pipes of steel or polyethylene to a solar evaporation pond or directly into injection wells, where it will return to the site underground. This contributes to recharge the reservoir and prevents any possible contamination. The separated brine can also be sent to a second separator before disposal in order to obtain more steam, although at less pressure-but useful in generating electricity. This arrangement is known as double-spacing (double-flash).

According to the way geothermal plants use steam, there are basically three types of geothermal power plants: unit, binary and combined cycle. Unit cycle plants directly use geothermal steam to move the turbine blades, binary plants use it indirectly to heat and expand a working fluid, which is sent to the turbine and finally, combined cycle plants are a combination of the two types above.

According to the efficiency with which geothermal fluids are used to generate electricity, unit cycle plants can be of two types: backpressure and condensation. The first plants are simpler, as after the steam coming from the separator has passed through the turbine, it is directly discharged to the atmosphere through a muffler. The turbine muffler is a vertical metal cylinder, open at its top, whose function is to make a secondary separation of steam used in the turbine before discharging to the atmosphere and reducing environmental noise generated by the discharge (Figure 8.2 S). On the other hand, condensation plants are more complex but more efficient. In this type of plant, the steam exiting the turbine is driven to another vertical cylindrical tank of large diameter (typically a direct contact condenser) which operates lower than atmospheric pressure and can generate more electricity with the same amount of steam. Hot water, the condensation product, is sent through a pumping system to a cooling tower to lower its temperature and return it to the same condenser. Excess water in the sink of the cooling tower is also sent to the injection system in order to return it to the same reservoir through wells (Figure 8.2 B). Backpressure plants are cheaper because they lack condenser and cooling tower. However, they are less efficient because they require about 12 tons of steam per hour, about 3.3 kilograms per second (kg / s) to generate a megawatt hour of electricity (MWh). In contrast, condensing plants require only 8 tons of steam per hour (2.2 kg / s) or less, per MWh generated. A variant of the unit cycle plants are dry steam plants to be installed to operate without water reservoir. These do not need a separator installed as the geothermal fluid is only steam.

Binary plants are even more complex because they include a heat exchanger where the geothermal fluid (water or steam) gives up heat and warms a working fluid with a lower boiling point than that of water. Then this fluid returns to the reservoir through an injector well . In the exchanger, the working fluid (usually isopentane, isobutane or other organic fluid) is gasified, passes through the turbine and leaves this through a condenser where it cools to return to its liquid state. Then it is pumped back into the heat exchanger in a closed, cyclic and continuous process , known as Organic Rankine (Figure 8.2c). In certain cases, the working fluid passes through a pre-heater before



Geothermal generatio schemes.

Source: Own elaboration.

passing through the heat exchanger, which is also fed by a geothermic fluid that has already exited. A variant of the binary cycle employs a so called Kalina cycle, which consists of using a mixed working fluid, consisting of ammonia and water, which is more efficient when transferring heat and can exploit geothermal fluids at even lower temperatures. This process involves more investment, but takes advantage of low temperature geothermal fluids, that otherwise, could not be used to generate electricity.

Finally, combined cycle geothermoelectric power plants consist of two turbines coupled to the same generator, in an arrangement that is practically a combination of schemes A and C of Figure 8.2. First, the isolated geothermal steam gets into one of those backpressure turbines, but upon leaving, it is lead to a heat exchanger instead of being sent to the muffler to discharge into the atmosphere. In this exchanger steam heats a working fluid, which once gasified, is sent to a second turbine coupled to the same backpressure turbine generator. After passing through the exchanger, the geothermal fluid returns to the reservoir, while the working fluid remains in the closed cycle previously described. Investment in this type of arrangement is the highest of all, yet it allows a very efficient use of geothermal fluids.

All types of geothermal power plants are routinely used in several countries to generate electricity commercially. There is even a 2 MW Kalina Cycle binary pilot plant, which was installed in Husavik, Iceland, in 2000. In Mexico, unit cycle plants are currently operating (backpressure and condensation) together with two small units of binary cycle in the field of Azufres, using isopentane as working fluid.

8.4 Geothermoelectricity in the world and in Mexico

The first commercial geothermal power plant of 250 kW, which was of binary cycle to prevent the corrosion that could provoke the salts dissolved in geothermal fluids if they went directly to the turbine, was installed in Italy in 1913. Slightly more than 10 years after 1924, the first producing wells were drilled in the Geysers geothermal field in the U.S., and the first kilowatts of electricity were generated to illuminate a nearby spa. However, the project was abandoned in 1930.

This field is located 120 kilometers north of San Francisco California. Steam is dry and is considered to date as the largest in the world. Its first geothermal power plant was installed in September 1960, with a capacity of 12 MW (Duffied et al 1994). In Japan, a tiny geothermal generator with a capacity of 1 kW was set up on the island of Kyushu in 1925, but the first geothermal power plant of 30 kW went into operation in 1951. The first exploration wells were drilled by 1958 in Wairakei geothermal field, New Zealand, and in 1963 a plant of 8.9 MW began operating.

By mid-2009, 24 countries around the world had a joint capacity of geothermal power more than 10,000 MW (Chart 8.2) led by the U.S. with 3.040 MW, representing almost 30% of the world. The geothermal power source in that country is sufficient to meet the demand of 2.4 million homes in California, and nearly 15,000 gigawatt hours (GW-h) generated in 2007 represented 4% of total electricity generated in the States with renewable sources, which include large hydroelectric plants. In the Philippines, which ranks second worldwide with 1.980 MW, one-fifth of the electricity generated is of geothermal origin. (Biodgett and Slack 2009).

Country	Capacity (MW)	Country	Capacity (MW)
1. United States	3,040	14. Turkey	84
2. Philippines	1,980	15. Papúa New Guinea	56
3. Indonesia	1,058	16. Guatemala	48
4. Mexico	958	17. China (including Tibet)	24.2
5. Italy	843	18. Portugal (Islas Azores)	23
6. Iceland	575	19. France*	16.5
7. New Zealand	570	20. Ethiopia	7.3
8. Japan	535.3	21. Germany	6.6
9. El Salvador	204.4	22. Austria	1.4
10. Costa Rica	163	23. Thailand	0.3
11. Kenia	162	24. Australia	0.1
12. Russia	110	Total	10,553
13. Nicaragua	87		

**Alsace and Guadeloupe (in the Caribbean).*

Chart 8.2
Global geothermal power capacity to June 2009.

Source: Own elaboration.

In Mexico, the current installed geothermal power capacity is of 958 MW, which places the country fourth in the world, as seen in Chart 8.2. There are 4 fields in operation: Cerro Prieto,in Baja California, Los Azufres in Michoacan: Los Humeros, in Puebla, and Tres Virgenes, in Baja California Sur. All of them operated by the CFE through its Geo-thermoelectric Project Management. Additionally, there is a fifth field waiting to be developed, the Cerritos Colorados, in Jalisco (Figure 8.3). All stations operating in the fields are integrated into networks and distribution channels operated by CFE staff, and served, same as all others, by the National Center for Energy Control (CENACE).

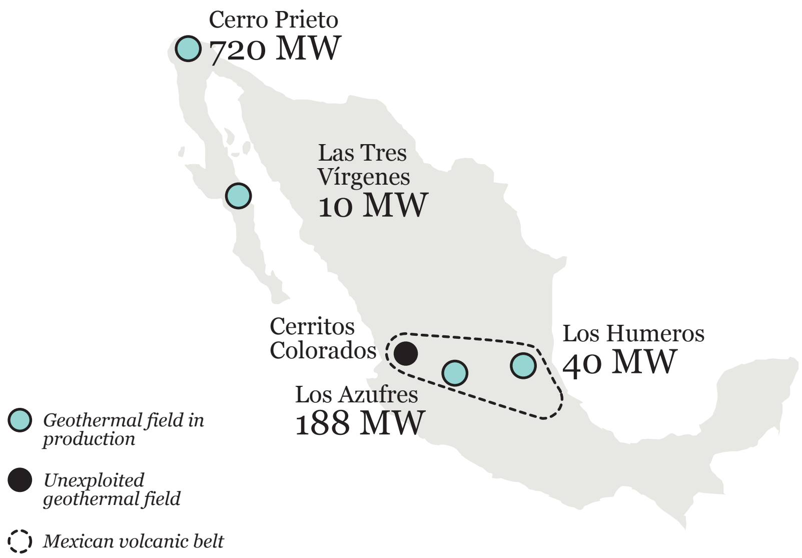


Figure 8.3
Untapped geothermal field.

Source: Own elaboration.

Note that the CFE is the second company with the largest geo-thermoelectric capacity installed worldwide, surpassed now only by the oil company Chevron, which owns nearly 1,200 MW of geothermal power plants operating mainly in the Philippines and Indonesia (Stephure, 2009).

Cerro Prieto is the largest and oldest of the Mexican exploitation fields and is considered the second largest worldwide after The Geysers. It is located in the state of Baja California, about 30 miles southeast of Mexicali, in the alluvial plain of the valley of the same name, near the U.S. border. The field is practically at sea level and from a geological point of view, it lies in a transtensional tectonic basin type, produced between two active lateral faults belonging to San Andres´ system: the Cerro Prieto fault and Imperial fault. In the subsoil of the basin, the thinning process of the continental crust has generated a thermal anomaly that brings heat to the geothermal system. The Cerro Prieto volcano, which takes its name from the field, is the only prominent volcano in the region. It is 260 meters high, composed by rhyodacitic to dacitic rocks, and its lavas were last extruded 10.000 years ago. However, it is unrelated to the heat source of the geothermal reservoir.

In the subsoil of the field, the lithology is composed of 4 packages of sediments and sedimentary rocks resting on a granitic basement. It outcrops at surface in the western part of the geothermal field, which shapes the Cucapá and Major mountains, and deepens under the field to about 4.000 meters. The field is hydrothermal of dominant fluid, with geothermal fluids contained in sedimentary rocks (sandstone lenses intercalated in shale) whose original luting has been altered and replaced by the action of these same fluids. The average thickness of this unit is 2,400 meters and the fluids are at temperatures between 300 ˚ and 338 ˚ C.

The first wells were drilled in Cerro Prieto around 1963, and by December 2008 there were a total of 369 wells, counting exploratory, producers and injectors, with an average depth of 2.353 meters, although the deepest well reaches 4.400 meters. In 2008, CFE had an average of 180 geothermal wells (167 producers and 13 injectors) in continuous operation, 24 hours a day, 366 days that year, so there were 45.9 million tons of separated steam (at a rate of 5,224 tons of steam per hour, or 1,451 kg/s) and 63 million tons of brine. Through open channels and pipes, this brine is sent to a solar evaporation pond built in the western part of the camp in an area of 14.3 km2. Inside there are embankments forming a spiral through which the brine moves through a pump station to deposit the contained salts and then inject them into the injection wells. In 2008, 19.6 million tons of brine were injected in the 13 wells mentioned before.

The separated steam was used to feed the 13 turbine generators also operated by the CFE, grouped into four central plants known as CP-R CP-II-III CP and CP-IV. CP-I plant is made up of four high pressure condensation units of 37.5 MW each, and a 30MW unit that works with low pressure steam, produced by partial evaporation of the separated water in two phases. These units began operation between 1973 and 1982. Each CP-II and CP-III central units consists of two condensing units of 110 MW (two turbines of 55 MW in tandem), which came into operation between 1986 and 1987. The newest central, CP-IV, was opened in 2000 and is composed of four condensing units of 25 MW each. The total installed capacity at Cerro Prieto is, therefore, of 720 MW, which generated 5.176 GWh in 2008 at an average annual plant factor of 81.8%.

Meanwhile, the geothermal field of Los Azufres is located in the northeast portion of the state of Michoacan, 80 kilometers east of Morelia, in a 2,800 meter high mountain and in the midst of a pine forest area declared as Reserve Forest since 1979. It is a volcanic field that is part of the MVB, a long province in the east-west and crosses the country from coast to coast in the center. Geothermal fluids, with temperatures up to 360 C, are hosted in andesitic volcanic rocks affected by three sets of structures (geological faults and fractures) caused by regional and local tectonic movements. The most important of these systems has an east-west direction and controls the movement of fluids in depth. The heat source from underground geothermal system appears to be associated with the magma chamber that fed the volcano of San Andres, the main prominence in the area.

The first exploratory work of the CFE in Los Azufres began in the seventies, when the first exploration well was drilled in 1976. To date, 85 exploratory, producer and injector wells have been drilled, with an average depth of 1.575 meters. In contrast, the most shallow wells, drilled in the south of the field, are just over 60 in continuous operation, with 39 producing wells and 6 injection wells. Producing wells generated 14.6 million tons of separated steam at an average rate of 1.668 tons per hour (t / h), equivalent to 463 kg / s as well as 4.53 million tons of brine which returned to the site through six injection wells. A geothermal plant made up of 14 turbo-generator units operates In Los Azufres, a condensation unit of 50 MW (unit 7) four condensation units of 25 MW each (units 12 to 16), seven backpressure units of 5 MW each (units 2, 3, 4, 5 , 6, 9 and 10), and two binary cycle units of 1.5 MW each. The first 5 Mw units began commercial operations in 1982 and the latest units, of 25 MW, did in 2003. Unit 1 was sold to Guatemala by CFE in 2002, after 20 years of continuous operation, while Unit 8 was transferred to Los Humeros geothermal field in 2003. The net capacity installed in the field of Los Azufres is, therefore, of 188 MW, which generated 1.517 GWh in 2008, with an average annual plant factor of 91.8%.

Los Humeros is another volcanic field, located in the eastern part of the MVB, within the limits of the states of Puebla and Veracruz, about 35 kilometers northwest of the town of Perote, Veracruz, and 2600 meters above sea level . From a geological point of view, the field is inside a volcanic structure called cauldron and known as Los Humeros cauldron, whose formation started half a million years ago with the rise of a magma chamber that led to violent eruptions. The rapid departure of more than 100 km3 of magma caused the collapse of a nearly circular area of 21 kilometers in diameter that formed the crater. A smaller cauldron housed within the first and called The Paddocks cauldron was formed about 100,000 years ago. The last eruptions occurred about 20,000 years. Also here are geothermal fluids, which have average temperatures of 320 C, though temperatures have been measured up to 400 C, cast into andesitic rocks, which in this case rest on a complex basement of sedimentary rocks (limestone), intrusive (granites) and metamorphic (e.g. marble, skarn and honrfels). In the central region of the field, known as Central collapse, deep fluids have acidic properties, which have lead to corrosion and overlay in the pipes from the wells. The site of Los Humeros, unlike the other two, is vapor-dominating, with little brine production.

The field began to be explored since the early seventies. To date, 43 geothermal wells have been drilled with depths ranging from 1.450 to 3.250 meters with a standard of 2,185 meters. During 2008, there were 23 wells in continuous operation, 20 of them producers and the other three injector type. These wells produced 4.83 million tons of steam and less than half a million tons of separated brine (0.46 million), which fully returned to the site. The average production of steam was 550 t/h, that is, 158 kg /s approx.

Los Humeros geothermal power plant has a net capacity of 40 MW; It is composed of eight backpressure units of 5 MW each. The first of them opened in April 1990. The latest unit went into operation in April 2008. These eight units generated a total of 313 GWh in 2008, with an annual plant factor average of 92%, being this one of the highest in all the country.

The geothermal field of Las Tres Virgenes is the latest being exploited in Mexico. Located in the northern portion of Baja California Sur State, about 40 miles northwest of Santa Rosalia in the northern volcanic complex of Las Tres Virgenes, outside the Mexican Volcanic Strip (Figure 8.3). It is also within the area of buffer zone of the biosphere reserve of El Vizcaíno, which, with an area of 2.5 million hectares, is the largest in Latin America. The field is located in a northeast-southeast depression area known as Santa Rosalia's Basin, which forms the boundary of a zone of tectonic deformation related to the opening of the Gulf of California. Las Tres Virgenes complex comprises three quaternary stratovolcanoes aligned north to south; the most recent and meridional, called La Virgen, had its last eruption in 1746. The underground geothermal system heat source is probably the feeding magma chamber of this volcano. The reservoir geothermal fluids are in intrusive rocks, (granodiorite) covered by volcanic and volcano-sedimentary rocks, and have average temperatures of 242 ° C with a maximum of 273 ° C.

CFE began to explore this field in the early eighties and drilled the first exploration well in 1986. To date, 10 wells have been drilled with an average depth of 1.993 meters and a maximum of 2.500 meters. In 2008, three producer and one injector wells, out of four geothermal ones , operated continuously , producing more than half a million (0.55 million) tons of steam on the surface, separately at an average rate of 63 T/h (18 kg /s). At Las Tres Virgenes site liquid is dominant, as in Cerro Prieto and Los Azufres, so the steam went out with 1.8 million tons of brine that is returned in full to the reservoir through the injection well.

The small plant of Las Tres Virgenes has a net capacity of 10 MW, consisting solely of two condensing units of 5 MW each, which began operation after 2001, but were officially opened in 2002. In 2008, the units generated 41 MWh with a plant factor rather low 47%.

8.5 Impact of geothermal energy in Mexico

The current geothermal power capacity in Mexico is, as stated, of 958 MW consisting of 37 units condensing turbine generators and binary cycle counter, whose capacity goes from 1.5 MW to 110 MW, and four currently operating geothermal fields. Together, these 37 units generated 7.047 GWh of electricity in 2008, thanks to the nearly 63 million tons of geothermal steam they received.

From a national perspective, geothermal power capacity accounts for only 1.9% of the total electrical capacity of the country, which was 51.105 MW in December 2008, for electric power utility, including the CFE and private power producers to sell legally its generation to the CFE. On the other hand, power generation of thermal origin represents 3% of the total power generated in 2008 for public service, which was 234.096 GWh. Incidentally, it is worth noting that over three quarters of this total (76%) were generated with plants that used some sort of derivative of petroleum or coal, which clearly indicates the dependence on fossil fuels. Meanwhile, hydroelectric plants contributed to 38.892 GWh, equivalent to 16.6% of the total. The only two nuclear power units operating in the country (Laguna Verde) generated 9.804 GWh (4.2%) and the two wind power plants in La Venta, Oaxaca, produced XXX GW/h (0.1%) (SENER, 2009).

The general contribution of geothermal energy to generate electricity in the country is not significant. However, it is of utmost importance when considering its impact on the local level. In the case of Cerro Prieto , the four geothermal power plants give their energy to the CFE distribution system in Baja California an isolated system of the national distribution network that includes major consumption centers as Mexicali, Tijuana and Ensenada. In this distribution system, geothermal energy provides nearly half of the total demand, and in the past, it has covered up to 80% thereof, as shown in Chart 8.3. In this case, it is clear that geothermal resources have had a major impact on the development of this portion of the country in the last 35 years.

Percentage of electricity	1973	1978	1983	1989	1994	2000	2006	2008
Geothermal plants	10.4	34.5	41.4	79.4	65.5	61.9	51.0	45.9
Other plants	89.6	65.5	58.6	20.6	34.5	38.1	49.0	54.1

Chart 8.3
Cerro Prieto contribution to electricity generation in the Baja California system.

Source: Own elaboration.

On the other hand, the two power units of Las Tres Virgenes are integrated into a small distribution network also operated by the CFE, and isolated from the national grid, which includes the towns of Santa Rosalia, Mulege and San Ignacio and in northern Baja California Sur. In this circuit, the electricity generation was carried out with nine plants and one of turbo gas, both with high fuel consumption which had to be transported by boat. At present, although the two units of Las Tres Virgenes have worked half of its total capacity, it is estimated that the energy generated in this field in 2008 contributed between 55% and 60% to meet their demand . Despite its low plant factor, electricity generated from Las Tres Virgenes had a very competitive cost, and even below that of other plants operating in Baja California. Obviously, geothermal power also has a significant impact on the development of this area.

Another case worth mentioning is that of a small geothermal power plant that operated outside the distribution network of CFE, near the town of Maguarichic, in Chihuahua. Maguarichic is a town located high in the Sierra Tarahumara, 350 kilometers from the city of Chihuahua. At the beginning of the project, there were 600 residents for whom electricity was available only from 19:00 to 23:00, thanks to a diesel generator with a capacity of 150 kW. The fuel was transported through a gap of 80 kilometers in length, which during the winter snow became impassable. About 7 miles northwest of the town, the CFE identified a geothermal area known as Piedras de Lumbre, with hot springs, fumaroles and hydrothermal alteration areas with surface temperatures between 42 ˚ C and 93 ˚ C, which extend over an area of 7 km2. After conducting exploratory studies, the CFE drilled two wells with depths of 50 and 300 meters while building a binary cycle turbo generator unit of net capacity 30 kW (335 kW gross capacity). The plant consumed about 60 t/h (16.7 kg/s) of water at an average temperature of 135˚ C and 150˚C, which yielded its heat in an exchanger to gasify isopentane, the working fluid passing through the turbine, and then it was condensed by a cooling tower. After yielding its heat , the brine was injected into the ground through one of the wells. Using federal, state and municipal funds, a small transmission line, 6.5 kilometers long and 34.5 kV voltage, was built to drive electricity to the town (Sanchez-Velasco et al 2003).

The plant began operating in April 2001, and ran automatically 24 hours a day, except during maintenance periods. Therefore, it managed to provide electric power continuously for the people who suffered a radical transformation from that point on. The community formed a commission responsible for supervising the operation and maintenance of the plant. The salary of three local workers trained by CFE personnel was paid, for carrying out basic routine activities of the plant, such as recording the major readings, reviewing alarms and resetting the unit when it was fired by a minor problem. The staff of the CFE was responsible for the maintenance and for solving major technical problems. By early 2008, the unit´s operation was no longer necessary as the CFE national grid reached Maguarichic. However, they could take advantage of a small, low temperature geothermal resource for seven years, insufficient to develop a large geothermal project integrated to the network, but capable of changing substantially the lifestyle of over 100 families.

8.6 Environmental and economic aspects of geothermal power plants

The environmental impacts of geothermal power generation process can be grouped into four categories: emissions of gases into the atmosphere, liquid waste, solid waste and noise. Gaseous emissions, the white clouds that identify geothermal fields, are almost entirely water vapor. To be precise, in Mexico more than 95% of these emissions is water vapor, and the remaining 5% is over 90% carbon dioxide, which is far less than the emissions of a conventional power plant generating the same amount of electrical energy, as shown in Chart 8.4.

Thermoelectric plants using:	Air emissions in kg / MWh			
	NOx	*SO2*	*CO2*	*H2S*
Coal, U.S. national average	1.96	4.72	994.71	0.00
Oil, U.S. national average	1.82	5.45	759.09	0.00
Natural gas, U.S. national average	1.34	0.01	550.25	0.00
Geothermal steam, U.S. average	0.00	0.16	40.32	0.05
Geothermal steam, Mexico average	0.00	0.00	135.07	2.20

Chart 8.4
Average atmospheric emissions by unit of generated electricity.

Source: Own elaboration with data from Kagel et al., 2005 and Fernandez, 2005.

This Chart compares the direct emission to the atmosphere of various pollutant gases provoked by the generation of one megawatt-hour power in various types of power plants, depending on the type of fuel employed and geothermal plants. The recorded figures are national averages for 2005, so there may be variations in a particular plant at a time. In the case of Mexico, it is the total average of the four geothermal site units mentioned before, although the emission of carbon dioxide per MWh generated varies from a low of 49.2 kg in Los Humeros units, to a maximum of 221.2 kg in those of Los Azufres. The average for Cerro Prieto is 117kg/MWh, but even there, it may vary from one unit to another. It should be noted that globally, the direct emission of CO_2 into the atmosphere from conventional geothermal power plants goes from 4 kg / MWh to 740 kg/MWh, with an international estimated average of 122 kg/MWh (Bertani and Thain 2002). In any case, the use of geothermal steam prevents the emission of nitrogen and sulfur oxides into the atmosphere, which are the precursors of acid rain. Besides, the emission of carbon dioxide, the main greenhouse gas (GHG) responsible for the phenomenon of global warming is less than a quarter of what a typical natural gas plant emits , or only 13% of what is given off by an average coal-fired power plant.

Geothermal power plants emit hydrogen sulfide (H-2S),while other power plants do not. However, in the four Mexican fields in operation, emissions are below the limits set by international standards. Due to the fact that there is no specific rule for this gas in Mexico, the CFE uses the established rule for geothermal fields in New Zealand, which is the strictest internationally, and which sets a limit of 0.5 parts per million of H_2S as hourly average. To verify this, there are stations in all fields of Mexico to measure the H_2S content in the air, taking automatic readings every 10 or 15 minutes every day. Therefore, the hydrogen sulfide does not imply a greater impact on the environment beyond its characteristic odor. It is worth mentioning that binary cycle geothermal power plants emit almost no greenhouse gases into the atmosphere because it is a closed loop (ie the direct emission of CO_2 from these plants is estimated at between 0 and 1 kg / MWh).

On the other hand, geothermal process waste fluids are brines: that is, water that is separated from the mixture extracted by subsurface wells. It is saline water, inappropriate for domestic or agricultural use, so it must evaporate or eventually return to the subsoil reservoir through injection wells to prevent any possible contamination of groundwater or surface water bodies. Injection is also beneficial because it contributes to recharge the reservoir, compensating partially or completely for the amount of geothermal fluid extracted. In order to ensure that there is no contamination of aquifers or water bodies, water from hot and cold springs identified at the periphery is sampled and analyzed periodically in all geothermal fields of Mexico. It should be noted that some of the salts dissolved in the brine, such as lithium and potassium chlorides, or even silica could concentrate and be exploited as industrial salts before injecting the waste water. Although there have been some attempts in the past, this has not been done in Mexico, partly because it belongs to the basic functions of the CFE, and also because there is no clear legal framework to do so.

Solid wastes occur only during the drilling of wells. They are the waste of the fluids used for drilling. Most of it comes from bentonite inert clay, and it is treated according to the respective environmental standard, since the drilling of all types of wells is regulated by the Ministry of Environment and Natural Resources (SEMARNAT .)

Finally, regarding noise, the main emission source is the discharge of the wells and back pressure turbine (without condenser) into the atmosphere. To reduce noise level , CFE developed and uses different types of silencers. The Commission even has a patent for a specific type of equipment. These silencers can reduce noise up to 80% at a distance of 3 meters from the source and up to 74% at a distance of 50 meters. This is within the limit of 90 decibels allowed by the Secretary of Labor and Social Welfare (STPS) for eight-hour working- days.

With regard to land use, no specific studies have been carried out in Mexico, but in America it is estimated that geothermal power plants use less land area compared to other fossil or renewable fuels. Looking back over a period of 30 years, the life cycle used to evaluate the environmental impacts of power projects, it is estimated that a geothermal power plant uses 404 m2 per GWh generated, while a coal-fired uses 3.642 m2/GWh (including land needed for the mines), while a solar thermal plant requires 3.561 m2/GWh , a solar photovoltaic 3,237 m2/GWh, and a wind-electric power currently employs 1,335 m2/GWh . (Blodget and Slack, 2009). For all the above, geothermal energy is considered one of the so-called green or environmentally sustainable energies.

From a different perspective, geothermal power generation in Mexico has the lowest unit cost of all types of power plants, and is superior only to that reported by hydroelectric plants. Chart 8.5 shows the annual generation costs average calculated by the CFE for the kWh produced in 2008 with plants using different technologies. The generation cost is expressed in current pesos per kWh and includes the following items: salaries and benefits, cost of labor obligations, fuel, maintenance cost (including service contracts) consumables and maintenance, depreciation, cost of funding (known as harvesting) cost of taxes and rights, CFE corporate overhead costs and other expenses CFE (CFE, 2009).

As shown in the Chart 8.5, the cost of generation in Mexico during 2008 ranged from a maximum of $ 7.85 per kWh for conventional power plants based on diesel, to a minimum of $ 0.49 for hydropower plants. Geothermal

Plant type	Unit cost in 2008 ($/kWh)
Thermoelectric (diesel)	7.85
Thermoelectric (fuel oil)	1.58
Gas turbine and combined cycle	1.38
Coal and dual (coal and fuel oil)	1.10
Nuclear	0.82
Wind	0.74
Geothermal	0.59
Hydroelectric	0.49

Chart 8.5
Average unit costs of generation in 2008 by technology type.

Source: CFE, 2009.

plants had the second lowest cost of generation. Of course, these are national averages which vary from one to another plant, even if they use the same technology and fuel, depending on various factors such as their capacity and seniority. To provide a more accurate idea, Chart 8.6 includes other costs of power generation for some specific individuals operating in the same region of generation of the CFE, with figures for 2006 expressed in current pesos from that year, and its updating in 2008.

Region	Plant	Type	Capacity (MW)	Cost ($/kWh)	
				2006	*2008*
Northwest	Cerro Prieto	Geothermal	720	0.32	0.35
	Puerto Libertad	Thermoelectric	632	0.93	1.02
	Las Tres Vírgenes	Geothermal	10	4.09	4.48
	Ciudad Constitución	Gas Turbine	33	6.93	7.60
West	Los Azufres	Geothermal	188	0.18	0.20
	Manzanillo II	Thermoelectric	700	0.85	0.93
Southeast	Los Humeros	Geothermal	35	0.31	0.34
	Mérida II	Gas Turbine	30	4.56	5.00
	Mérida II	Thermoelectric	168	1.15	1.26

Chart 8.6
Average unit costs of generation in specific power plants in 2006 (in 2008 Mexican pesos).

Source: Own elaboration.

It can be seen that the costs of generating geothermal power ranged from $ 0.18 per kWh in Azufres and $ 4.09 for Las Tres Virgenes expressed in current pesos of 2006, while generation costs obtained at Cerro Prieto and Los Húmeros were very similar. Although unit costs in Las Tres Virgenes is high, the fact that this plant operates under an isolated distribution system in the Baja California peninsula should be considered, as the operating cost of conventional power plants is higher than the national average because all fuel must be transported from the other side of the gulf. However, despite being higher than in other geothermal fields, the unit cost of electricity generated in Las Tres Virgenes is very competitive with other plants that are relatively close, as that of Ciudad Constitución, included in the same Chart.

8.7 Direct uses of geothermal energy

In 2005 around 75 countries worldwide used geothermal energy in various applications directly. The list was headed by the United States with an installed capacity of 7.817 thermal megawatts representing 28% of the world capacity and an annual use of 31.239 terajoules, equivalent to 12% of total usage in terms of energy. Sweden ranked second in terms of installed thermal capacity with 3.840 MWt, but with a more intensive use of its resources with 36.000 TJ / year. However, the world's first direct use of geothermal energy was occupied by China with 45.373 TJ / year , although it only had 3.687 MWt of thermal capacity. In a distant fourth place was Iceland, with 1.791 MW /t ,and an annual geothermal use of 23.813 TJ (Lund et al., 2005).

Mexico was among the countries with the least direct use of geothermal energy. The updated figures for 2008 have not changed much since it is estimated that the country had an installed capacity of 156 WHT and an annual use of 4.023 TJ for almost all resorts and spas in 18 states of the Republic (Gutiérrez-Negrin et al 2009). The CFE has developed some pilot projects for direct use in the field of Los Azufres using the heat from the brine prior to injection wells. These include a separate heating system for their facilities in this area, a wood drying chamber and a fruit and vegetable dehydrator.

In Los Azufres the temperature can get to 3 °C or less in winter time, so CFE designed and installed a hydronic heating system in their residence offices and visitor homes that take a fraction of the brine residual energy. Part of this is conducted to a heat exchanger which, without mixing, yields its heat to a closed circuit where sweet water is circulating. This water is pumped into the radiators installed in the areas to be heated, which performs the transfer of heat by natural convection. In each area there is a thermostat that controls temperature automatically and keeps it at 22 ° C. The use of geothermal brine is about 1 ton per hour (Sánchez Chávez Velasco and Rangel 1997)

The wood drying chamber, which also works in Los Azufres, is 8 meters long, 3.5 meters wide and 3.5 meters high with a capacity of 9 000 feet / table. The heat source is the geothermal fluid that reaches 170 ° C and provides 40 kilojoules per second (kJ / s) of heat energy. Operating fans are used intermittently to keep the temperature uniform within the chamber, between 60 ° C and 77 ° C.

There are air extractors that operate continuously to remove moisture and to maintain the established ranges of temperature and humidity. They are used to dry pine, oak and ash in one tenth of the time required to obtain a natural and uniform drying and final moisture percentages ranging from one third to one half of the remaining moisture with a natural drying (Pastrana Melchior 1997).

The fruit and vegetable dehydrator, measures 1 meter long by 3 meters wide and 2 meters high. It has a capacity of 448 kg of fruit or vegetables . It requires 10 kJ / s of heat energy, which is provided with 0.03 kJ / hot water at a temperature of between 40 and 60 ° C ° inside. The heating system comprises two serpents, a thermometer, a manometer and a pressure control valve. The air circulation system is an axial fan 120m3 per minute. The dehydrator's operation consists of raising the temperature of air flowing in its interior, passing through a heat exchanger. When moving through fruit or vegetables , hot air causes evaporative water loss in plant tissue, to obtain a product with the desired humidity (Casimiro Espinoza, 1997). Although the area surrounding the field of Los Azufres is dedicated to wood and fruit production, both the drying chamber and the dehydrator have only been demonstration projects , but have not been traded on an industrial scale.

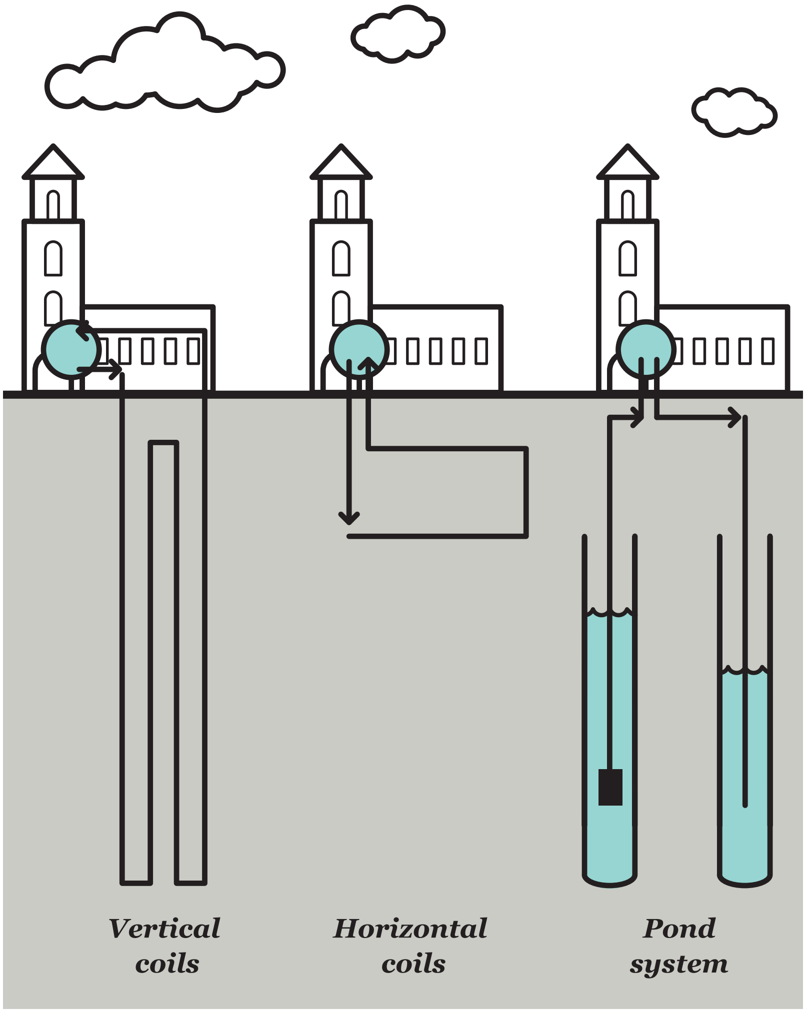
Worldwide direct uses of geothermal energy in 2005 totaled an estimated total capacity of nearly 28,000 MWt: that is almost three times the global geothermal power capacity. With this capacity, just over 261.000 TJ were produced annually , equivalent to 72,622 thermal equivalent-hours gigawatts per year, for an average annual plant factor of 30% (Chart 8.7)

Application type	Capacity (MWt)	Use (TJ/ year)	Plant factor
Geothermal heat pumps	15,723	86,673	0.17
Spas and health resorts	4,911	75,289	0.49
Heating	4,158	52,868	0.40
Greenhouses	1,348	19,607	0.46
Aquaculture	616	10,969	0.56
Industrial uses	489	11,068	0.72
Refrigeration and thawing	338	1,885	0.18
Agricultural drying	157	2,013	0.53
Other	86	1,045	0.39
Total	27,826	261,417	0.30

Chart 8.7
Source: Lund et al., 2005.

The above Chart shows that the direct use of geothermal energy in the world corresponds mainly to geothermal heat pumps. These take advantage of the ground temperature, which remains relatively constant throughout the year at shallow depths between 3 and 100 meters. This buries a closed system of plastic piping, in horizontal arrangement (a 1 or 2 feet deep) or vertically (through a well aged 30y 250 meters deep) under a given surface. Using a pump, fresh water is circulated (which, if necessary can be mixed with antifreeze) through pipes buried in which way the water is gaining ground temperature.

In the summer, underground temperature is lower than the environment and out of the water pipe, water can be used to cool the house or building through a conventional air-conditioning ducts. In winter water comes out at a higher temperature than the environment and, through the same system, it can be directed to a tank to get hot water. This is known as a closed loop but an open cycle can also be used. This uses groundwater or from a lake directly in a heat exchanger and then discharges it into another well, in a stream or lake or even onto the floor (Figure 8.4).



Closed systems (left and center) and open (right) heat pumps. The most commonly used system is to the left, with heat exchanger wells.

Source: Lund, 2000.

Geothermal heat pumps reduce the power consumption from 30% to 60% compared to traditional cooling or heating systems, since in this case electricity is only used for collecting, concentrating, and delivering heat through a pump, but not to produce it (Bloggett and Slack 2009). In 2005, it was estimated that there were about 1.3 million homes in 32 countries that used geothermal heat pumps as heating system, and to a lesser extent as air conditioning (Lund et al, 2005). By 2008, the estimate was about 3 million users of these pumps only in the U.S. , with approximately 800 000 operation units and a capacity of 9,600 MWt

Although geothermal heat pumps do not seem to have many opportunities for development in Mexico due to mild weather in most of its territory, there are possibilities for other direct uses of geothermal energy, apart from resorts and spas. The low to intermediate temperature geothermal resources are abundant in the middle of the country: a recent study estimated that the total reserves of 276 locations in 20 states identified springs in the country, with temperatures between 60 ° and 180 °C, are of 2.26 x 1.010 MWt, the equivalent of the heat energy contained in a thousand 900 million barrels of Arabian Light crude oil type (Iglesias and Torres 2009). These resources of low to intermediate temperature could be used in aquaculture for rearing fish in ponds with controlled temperature, such as tilapia, bass, salmon or trout. They could also be used in industrial processes that require hot water, as it is currently done in several countries for concrete curing (Guatemala and Slovenia), for the pasteurization of milk (Romania), in tanneries (Slovenia and Serbia) to produce carbon dioxide (Iceland and Turkey), in industrial laundries (USA), in the paper industry (New Zealand) and for the extraction of salts (Italy and Vietnam) (Lund et al 2005). Regarding the latter it may be noted that the geothermal brine from Cerro Prieto field, for example, contains more than 1.600 parts per million (ppm) potassium and about 18 ppm lithium, so it is calculated that up to 80,000 tons of potassium chloride could be extracted and about 4,000 lithium salts with large demand in the domestic and international markets.

8.8 Prospects and obstacles for development of geothermal energy in Mexico

The prospects for geothermal development in the already known fields include the following CFE projects. The CP-V project in Cerro Prieto involves the construction of two new condensation units and of 50 MW each to replace the two oldest units of 37.5 MW from the central plant CP-I in operation since 1973. The new 50 MW units will be more efficient than the old ones, so they will consume about the same amount of steam but will generate more, thus getting a net gain of 25 MW. This project is scheduled to enter commercial operation in April 2011 (CFE, 2008). Los Humeros II project is under construction in Los Humeros field. The project is the construction and installation of a condensing unit of 25 MW, which will start operating in 2011 (CFE, 2008). There are also plans to install seven binary cycle units of 3 MW each, which would work with the remaining steam of seven of the backpressure units currently discharged to the atmosphere. With both projects an additional net capacity of 46 MW could be obtained.

In the case of Los Azufres, CFE is studying the feasibility of Los Azufres III project, also composed of 2 stages. The first has a unit of 25 MW and the second has a unit of 50 MW, both of them condensation units. This initiative includes the dismantling of the seven backpressure units, which currently operate with a combined capacity of 35 MW, so the net increase capacity would be 40 MW. With this, the installed capacity in Los Azufres would amount to 228 MW, with essentially the same current consumption of geothermal steam.

In addition, there is a fifth geothermal field in Mexico that is practically ready to generate electricity. This is the Cerritos Colorados field, located on the outskirts of the city of Guadalajara, Jalisco, inside a volcanic caldera (La Caldera de la Primavera) in the western portion of the MVB (Figure 8.3). In the eighties the CFE drilled 13 wells with depths of between 670 meters and 3.000 meters, and almost six of them were producers. According to the characteristics of these wells, it is known that geothermal fluids are contained in a package of volcanic rocks in the field´s subsoil (andesites and tuffs) with a total depth of 2,400 meters and resting on a base of intrusive rocks (granites). The hydrothermal fluid reservoir is dominant at temperatures between 250 ˚ 348 ˚ C (Gutierrez-Negrin 1988) and based on the quantification of the resource models and numerical simulation, it has a proven capacity of 75 MW. The field is within Bosque de la Primavera, which has a total area of 36,000 hectares. In early 2009 SEMARNAT finally approved the Environmental Impact Statement, submitted by the CFE for the construction, installation and mounting of two condensing units, one of 25 MW and another 50 MW in two stages, as well as a transmission line 69 kV of 14.5 km in length. It is expected that the first unit is ready by 2012, so that this geothermal resource could begin to be harnessed deferred over 20 years..

Therefore, the country's proven geothermal reserves from high-temperature hydrothermal deposits currently total 186 MW: 25 MW in Cerro Prieto, 40 MW in Azufres, 46 MW in Los Humeros and 75 MW in Cerritos Colorados. These 186 MW amount to 18% of the current installed capacity geothermal power.

The CFE Geothermoelectrical Project Management has identified 545 geothermal areas, several of which have already been explored in detail in search of high-temperature resources for electricity generation from large scale. These last include Tulecheck areas in Baja California, Acoculco in Puebla, La Soledad in Jalisco, Nayarit San Pedro Dome and Tacana volcano in Chiapas. In the first two areas, the CFE has carried out more exploratory studies recently and has drilled two deep wells in Acoculco. Despite this, it appears that there are no more large deposits of high temperature to be discovered in the country, such as Cerro Prieto o Los Azufres. Additional high temperature deposits that might be discovered and exploited in some of the areas mentioned will probably have a size between that of Los Humeros and Las Tres Virgenes; that is, about 20 to 25 MW. Likewise, if five new conventional geothermal fields are being considered in the medium term, additional capacity will be between 100 and 150 MW, the equivalent to 13% of current capacity.

But in Mexico there are still untapped geothermal resources in deposits of medium to low temperatures, in hot dry rock reservoirs, especially those hidden or without surface thermal manifestations, and in hydrothermal windows of the Gulf of California. With regard to the first geothermal resources, CFE identified nearly 50 areas in nine states of the Republic with underground temperatures between 120 ° and 200 ° C. While there are not enough areas to install unit cycle plants, they could certainly support the operation of modular binary cycle plants like the one that worked several years in Maguarichic, Chihuahua. There are no estimates of the likely geothermoelectric potential of these resources, but from the study of thermal reserves of Iglesias and Torres (2009) it seems reasonable to assume that this potential would be at least similar to the current geothermal power capacity of the country, that is about 1,000 MW Power in round numbers.

Of course those resources of medium to low temperature could also be used for various direct uses worldwide. It is estimated that by 2020 direct uses of geothermal energy could reach almost 174.000 MWt , of which 82% (143,000 MWt) would be installed on heat pumps and the other 18% (30.900 MWth) in other direct applications.

As for hot dry rock geothermal resources that can be developed as enhanced geothermal systems (EGS), the principle is very simple, though still difficult to implement. In subsoil areas where high temperatures without geothermal fluids are detected, a network of fractures in rocks is created or enhanced, using techniques such as hydro fracturing or thermal fracturing, consisting of cold water injected under pressure into a well. Subsequently, another closer well is drilled at a similar depth. In the first well temperature water is injected, which is heated as it descends, infiltrates through the created or enlarged fractures network, and is recovered in the second well at a temperature above the injected ranging from 150 ° C and 200 ° C. Hot water or steam can be obtained on the surface then used to generate electricity with binary plants or for any direct use (Figure 8.5).

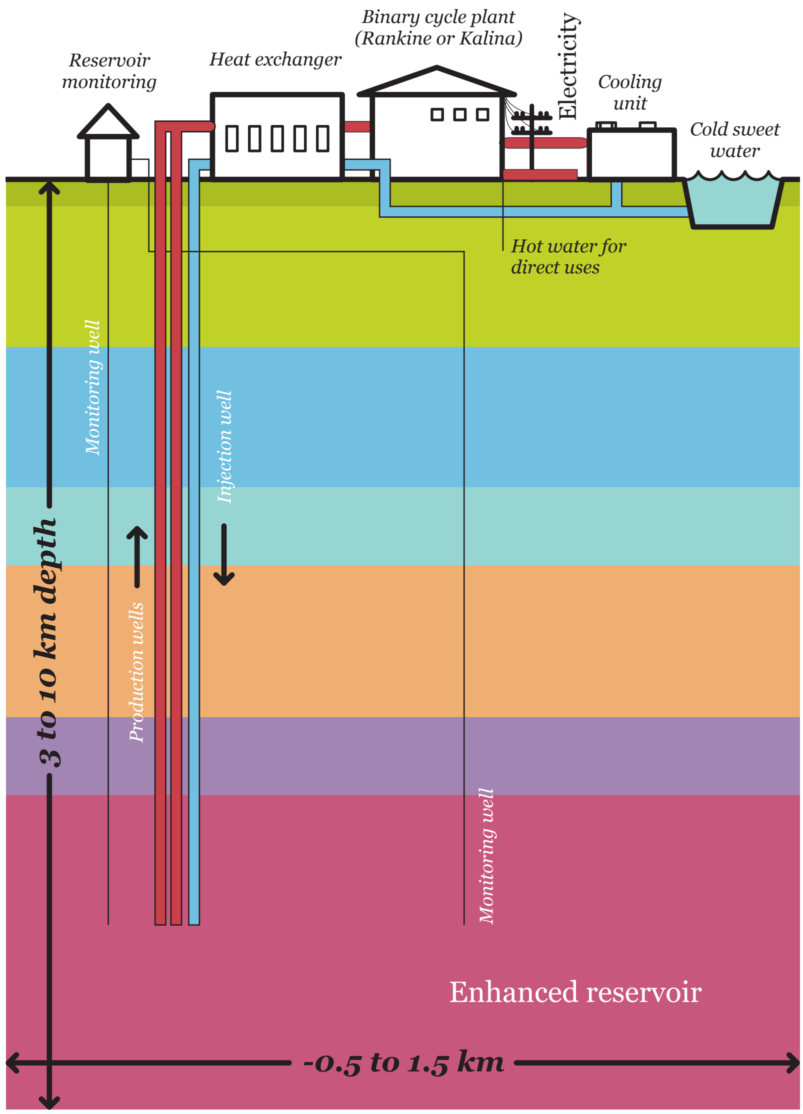


Figure 8.5
Schematic of an enhanced geothermal system (EGS).

Source: Haring, 2007.

There are currently some such projects in development in Australia, USA and Germany, and two small pilot plants that use EGS reservoirs are already operating in France (Alsace, with 1.5 MW) and Germany (Landau with 2.5 MW) (Baumgartner et al 2007). There is no data on unit costs of generation, but investment costs are estimated between $ 13,000 and $ 21,000 per installed kilowatt , well above the investment cost of a conventional geothermoelectic plant which has an average cost of $ 2,000 per kilowatt (excluding wells). Yet Mexico´s geothermoelectric potential on EGS resources is at least equal to the current installed geothermoelectric capacity , resulting in 1,000 MW more, where costs are competitive.

Finally, there are the submarine hydrothermal systems, located in vents on the ocean floor ridges. At the bottom of the Gulf of California vents at temperatures up to 360 °C and other shallower and cooler ones on the Pacific coast have been identified . Theoretically, you can generate electricity from a submarine hydrothermal vent encapsulated by a binary cycle plant, as described by Hiriart and Espindola (2005). Although it is a technology that is still in design phase, it is estimated that the geothermoelectric potential of this undersea resource is similar to EGS resources (Hiriart et al 2009). Therefore, geothermal resources in Mexico submarine windows could add a thousand MW of electricity in the long term.

In summary, the prospects for development of geothermal energy in Mexico include a minimum potential of 3,000 MW additional installed capacity and the current proven reserves (Chart 8.8).

To date there are no major barriers to continue taking advantage of conventional, high temperature geothermal reservoirs in Mexico, both in the already known fields and in the few ones that remain to be discovered and exploited. But for unconventional geothermal resources such as medium to low temperature reservoirs and the probable submarine deposits, hot dry rock reservoirs and offshore fields, there are both technological and economic barriers.

Among the barriers for the development of low to medium temperature and hot, dry rock reservoirs is a lack of specific, cheap exploration and evaluation techniques , particularly when these superficial deposits lack superficial evidence. Another obstacle is the routine drilling techniques that reduce permeability of subsurface rocks by the interaction of these with drilling fluids, but that could be solved by using a drilling mud that exerts less pressure (such as the so-called underbalanced drilling , or NBD, Near-

Type of reservoir:	Installed capacity (MW)	Proven reserves (MW)	Probable reserves (MW)	
Place / Term (years)	*Current*	*Short (<5)*	*Medium (5-10)*	*Long (>10)*
Cerro Prieto, BC	720	25	—	—
Los Azufres, Mich.	188	40	—	—
Los Humeros, Pue.	40	46	—	—
Las Tres Vírgenes, BCS	10	0	—	—
Cerritos Colorados, Jal.	0	75	—	—
Other high temperature geothermal areas	0	0	100-125	—
Low to medium temperature reservoirs	0	0	~1,000	—
Hot dry rock reservoir (EGS)	0	0	~1,000	—
Offshore fields	0	0	0	~1,000
Total	958	186	2,100-2,125	1,000

Chart 8.8
Installed power capacity and geothermal reserves in Mexico.

Source: Own elaboration.

Balanced Drilling) or by using aerated fluids. In fact, it requires a new generation of geothermal drilling aimed at reducing well costs, which in hot dry rock systems or low temperature, can account for half of the total project investment. Also in hot dry rock reservoirs, sufficiently precise fracturing techniques have not been yet developed to produce or improve the fracture network in the conditions required.

Another technological hurdle is the low efficiency of geothermal fluid heat exchange with working fluid in binary cycle plants. The net current efficiency with which plants convert this type of heat into electrical energy is between 5% and 15%, while that of conventional geothermal power plants ranges from 15% to 25%.

Among the economic barriers, it should be remembered that while in Mexico the unit cost of electricity generated from conventional, high temperature geothermal resources is very competitive, the cost of energy generated by low to medium temperature , hot dry rock resources will be, at the beginning, much higher. Therefore, it is necessary to establish a subsidy per geothermal kWh that facilitates competition with implicit subsidies that power plants based on fossil fuels receive , or increase the unit price of electricity produced by these plants to integrate the cost of tons of CO2 emitted into the atmosphere. One way to subsidize the installation of geothermal power plants that use these new resources is through specific legislation for geothermics.

To date, geothermal resources in Mexico are in the water, at a higher temperature above 80° C, provided by the National Water Act. However, these resources are actually qualitatively different to those for drinking and other uses water, and therefore require a specific legislative management. Moreover, the National Water Act does not contemplate their use, which is the main product of geothermal energy, and does not necessarily imply a consumptive use of these fluids. Therefore, a mechanism to protect geothermal reservoirs and to promote its development would be the establishment of specific regulations with a licensing system that allowed its use in an area whose imaginary boundaries went from the surface to the subsurface. This would prevent the simultaneous exploitation of two or more dealers of the same geothermal reservoir.

8.9 Conclusions and recommendations

Geothermal energy is a renewable resource, since the energy obtained is continuously replaced with more energy on a similar scale to that required for its production. For this reason, geothermy is not a mineral resource and it can be exploited in a sustainable way with adequate production rates to the specific characteristics of each site (size, temperature, pressure, natural recharge, etc). The production of geothermal fluids creates a cone of depression in the ground which, in turn, produces more fluid to replace those being extracted, and tries to restore the initial conditions of the site. This natural resilience of geothermal fields, which is non- existent in mineral or oil reservoirs, is the basis for its sustainable use.

Worldwide, the direct uses of geothermal energy for heating, spas, greenhouses and other agricultural and industrial uses, including geothermal heat pumps, have been developed much more than its indirect use for electricity generation. In Mexico, the opposite occurred, and at present the country has a capacity of 958 MW geothermal power in operation , with proven additional reserves of at least 186 MW and additional probable reserves of at least another 3,000 MW. But for the development and exploitation of unconventional geothermal resources, such as the low and medium temperature hot dry rock and the offshore, we need to overcome the current technological and economic barriers that make them unaffordable.

It is advisable to research and implement drilling techniques that bring well costs down. At the same time, it is essential to create new materials at lower costs (pipes, pumps, additives, heat exchangers, cooling systems) and integrate innovative designs, so that the whole system becomes more efficient and economical. In that sense, cascade systems (or multipurpose projects) in which the geothermal fluid is used to generate electricity and in other direct uses (heating, agricultural and industrial processes, recovery of valuable minerals in the brine) can be a technological solution. Additionally , the way to reduce the use of stainless steels in certain plant components must be found.

Added to this, it would be advisable to have specific legislation for geothermal energy. This should include the initial grant for the development and exploitation of geothermal resources, particularly the unconventional ones, through fiscal stimulus, or other mechanisms like renewable, environmentally benign energy elsewhere. This would increase the availability of services for geothermal exploration, attract investment in research and development and strengthen international cooperation in this sector. It is also advisable that both conventional and unconventional new geothermal projects call upon the Clean Development Mechanism (CDM) of Kyoto Protocol for carbon credits or certified emission reduction (CER) needed to bring down the total unit cost.

The above will undoubtedly help to ensure the country's energy supply , to mitigate the effects of climate change and strengthen a diversified power market in a socially, environmentally and economically sustainable way.

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9. Solar Photovoltaic Energy

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9.1 Introduction

9.1.1 Technology: Function Principles

Cells, thin film and photovoltaic modules

The conversion of the luminous flow (photons) in electrical currents (electrons) is a sub-atomic process that occurs in the semi-conductor elements of the periodic table such as silisium (Si), Indio (Ln) and selarium (Se) among others. The semi-conductors characteristically have two layers; one naturally positive and one negative. When exposed to the luminous radiation, the semi-conductor material previously contaminated with other elements generates an electrically-charged field which translates into a difference in voltage between both layers (Vanek & Albright, 2008).

Historically, the most widely used semi-conductor is silisium which is used to manufacture crystalline cells (which can be mono or poly-crystalline) as well as thin film. Although silisium is the main component of sand and is the second most abundant element in the earth´s cortex after oxygen part of its commercial success derives from the knowledge and the infrastructure that the electronics industry has generated during more than a half century.

The crystal silisium (Si-c) value chain is sufficiently mature that the manufacturers of the finished product (photovoltaic modules) guarantee 80% of the original efficiency for 25 years. Some of these manufacturers are technological companies that are among the most important in the world. Solar-grade silisium crystallizes in bars, industrial reactors and are cut into wafers that are continually thinner (an average of 0.17 mm in 2008) (EPIA, 2009). These wafers are thermally and chemically treated, are tested, classified and are converted into photovoltaic cells. The wattage of each cell varies between 1 and 3 peak-watts (Wp). The cells are interconnected, are encapsulated and are sanded in a photovoltaic module. The wattage of the modules that are used on the roofs in many parts of the world oscillates between 80 Wp and 200 WP. The following figure shows the steps in the process:

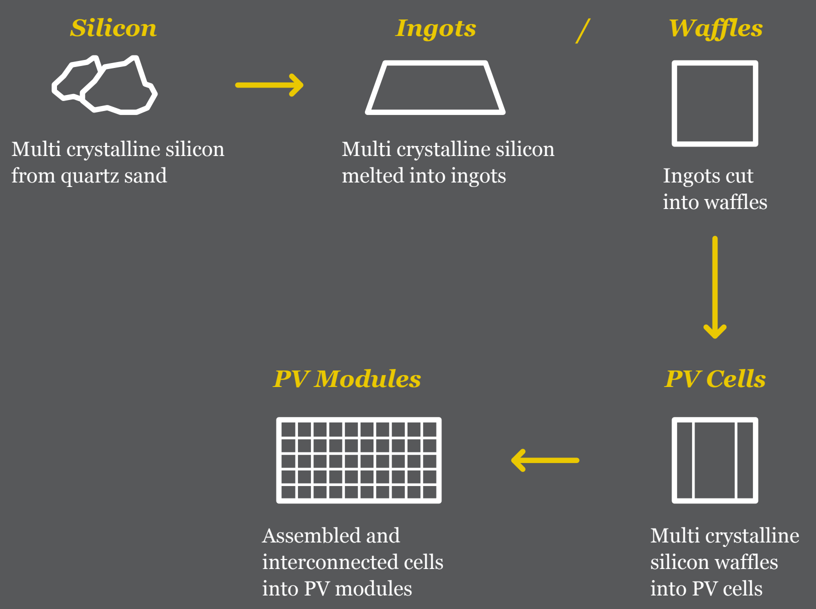


Figure 9.1
Value Chain Multi-crystalline Silisium

Source: BNET Industries, 2009.

The market offers technologies that are not based on crystallized silisium and the scarcity of this raw material during the middle of the decade has led to its increased use. With this technology modules using amorphous silisium (S-a), cadmium ((CD), selarium of copper and Indio (CIS, CIGS) have been produced. These modules use lower cost materials however their efficiency rate is much lower than the modules based on Si-c technology or the companies are not sufficiently mature to maintain a solid supply.

Solar panel generation conditions

A solar panel or photovoltaic arrangement is a grouping of photovoltaic modules. The modules are interconnected “in series” or “in parallel”. A solar panel can contain any number of modules depending on the capacity of the system to which it will be connected. A photovoltaic solar panel based on any of the existing commercial technologies available takes advantage of the direct solar radiation (the sun) as well as from the diffuse (the rest of the sky) which allows it to generate electricity even on cloudy days. The energy obtained during any given moment of the day depends on the angle of contact with the earth´s surface of the solar rays. In this manner, the maximum power value (WP) is reached at noon when the rays are perpendicular to the surface of the panel. To counterbalance the loss of power in the morning and the afternoon, mobile panels which follow the sun are used. These instruments work like a sunflower and follow the sun´s trajectory during the day in order to maintain the photovoltaic surface constantly perpendicular to the solar rays. Compared to fixed panels, the use of a mobile panel will increase the energy generated by 30 percent during a clear day. However, the market contains primarily fixed panels with the panel surface facing the equator and with an angle determined by the latitude of the location.

The commercial photovoltaic modules with crystalline cells are capable of transforming from 14 to 16 percent of the total solar energy received per square meter of the earth´s surface. At the extreme lower section of the module are the organic cells which have an efficiency of 5.4% (IEA, 2007). By comparison, the thin film technologies record an efficiency of between 5 and 11 percent and therefore occupy, in some cases, double the space in order to generate the same peak power as the crystalline units. On the other hand, the Si thin film modules have the advantage of being more sensitive to the diffuse or indirect radiation. For example, a polycrystalline commercial module with a power value of 125 WP has a surface of 0.93 square meters (m2) while a Si-a thin film module with a power value of 124 WP measures 1.95 m2 but generates between 20 and 30 percent more energy during an average day.

Functioning and Components of the Photovoltaic Systems

The solar panel generates direct current (DC) only during the day and therefore requires a complete electric system in order to take advantage of solar energy for real applications. These systems are called photovoltaic (PV systems). The capacity of the PV systems is measured in terms of the capacity of its components in accordance with the energy needs and the efficiency losses of each one of these. Generally speaking, they are classified in two types: autonomous (off-grid) and connected to the electrical grid (on-grid).

The off-grid PV systems have a battery bank to store energy so it is available 24 hours a day. The batteries are charged using a photovoltaic charger which maximizes the accumulation of energy and protects the panel and the batteries. In countries with a large rural population and with government incentives for photovoltaic co-generation, the off-grid PV systems are prevalent in the market. For example, in Mexico at the end of 2007, these systems represented close to 98% of the total photovoltaic systems installed in the country (IEA, 2008).

On the other hand, the on-grid systems generate electrical energy without storing during the day. The solar panel is connected to a grid inverter which injects the energy to the power source at the same time that it is generated. The user can consume this energy or he can deduct it from his electrical bill or sell it to the national grid. In places with access to energy generated by conventional methods, the on-grid PV systems produce greater income than the off-grid systems. This type of system is more prevalent in the world due to its greater presence in the electrical energy generation schemes of the countries especially in those countries that signed off and committed to emissions reductions in the Kyoto Protocol. For example, in Germany this type of system represented more than 99% of the total accumulation at the end of 2007 (IEA, 2008).

The PV systems can be hybrid and receive energy from other sources such as aero generators, micro-hydraulic turbines, and motor generators among others. This characteristic allows the systems to be more efficient, for example, on the coast where there generally are wind currents and fog. An example of a hybrid wind-solar power system can be found at the Autonomous Technological Institute of Mexico (ITAM) south of Mexico City. The electrical diagram of this system follows:

Another characteristic which makes the PV systems superior to conventional systems is the use of modules. The increase of generation or storage capacity of these units can be achieved by adding PV modules or more batteries without discarding or interchanging costly components. Likewise, if the need arises to increase alternate current (AC) electrical power to cover in-house consumption or to return power to the grid, all that is needed is an increase in the number of inverters in parallel.

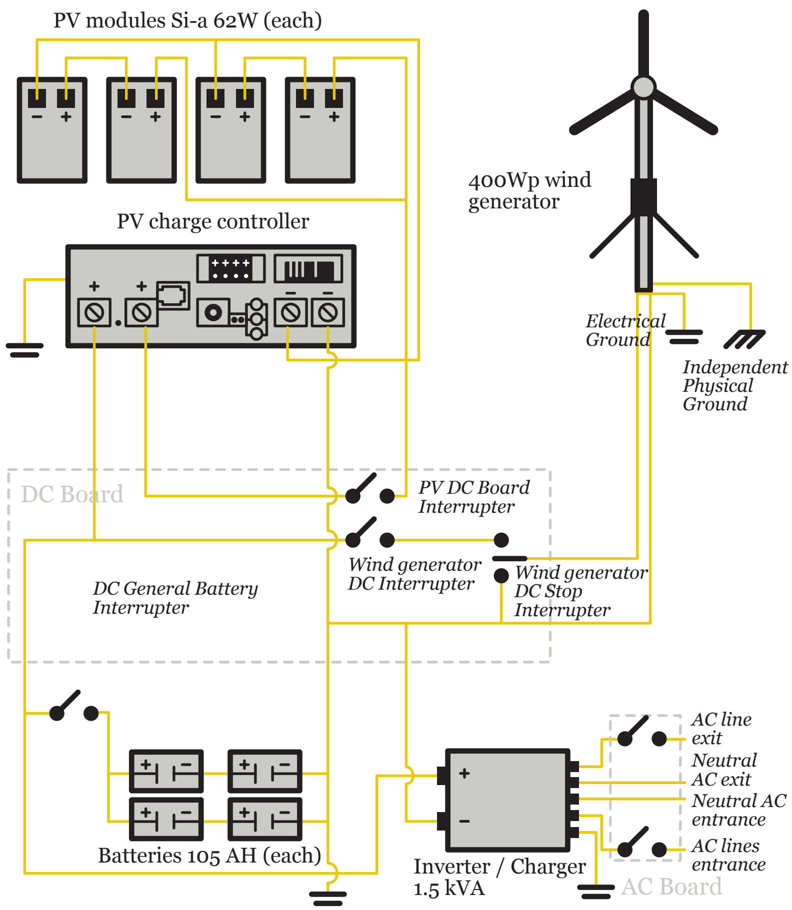


Figure 9.2
Example of Electrical Diagram of Hybrid System PV-Wind Powered.

Source: ITAM, 2009.

9.1.2 Applications, Capacity and Technical Limitations

During the 20th century, the off-grid PV systems were used in greater numbers as they were more affordable to operate compared to conventional systems for covering energy needs in remote areas that were distant from the national power grid. Therefore, at the end of 1992 they represented approximately 74% of the total installed photovoltaic systems. This panorama was dramatically inverted at the end of the decade of the 90´s with the implementation of public policies designed to promote investigation, production and consumption of PV systems in a great number of countries. In 2000, the off-grid systems represented less than 40% of the total and by the end of 2007 they were only 10% of the total (IEA, 2008).

Autonomous or Off-Grid Systems

The most common off-grid PV systems are the ones designed to cover domestic needs in rural areas principally for lighting and small drinking water pump systems; these applications abound in Mexico. They also represent a very popular solution to cover the energy supply at remote installations such as for eco-tourism, education and community centers, and public lighting. At solar panel installations smaller than 10kWp, the off-grid PV systems have shown to be highly reliable and efficient with a useful life greater than 30 years.

Notwithstanding, these systems do not have the storage capacity to supply great amounts of energy for example, to an industrial plant as the electricity produced has to be stored at battery banks. Moreover, given their cost and the space they occupy, the excessive application of batteries leads to problems related to the balance of the electrical charges as well as to an accumulation of explosive gases at the site where the batteries are located. However, other options for the accumulation of energy are available such as compressed air in pressurized tanks (CAES, English initials) and afterwards, its discharge through a turbine that generates electrical power.

On-Grid PV Systems

The on-grid systems are classified as two types: central and distributive. The central systems are usually installed in vast extensions of land regulated by using long-term contracts and are connected to the power grid. The distributive systems are generally installed on roof tops, walls and windows of buildings and houses and are therefore geographically disperse. The photovoltaic integration at buildings or BIPV (Building Integrated Photovoltaics) is growing more popular. This is due in part to that in the European Community, the United States of America as well as in Mexico the authorities are standardizing (obligatory at certain levels) energy savings and the use of renewable energy at new buildings as well as to the fact that one of the more viable options for builders is BIPV.

Motivated by the incentives to sell solar energy to the grid at a price several times higher than the purchase price, the private builders install on the roof shingles the on-grid PV systems with a capacity that fluctuates between 1 kWp and 10 kWp. Due to the high level of reliability of the PV systems, the investors see solar photovoltaic energy as a great business opportunity leading to centralized projects that occupy vast extensions of territory. These systems present capacities that vary from hundreds of kWp to several MWp. Although the more extensive projects are found in Germany, United States of America, Spain and Japan, the on-grid systems have proliferated throughout the world such as in Eastern Europe, South Korea, India and other countries.

9.2 The PV Market: Industry and Politics

9.2.1 Production and Consumption Around the World

The use of renewable energy as a possible solution to climate change and the positive results obtained from investigation have promoted the development of all the fields of photovoltaic technology and the associated industries. Moreover, the long-term government incentives which are strategically planned and organized have also become a strong factor contributing to the development of this industry. In the new millennium, photovoltaic technology has a strong international industry in growth the same as any other important productive sector in the world. The use of solar photovoltaic energy is a part of the energy strategy in many countries and is on the agenda of several international organisms such as the United Nations and the World Bank.

A great many international industrial associations operate throughout the world such as the ISES (International Solar Energy Society), together with the regional organizations such as the EPIA (European Photovoltaic Industry Association) and the national organizations such as the NASE (National Association of Solar Energy) in Mexico. Some private and government centers such as the SANDIA Laboratories in the United States of America and universities such as the University of California at Berkeley and the National Autonomous University of Mexico (UNAM) carry out applied investigations. The photovoltaic energy companies are listed on the stock exchange such as the NASDAQ, sponsor soccer teams such as the Royal Sports Club Español and take part in the diversification plans of giant oil companies such as BP (British Petroleum). Although the solar energy market cannot be compared in size to the oil market, the photovoltaic products are now part of the daily life of people all over the world from remote villages to great cosmopolitan centers.

In 2007, with an installation of barely 2.39 GW, the industry employed one hundred thousand people and represented a business with a value of approximately 17 billion dollars (IEA, 2008). In 2008, installed capacity doubled which positively impacted the economic growth of the silisium producers and the banks which financed the projects. A synthesis of the supply chain of the PV industry follows:

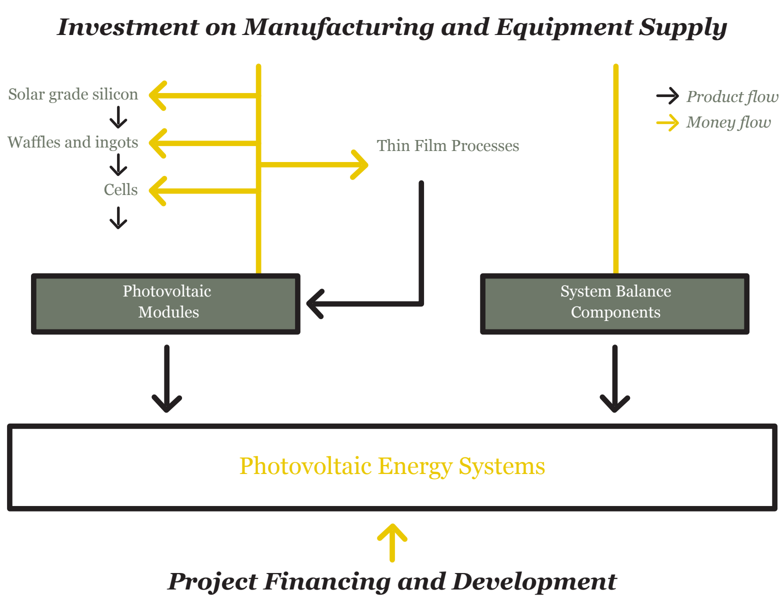
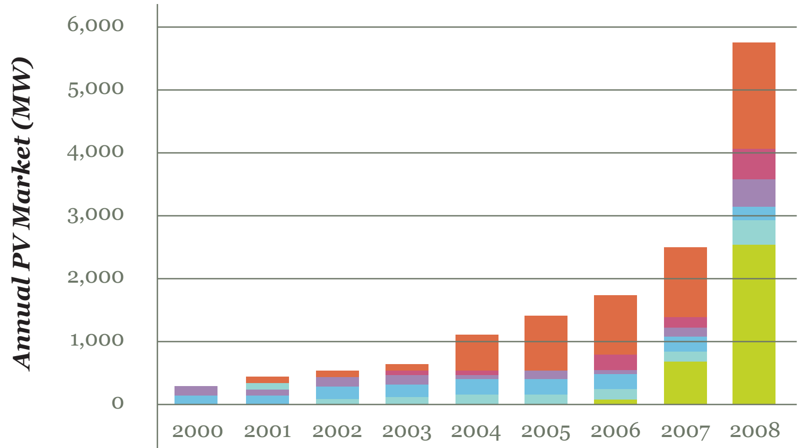


Figure 9.3
Supply Chain for the Photovoltaic Industry

Source: IEA, 2008

The PV capacity installed worldwide has increased 49% annually since the year 2000 helping grow all the industrial sectors that are a component of its supply chain. As a result, this industry is currently the fastest growing in the world. However, the market distribution among the countries is irregular. The maximum growth during the past decade was registered in Spain with a astonishing 254% annual rate beginning in 2005. In second place is Germany with a stable annual growth of 74%. By the end of 2008, a total installed capacity in solar panels of 14,730 MW was recorded. It should be mentioned that this capacity is greater than the projections made at the beginning of the decade (EPIA, 2009).



	2000	2001	2002	2003	2004	2005	2006	2007	2008
Germany	40	78	80	150	600	850	850	1100	1500
Rest of Europe	10	16	16	50	30	30	37	108	492
Rest of the World	94	75	104	98	53	12	196	207	485
Japan	112	135	185	223	272	290	287	210	230
United States	22	29	44	63	90	114	145	207	342
Spain	0	2	9	10	6	26	88	560	2511

Figure 9.4
Annual Report of the Photovoltaic International Market.

Source: EPIA, 2009

Of the installed photovoltaic capacity of almost 15 GW throughout the world, Europe accounts for 65% or 9 GW; Japan has 15% or 2.1 GW and the United States of America close to 1.2 GW or 8%. During 2008, the most important market was Spain with 45% of the total installations in the world. Although the projections indicated that only 1 GW would be installed in the country during that year, 2.5 GW were installed thanks to the announcement by the Spanish government of the reduction of subsidies at the end of the year. The investors and companies took advantage of this opportunity up to the last day. Other countries that also posted notable growth rates in 2008 were Italy (with 258 MW) and South Korea (274 MW). Likewise, in that year, new markets surged: France (105 MW), Czech Republic (51 MW), Portugal (50 MW) and Belgium (48 MW) (EPIA, 2009).

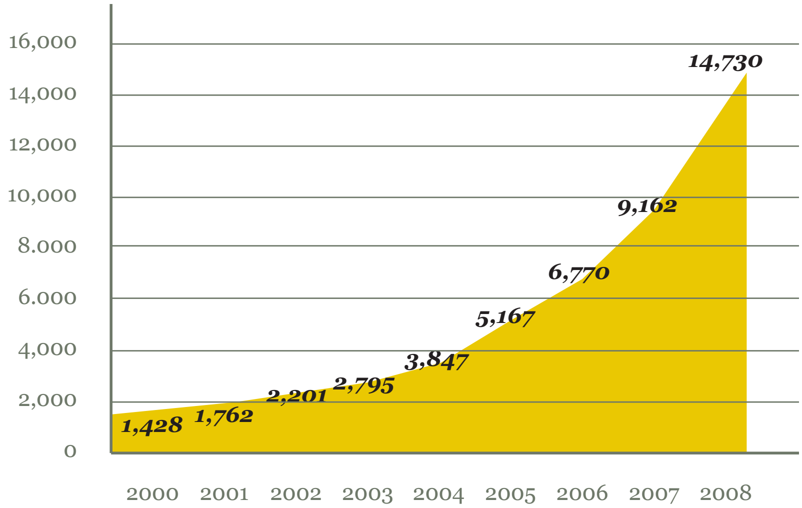


Figure 9.5
Cumulative global PV capacity.

Source: EPIA, 2009

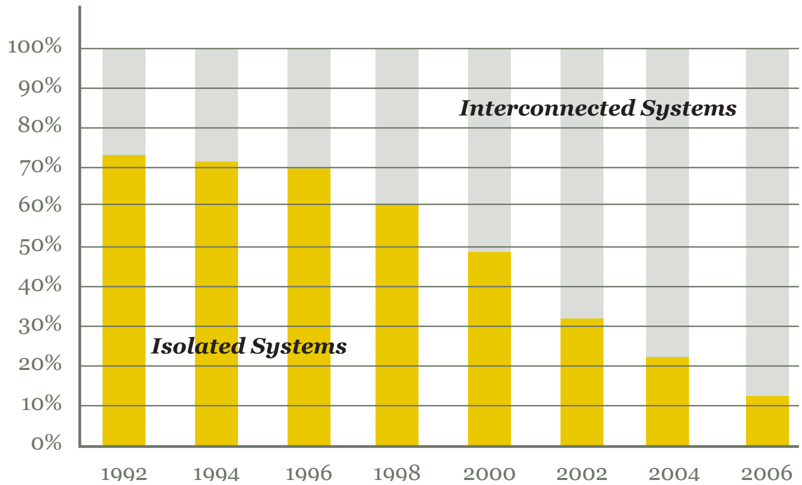


Figure 9.6
Worldwide Accumulated Photovoltaic Capacities

Source: IEA, 2008

The number of off-grid systems dropped within the photovoltaic installations while the number of panels that supply solar energy to the grid increased. In 1994, only 20% of the PV modules were connected directly to the grid while in 2007 these represented 90%. The increase in competition, the entry of new players and the discovery of the enormous economic and technical potential of these systems improved the rentability of solar energy. As the global demand increased especially in Europe, The Popular Republic of China became the main supplier of photovoltaic cells in 2007 with 29%

of the supply followed by Japan with 22% and Germany with 20%. In 2007, the company with the greatest production was the German company, Q-Cells with 9% of the cell market. Notwithstanding, the Chinese companies Suntech and Yingli together represented 11% of the cell market (EPIA + Greenpeace, 2008).

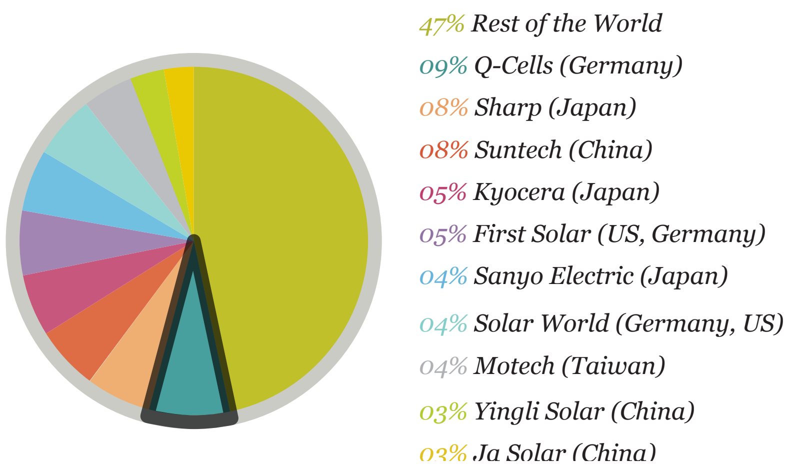


Figure 9.7
Producers of Photovoltaic Cells in 2007.

Source: EPIA + Greenpeace, 2008

The crystalline silisium based technologies represented 87.4% of the total production in 2007 (EPIA + Greenpeace, 2008). However, compared to other technologies, their participation declined from 94% of the total production in 2005 (IEA, 2008). This owed to the fact that investigation and development carried out to reduce the production costs of the PV modules found a solution in the use of photovoltaic material (as if it were paint) such as glass or polymers instead of using the conventional process of cutting the bars and the interconnection of the fragile crystalline cells. This alternative is called "thin film"; its economic competitiveness resides in the savings of photovoltaic material as its thickness is much lower than the crystalline cell (EPVTP, 2007). On the other hand, this technology faces a challenge to increase its maximum commercial efficiency currently at 11% and reduce its production costs. The El Dorado Solar Energy Power Plant which uses modules made of tellurium cadmium is one example of how the industry is betting on the success of the "thin film" technology. This plant located in the desert of Nevada currently has a capacity of 10 MW using 167,000 PV modules which took 6 months to install. The objective is to reach 58 MW or close to one million PV modules (REW, 05/2009).

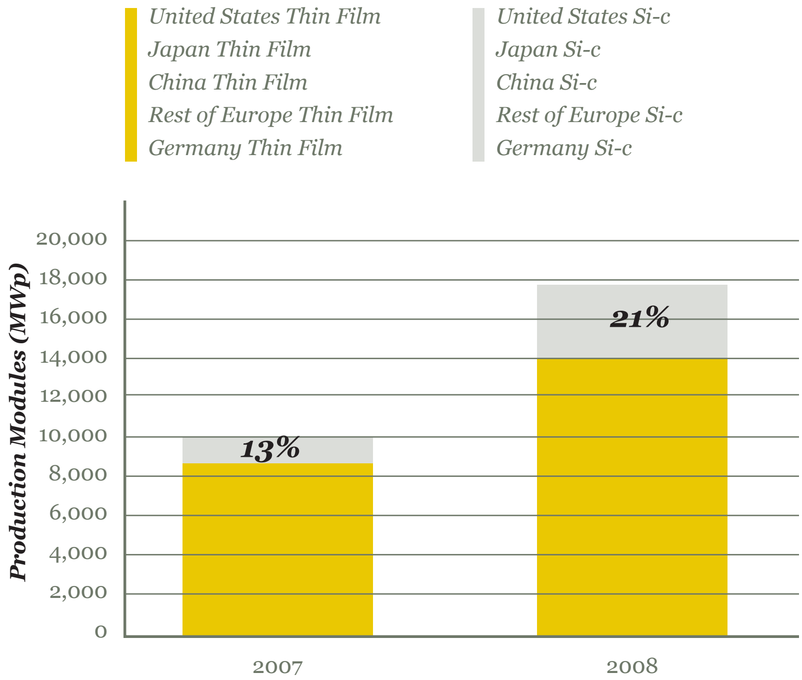


Figure 9.8
Production capacities by technology.

Source: S&W Energy, 2008.

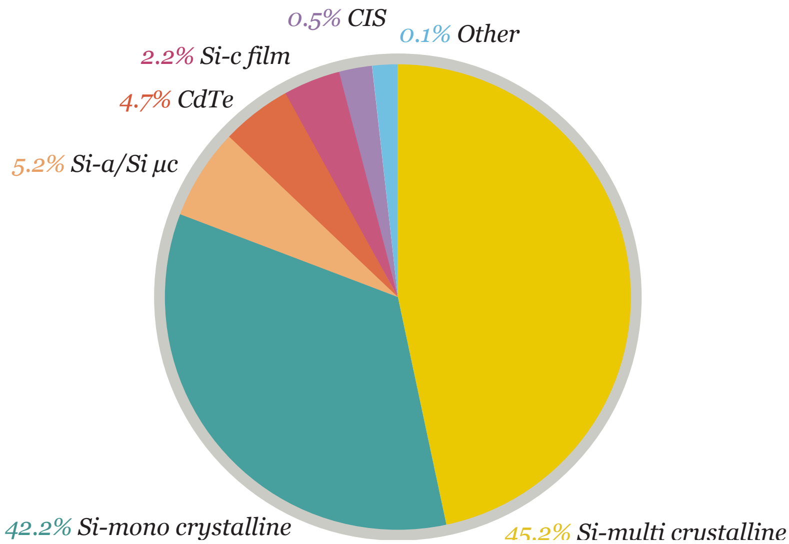


Figure 9.9
Technology Quotas of Cells in 2007

Source: EPIA + Greenpeace, 2008.

9.2.2 Support Policies

Technologies directed towards energy efficiency as well as renewables generation share two characteristics: their initial investment is almost always greater than the investment in a traditional project and their operating and maintenance costs are usually lower than the conventional projects. The combination of these two factors implies that there will be an investment payback period and in order to predict and plan the economic benefits, the project must be evaluated at the medium or long term. In addition, the period that must be financed before reaching the break-even point is many times longer than the time anticipated by the investors. This problem is magnified by the lack of liquidity in the companies due to the global financial crisis. For this reason, the governments must intervene in order to develop the renewable energy markets before the conventional energy sources lose their economic or environmental viability. One example is the vision presented by the European Community PV Policies Group which views the development of the PV market based on three short and long term objectives: security of the energy supply, economic growth and employment; contribution to Europe´s position with an economy based on the know-how and contribution to the reduction of CO2 emissions; and the mitigation of the effect of climate change (PV Policy, 2007).

Government PV Strategy

How have the governments contributed to the development of the photovoltaic technology in their countries? First, they included concrete objectives regarding photovoltaic capacity in their long term energy strategies. Setting these objectives for the use of photovoltaic technology in their government´s strategy is due to several motives. On the one hand, all the countries acquired an obligation to reduce carbon emissions although, in some cases such as Mexico, these are voluntary. The most employed methods used to reduce GEi emissions into the atmosphere are energy efficiency, the capture of gases emissions and the use of renewable energy sources.

A second motivation to use PV technology is the technical and economic viability it gives in order to supply electricity to geographical areas that are remotely located to the electrical power grid as in the case of India. Finally, the third motive is long term energy security. The uncertainty regarding the future supply of carbon fossil-based energy, the fear of nuclear plants, the terrible ecological impact of the hydroelectric plants and the costly operation and maintenance of the aero-generators makes photovoltaic solar energy a secure, silent and reliable energy source.

Countries which have already begun to carry out specific activities (political, financial or promotional) in order to develop the photovoltaic market are: Germany, Australia, Austria, Bangladesh, Belgium, Bulgaria, Canada, China, Cyprus, South Korea, Denmark, United Arab Emirates, Slovenia, Spain, United States of America, France, Great Britain, Greece, Holland, Hungry, India, Israel, Italy, Japan, Malaysia, Morocco, Mexico, Norway, Portugal, Czech Republic, Senegal, Sri Lanka, Sweden, Switzerland and Turkey.

In order for it to be successful, the photovoltaic policy must be focused in an integral and complete manner, planning with clear objectives, a regulatory framework, financing and promotional schemes and the evaluation of the impacts on the market and the efficiency of the policies. The following figure illustrates a model proposed by the European Community.

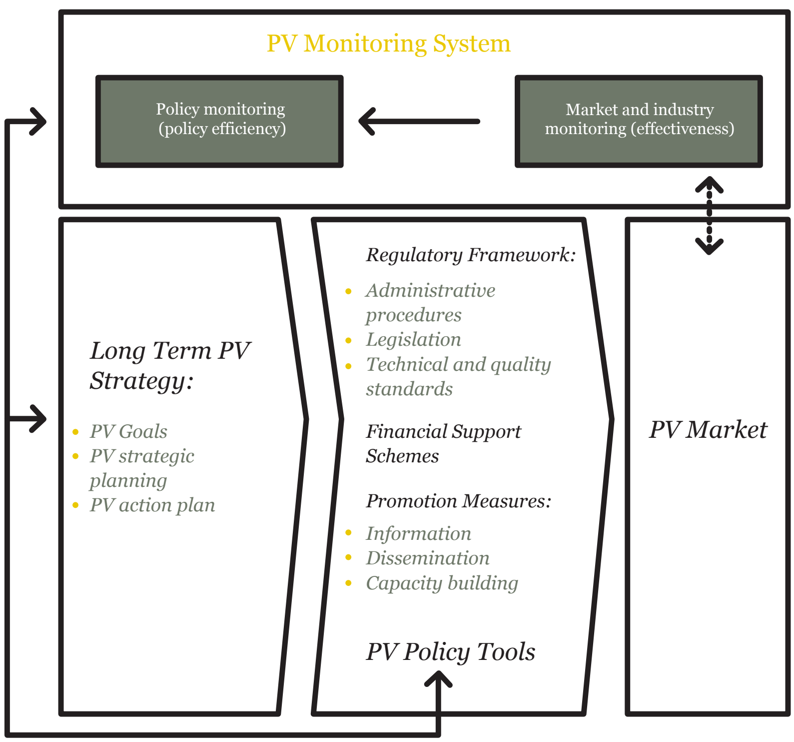


Figure 9.10
Comprehensive approach to PV policies.

Source: PV Policy Group, 2007

Incentives for Investigation and Development

In order to help grow the new photovoltaic industry, the governments have supported development and investigation activities (D+I) with the objective of improving the quality, the rentability and the supply capability of the PV technologies. The D+I activities are carried out throughout the supply chain and are not only applied to the product per se but also to the production processes. In addition to the promotion of the D+I activities in the academic centers and institutions, the coordination of the government, private and investigation sectors in line with common goals is essential.

Several examples exist worldwide such as the European Platform of Photovoltaic Technology which centered its strategic investigation agenda on the reduction of costs and a search for price parity with the on-grid systems. In the United States of America, the Energy Department is looking for ways to partner with industries and universities through the Solar America initiative (SAI) and the D+I programs are separated into basic investigation, advanced materials and market transformation. The German investigation strategy is centered on crystalline silisium, and “thin film” technologies, systems integration technology and to a lesser degree on organic cells. On the other hand, Japan carried out its Four Year Plan for the Investigation of Photovoltaic Generation Technology – in which the development of photovoltaic systems for large-scale implementation and the storage of electrical energy standout. South Korea, on the other hand, concentrated the D+I efforts in improving the technology for the manufacture of cells, sheets and bars as well as in topics related to BIPV. In Norway, in addition to the strong government support for the national crystalline silisium industry, REC, a Norwegian company, invests annually close to $30 million dollars in D+I related activities.

In 2007, the countries of the Organization for Economic Cooperation and Development (OECD) that participate in the Photovoltaic Systems Program (PVSP) sponsored by the International Energy Agency (IEA) invested close to $330 million dollars in this sector. Also during 2007, the U.S. government was the most “generous” investing $138.3 million dollars in photovoltaic I&D activities, followed by Germany ($61 million dollars), Japan ($38.9 million dollars), and South Korea ($18.4 million dollars). Among the countries in this group with lower investment amounts are: Israel ($100,000 dollars), Mexico ($270,000 dollars), Sweden ($3.5 million dollars) and Denmark ($4.6 million dollars) (IEA, 2008).

Consumption Incentives

Governments have also supported the development of the PV industry and market with consumption incentives through financing and promotion. The support measures applied by the OECD countries are classified as follows: incentives for the initial investment, incentives for generation of electrical power through the use of renewable energy sources and regulatory procedures. Of all the measures the most successful is the feed-in-tariff which consists of the connection of a PV system to the electrical grid; with this instrument energy is supplied at a purchase rate established during a certain period (which can be up to 20 years) (Bradford, 2006). In addition to the feed-in-tariffs other incentives can be applied. Financial support can come from the government budget, from bank credits, from international monetary funds, from the Clean Energy Development Mechanisms (CEDM) monetary fund and from special taxes levied against the countries that most contaminate the environment, among others.

In the past, all the money for consumption incentives came from the government budget which was unsustainable. The world however is full of ingenious financial solutions which only require planning and organization. In 2007, the German electrical energy suppliers paid the owners of PV systems connected to their feed-in-tariffs between E0.38/kWh and E0.54/kWh. Although, the cost of traditional electricity was three to five times lower than the solar energy tariff, the difference did not come from the government but from the fact that the electrical energy companies charged-off this difference to the other users. The part of the incentive paid to the group of solar energy companies by each consumer was no more than E0.20 per month even though Germany was the world´s largest PV market that year. In this case, the government only instigated the feed-in-tariffs scheme among the users and the electrical energy companies without subsidizing one Euro (EPIA, 2008).

The direct subsidies to capital are as equally important as the feed-in-tariffs in the PV market and are easier to implement. These are traditional subsidies for the goods and services market in which, some institution covers a fixed amount of the investment in PVs (commonly a fixed amount per kW of installed panels). For example, California grants subsidies for PV investments that amount to $2.5/WP for residential and commercial installations smaller than 100 kWp (EPIA, 2008). In other words, this subsidy represents close to one third of the investment required to install a PV system.

The main criticism of this scheme is that it does not promote efficiency or energy generation and that it can have an inflationary impact on prices (IEA, 2008).

Support mechanism	Countries using the support mechanism	Type of mechanism
Feed-in-tariffs	Germany, Australia, Austria, Canada, South Korea, Spain, United States, France, Israel, Italy, Portugal, Czech Republic, Switzerland	Incentive kWh (energy)
Direct subsidies to equity	Germany, Australia, Austria, South Korea, Spain, United States, France, Britain, Italy, Japan, Czech Republic, Sweden, Switzerland	Incentive system kW or cost
Tax Credits	Canada, South Korea, United States, Britain, Japan, Portugal, Czech Republic, Switzerland	Incentive system kW or cost
Green electricity schemes	Germany, Australia, Austria, South Korea, Spain, United States, France, Britain, Italy, Japan, Czech Republic, Sweden, Switzerland	Trade kWh or value associated
Renewable portfolio standards	Australia, United States, Britain, Japan, Sweden	Regulation
Requirements for sustainable construction	Germany, Australia, Canada, South Korea, Spain, United States, Portugal, Czech Republic, Switzerland	Regulation

Chart 9.1
Key PV support mechanisms by country in 2007.

Source: IEA, 2008

Tax credits are also an investment incentive for PV systems such as tax discounts and accelerated depreciation. For example, the U.S. government, through the Energy Policy Law set up a 30% tax credit for an amount up to $2,000 dollars. In the case of Mexico, the PV systems are depreciated for tax purposes at 100% the first year. The main criticism of this measure is that it could lead to higher taxes leading to political problems (EPIA, 2008).

Other schemes are related to green electricity. The most common examples are Taxable Green Certificates (TGC) and the Clean Energy Development Mechanisms (CEDM). The latter are used to finance projects that promote a reduction in GEI emissions. Specifically, they allow highly industrialized nations to carry out projects to reduce CO2 emissions in developing countries where the investment cost is lower. The project generates an Emissions Reduction Certificate (ERC) which is purchased by the industrialized nations at a specific price tied to the carbon market. These certificates are used to reach an internal emissions reduction goal. However, very few PV projects qualify for this certificate; in 2007, only two out of the 649 certified projects were solar energy projects (EPIA, 2008). Also, companies acquire obligations in terms of the amount (absolute or relative) of renewable energy present in their generation portfolio. The criticism against this type of scheme is that it distortions the economic functionality of the private electricity market.

Finally, the requirements for "green constructions" are regulatory obligations concerning certain specific goals for energy efficiency and renewables generation in the construction of buildings. In the United States of America, the Energy Department and the Office for Building technology created the U.S. Council for Green Buildings which developed the standards to improve economic and environmental effectiveness of the commercial buildings. The result of this work is the Leadership in Energy and Environmental Design (LEED) which is a qualification and measurement system that classifies the building construction projects in categories very similar to Olympic medals (Gevorkian, 2007). LEED is also being implemented in Mexico.

9.3 The Photovoltaic Market in Mexico

The main applications of photovoltaic technology in Mexico have been the rural electrification and the telecommunications as in order to supply electricity to the homes and low consumption repeating stations, the investment in an off-grid photovoltaic system is lower than the investment needed to connect the system to the grid. Currently, the on-grid photovoltaic projects represent proportionally the fastest-growing systems. In total, the photovoltaic capacity in Mexico grew 9.3% annually with an average increase of 1.02 MW each year during the period 1992-2008. In 1992, Mexico with 5.4 MWp was only 0.2 MW lower than the installed PV capacity in Germany. The difference, 17 years later, was 5,340.3 MW. In 2007, 20 MW was surpassed although the number of systems still operating is not available.

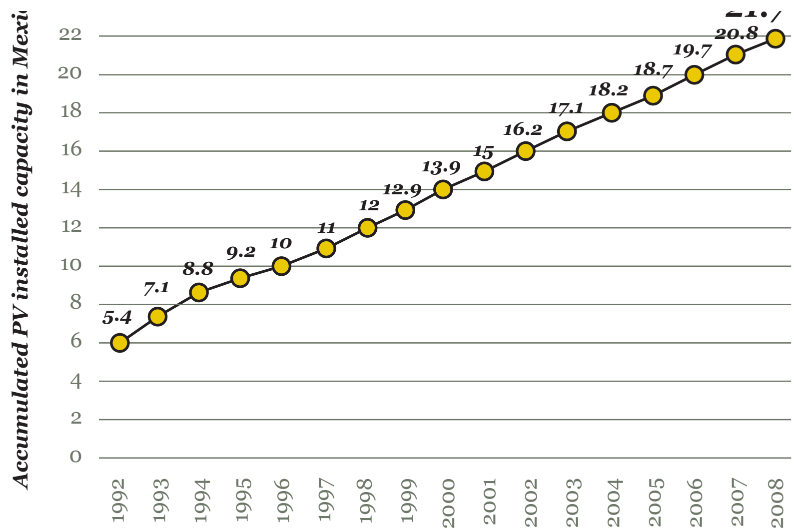


Figure 9.11
Cumulative PV capacity in Mexico.

Source: IEA, 2008.

9.3.1 Production and Consumption

The Mexican Association of Suppliers of Renewable Energy (MASRE) projects that by the end of 2008, the accumulated PV capacity reached 21.7 MW. During the last years, installed PV capacity has increased by approximately 1 MW per year – 15% related to on-grid systems during 2007 and 20% during 2008 (IEA, 2008). Of the total PV capacity added during 2008. Wal-Mart installed an on-grid PV system of 174 kW (ANES, 01/2009) at Aguascalientes. Based on available information, it could be said that off-grid systems represent at least 95% of the total systems installed. In reality, in Mexico precise information about installed capacity and its characteristics is not available as the companies are not obligated to share capacity information related to PV systems sales. A clearer perspective could be given by Dr. Arturo Morales from the Advanced Studies Center at the National Poly Technical Institute who estimated that accumulated capacity was between 21 and 25 MW in 2007.

Supply Chain

The supply chain scheme that predominates in the photovoltaic solar energy market consists in that the distributor imports PV systems components and he directly or through a subcontractor installs the system. This system has predominated because of the non-existence of a national industry for the development and fabrication of PV components. Therefore, the distribution channel for PV systems would be the following:

Importer/Fabricator –-- Distributer/Installer --– Final Client

Companies

Two industry associations group some of the PV companies: the AMPER and the National Solar Energy Association (NSEA) founded in 1976. In February 2009, the NSEA grouped 98 photovoltaic and solar thermal companies (NSEA, 2009). Additionally and to complete this data base, micro and small companies which are not registered in this association as well as foreign transformers (maquiladoras) should be added. The majority of these transformers is mainly located along the United States-Mexico border and fabricates photovoltaic modules for Japanese, American and German companies. Since 2004, Kyocera Corporation operates a 36 MW per year production line in Tijuana, Baja California. Since the end of 2002, Sanyo Electric Company transforms 12 MW per year of multi-union cells at its Monterrey, Nuevo Leon plant (EC JRC, 2008). In June 2008, Q-Cells announced that it would invest up to $3,500 million dollars in the construction of a plant to manufacture “thin film” modules in Mexicali (IEA, 2008). The modules produced by United Solar Ovonics imported by the United States of America, were assembled in Tijuana.

Prices

In general, PV modules the same as the inverters, the charges controllers, the bulk of the solar batteries and even the direct current breakers are imported. Until now, the Mexican market has been too small to promote the development of a Mexican national production plant which means that the costs of a PV system depend entirely on the parity rate between the Mexican peso, the US dollar and the Euro. Data from the Secretariat of Energy for 2005 shows that the systems are sold at a price between $3,500 and $7,500 dollars per kW installed which is equivalent to an amount between $0.25 and $0.5 per kWh generated (GTZ + SENER, 2006). For 2007, the information from the IEA shows mean prices of $14.6 dollars/Wp for off-grid systems with less than 1 kW capacity and $7.9 dollars/Wp for on-grid systems with less than 10 kW capacity. It also shows a range of between $4.6 and $6.5 dollars/Wp for random photovoltaic modules (IEA, 2008).

Investigation and Development

In 1977, the CINVESTAV developed, manufactured and installed the first PV module made in Mexico and by 1982 it had a pilot plant with capacity to produce 25 kW per year (NSEA, 02/2009). On the other hand, the National Autonomous University Engineering Institute within the auspices of the IMPULSA project carried out D+I activities to build a plant for desalinization in northern Mexico applying photovoltaic technology (Official Gazette, 06.08.09). In several other universities, investigation is carried out related to the use of other photovoltaic applications such as at the ITAM´s Center for Technological Development (CTD) where hybrid solar-wind power systems are studied.

On behalf of the federal government, the Institute for Electrical Investigations (IEI) has a Department of Non-Conventional Energy which studies the limits of PV penetration in systems distributed throughout the northern regions of the country and in general, on the use of PV in communities with high solar radiation. This study is part of a three year program to identify and remove barriers to large-scale implementation of on-grid PV systems (IEA, 2007, 2008). Another area of activity is the construction of on-grid PV systems in areas of extreme weather conditions and three-phase (220 volt) electrical energy supply. Inverters have also been the subject of D+I activities at the IEI. Similarly, the IEI as worked closely with the Federal Electrical Commission (CFE) in the Rural Electrification Program and in the operation of hybrid solar-wind generators (IEI, 2009).

9.3.2 Laws to Promote Market Development

The 2007-2012 National Development Plan in its section 10.1 “Strategy” in chapter 4 titled Environmental Sustainability establishes as its goal “to promote efficiency and clean technologies (including renewable energy) for the generation of energy. To achieve this, the promotion of carbon-free energy sources such as wind, geothermal and solar energy is indispensable. At the same time, it is critical that policies be put in place to promote low-emissions public transportation, establish fiscal incentives to promote sustainable energy projects, carry out an economic valuation of the benefits derived from this type of energy and finally, promote investigation into lower energy-intensive technologies. These objectives are set within the framework of the Law to Promote Electrical Energy for Public Services (LEEPS), which allows private citizens to generate electricity for their own consumption, for co-generation or for sale to the CFE. The permits for co-generation and the contracts for the sale of surplus energy will be handled by the Energy Regulatory Commission (ERC) (GTZ and SENER, 2006). In the case of solar energy, it is possible to connect PV systems to the national electrical grid and sell the surplus to CFE through the permit and contract provided by the ERC. The price paid by the CFE to private suppliers has been equal to or lower than the conventional electricity costs.

Currently, the main source for the generation of electrical power in Mexico is thermoelectric followed by the giant hydroelectric plants. The non-hydroelectric renewable energy barely added up to 3.13% of the total energy sources in 2008 thanks mainly to the geothermal capacity (SIE, SENER, 2009). Of the 21.7 MW from solar energy close to 70% of the accumulated photovoltaic capacity continued to operate in 2008. Also, during this year there was a total of 1,825 effective hours of sunlight, allowing for PV generation of 27.7 GWh which represented 0.01% of the national electrical energy portfolio. The majority of this capacity was installed within the framework of the different rural electrification programs.

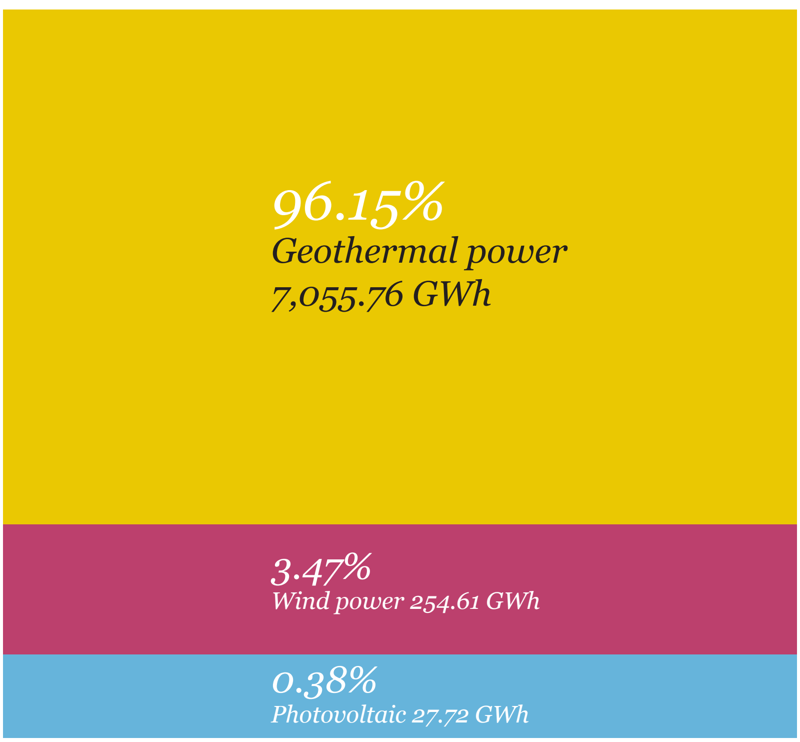


Figure 9.12
Renewable Energy Quotas in 2008.

Source: SENER, 2009

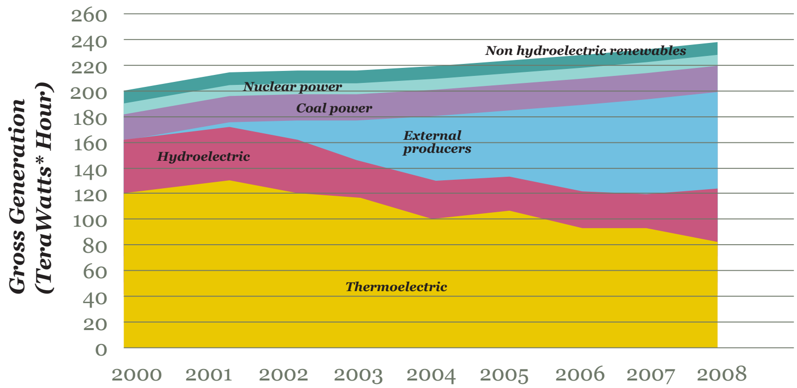


Figure 9.13
Sources of Gross Generation.

Source: SENER, 2009

The most important step to include Mexico in the "clean electricity" global market was taken on November 28, 2008 when the Law for the Optimum Use of Renewable Energy Sources and the Financing of the Energy Transition was published in the Official Gazette (LAERTFE) (Official Gazette, 28.11.08). This law sets the goal that by 2012, 8% of the energy generated must come from renewable energy sources (excluding the giant hydroelectric plants). If we consider that the average annual growth rate of the installed generation capacity is equal to consumption of 5.2% as suggested by the document Perspective of the Energy Sector 2005-2014 published by the SENER, the installed capacity of renewable sources excluding hydroelectric plants must grow by 2.13 times in four years (2008 to 2012) in order to meet the stated goal set by LAERFTE (SENER, 2006).

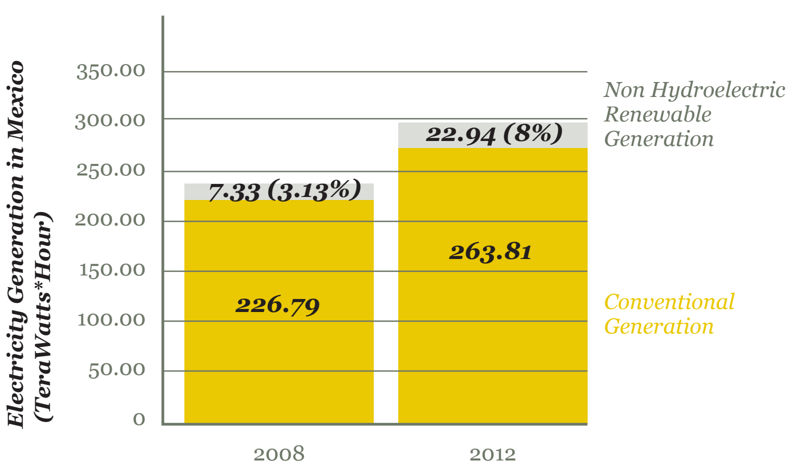


Figure 9.14
Conventional and Renewable Generation in 2008 and 2012 assuming 8% Renewables excluding hydroelectric plants for 2012 as set by LAERFTE

Source: SENER, 2009 .

Another critical element needed for the development of the photovoltaic market as set by the LAERFTE is the establishment of a fiduciary fund which during the first year will set aside 55% for a "Green Fund" in order to promote advanced technologies such as the photovoltaic, 10% for a "Rural Electrification Fund" in which the principal solution is the use of photovoltaic systems and 15% to the fund for the "Investigation and Development of Renewable Energy Technologies". The remaining 20% can be used to promote less advanced technologies, bio-combustibles and non-electric applications. An investment of $600 million dollars is expected each year in order to promote public and private sector investment in renewable energy projects using established technologies and another $400 million dollars per year for D+I investments as well as investment in less advanced renewable energy technologies (GTZ and SENER, 2006).

9.3.3 Programs and Incentives

National Solidarity Program (NASOLPRO)

The first national program for rural electrification was set up within the framework of the National Solidarity Program (NASOLPRO) during which 50,000 off-grid PV systems were installed in rural communities. This program was sponsored by the CFE, IEI, state and municipal governments as well as some private industries. The principal applications were for lighting, pumping of fresh drinking water and a rural telephone system (SENER, 2002).

Shared Risk Fiduciary Fund (SRFIF)

The Shared Risk Fiduciary Fund (SRFIF), an agency of the Department of Agriculture, Livestock, Rural Development, Fishing and Feed has a program to finance PV systems designed to provide pumping capabilities in the agricultural sector. Its name is "Project for the Sustainable Rural Development of Alternative Energy Sources in the Agro-industries which Promote Energy Efficiency in the Agricultural Sector". Since 1994, the SRFIF has set up a joint technical collaborative effort with Sandia Laboratories in the United States of America. Since 2000, $8.9 million dollars has been financed by the Global Environmental Fund (GEF) with the approval of the World Bank, $13.7 million dollars from monies provided by the federal program "Alliance for the Agricultural Sector" and the farm producers contributed another $6.9 million dollars. Other organisms that participate in the SRFIF are the SEMARNAT, the SHCP and NAFIN. The program was still functioning as of 2010 (FIRCO, 2009).

The Energy Integral Services Project

This program is similar to the National Solidarity program with three-party financing which is distributed equally between the GEF of the World Bank, the Federal Government (through the SENER) and the four participating state governments: Oaxaca, Chiapas, Guerrero and Veracruz. The objective is supplier electricity to 50,000 homes which at present do not have electrical power (IEA, 2007). This means, 2,500 rural communities electrified by solar energy (Official Gazette, 06.08.09). The federal government provides it funding through the program "Alliance for Agriculture".

PV Connection to the Power Grid

June 27, 2007, the ERC published in the Official Gazette the approval of the model contract for the interconnection of small-scale solar energy sources which allows for the installation of one net or bidirectional meter. In the case that there is a negative difference either for the energy supplier or for the client of the electric company, this difference may be reimbursed (Official Gazette, 27.06.07). At the same time, a program is carried out for the investigation and elimination of barriers to the use of large-scale PV systems which is sponsored by the IEI, the United Nations Development Program (UNDP) and the ERC.

International Support

Multiple small scale projects were developed thank to the financing or technical support provided by international organisms. Throughout the Republic, projects have been launched that benefit the communities as well as technical demonstrations. Among the organisms that standout are the German Technical Cooperation (GTZ), the United States Agency for International Development (USAID), the Sandia Laboratories and the National Renewable Energy Laboratories (NREL) from the United States of America.

Income Tax law

The clauses related to energy generation are found in article 40 and 219 of the Income Tax Law. Article 40 states the terms for deductibility: "the maximum percentage authorized relating to fixed assets by type of goods [..]: 100% for machinery and equipment used for energy generation using renewable energy sources". Article 219 states that "a fiscal stimulus is given to the taxpayers for technical investigation and development projects that are carried out during the tax period which consists of a fiscal credit against the income tax owed equivalent to 30% of the cost and investment carried out during the period for the investigation and development of technology […] the taxpayers may apply the difference vs. the income tax during the subsequent 10 tax periods until the entire credit is applied".

9.3.4 Barriers

Technical

In the off-grid systems, the lack of maintenance principally of the batteries leads to failures after a few years in operation. Furthermore, the technicians need to be trained in how to install and maintain the systems, greater customer satisfaction is needed and the basis for market development must be promoted. Lastly, a regulatory framework for PV products or projects that contains a minimum of quality and efficiency parameters must be provided.

Social and Cultural

Insufficient information and a lack of understanding of the scope of the PV technology exist among the rural consumers. As a result, there is a lack of a long-term vision of the savings that the system would generate although a larger initial investment is required.

Institutional

The government lacks concrete objectives in terms of the photovoltaic capacity to be reached. The fiscal incentives are insufficient to promote market growth although sizeable subsidies exist for the conventional energy market. In addition, external environmental factors are not considered in the economic analysis of the energy projects.

Financial

There is very little understanding of the cycle of a project and about the need for a cash-flow analysis as well as very limited knowledge related to the amount and the capacity of the private and government sectors financing programs.

9.4 The Micro-Economy of Photovoltaic Energy

9.4.1 Supply

Initial investment in manufacturing

The investment in manufacturing infrastructure depends on the minimum production capacity and the time required for operation start-up. A silisium production plant needs close to $250 million dollars and at least two years for construction. For a plate or sheets plant with a minimum capacity of 50MW per year, a minimum investment of between $30 and $40 million dollars is required. A company that produces PV cells can be competitive at 20 MW per year and have a construction cost of close to $10 million dollars. A PV modules assembly plant could have a capacity of 10 MW per year, require a capital injection of $2 million dollars and possibly could be built and start-up in less than a year (REW, 3/2008).

Cost Integration

The total cost (minus depreciation) of an on-grid residential PV system is the sum of the cost of the PV modules, of the system balance components (invert-

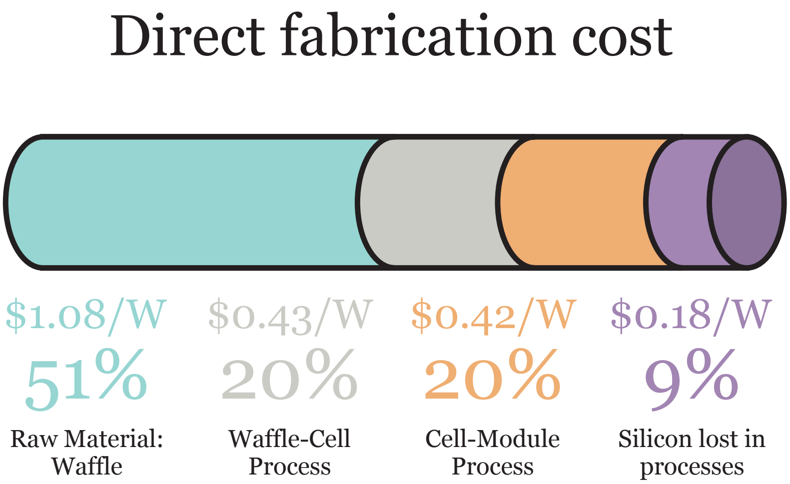


Figure 9.15
Direct Cost of a Polycrystalline Module

Source: REW, 2008

er, cables, etcetera) and the installation. The financing costs are not sufficiently generalized to be able to include them in the analysis. The portion related to the modules fluctuates between 50 and 70 percent of the total value of the system in relation to its application and its size (EC PVTP research, 2007). If the estimated installation cost fluctuates between 10 and 15 percent, the cost of the system balance components is between 25 and 40 percent. Among the system balance components, the inverter has the greatest economic weight. Among the main cost optimization variables associated with the inverter are the cost of production and the efficiency of the apparatus.

The cost of the multi or polycrystalline modules depends on three factors: the cost of the polycrystalline silisium, the efficiency of the PV cell and the rate of conservation of the silisium in the chain from the sheets to the modules. The following figure illustrates an example of a chain with a 50 MW capacity per year, a process silisium conservation rate of 85%, a polycrystalline silisium cost of $70 dollars/kg and cell efficiency equal to 16%. With these assumptions, the direct fabrication cost of the PV module is $2.11/Wp (REW, 2/2008).

9.4.2 Demand

Solar energy is a perfect substitute in the case of the demand of a population with access to the electric power grid. The demand has moved to the right thanks to the shift of the supply curve. While waiting for greater

Country	*Feed-in-Tariff (FiT)*	Green Certificates (GC)	Duration of FiT or GC	Investment Subsidy	Other incentives	Residential electricity price1
Germany1	0.35 – 0.47 €/kWh	---	20 years	Regional programs	Depreciation extended for 20 years, exemption from VAT, soft loans 35% - 100% of investment up to 20 years	0.26 US$/kWh4
Australia2	0.44 – 0.66 AU$/kWh	---	10 years	8,000 AU$/systen	---	0.10 – 0.14 US$/kWh4
Belgium1	---	0.15 - 0.65 €/kWh	10 to 20 years	20% to 50%	Fiscal Discount 40%, 13.5% deductible installation	---
Bulgaria1	0.37 – 0.40 €/kWh	---	25 years	---	Soft credit up to 20% of the investment	---
South Korea2	0.45 – 0.62 US$/kWh	---	15 years	60% to 100% residential	Soft loans, renewable standards, green buildings	0.10 US$/kWh3
Spain1	0.32 – 0.34 €/kWh	---	25 years	---	6% tax discount	0.19 US$/kWh3
United States2	0.32 US$/kWh	---	---	Programs in 19 States	30% tax discount	0.10 US$/kWh3
France1	0.32 – 0.57 €/kWh	---	20 years	---	"Green" credit (3% to 5%) between 5 and 10 years. 50% tax discount	0.17 US$/kWh3
Greece1	0.40 – 0.50 €/kWh	---	20 years	20% to 40%	20% tax discount, soft loans (4%)	---
Italy1	0.36 – 0.49 €/kWh	---	20 years	---	Reduction of VAT from 20% to 10%, electricity counter	0.27 US$/kWh3
Israel2	0.52 US$/kWh	---	20 years	---	---	---
Mexico2	---	---	---	---	Accelerated depreciation the first year, 100% deductible	0.11 US$/kWh3
Portugal1	0.65 €/kWh	---	15 years	35%	Reduction of VAT from 21% to 12%, soft loans (0%)	0.23 US$/kWh3
United Kingdom1	---	Renewables Obligation Certificates between £35 and £50		50%	VAT reduced to 5%	0.23 US$/kWh3
Romania1	---	38.87 €/MWH	---	Budget of €70 million	---	---
Switzerland1	0.30 – 0.56 €/kWh	---	25 years	---	---	0.16 US$/kWh3

Chart 9.2
Summary of Consumption Subsidies in Select Countries.

1-Source: EPIA, 2008 except the price of electricity
2-Source: IEA, 2008 except the price of electricity
3-Source: IEA, 2008
4-Source: IEA, 2008.

growth of the supply. The governments "drive" the demand through the use of subsidies and regulations. The regulations are getting more regular while the norms are becoming stricter; in conjunction with this; consumption subsidies are destined to decline and disappear over time. It is important to mention that the use of incentives and their exact monetary value depend on several factors such as the budgetary limit on subsidies or programs, the length of time the incentive is available as well as the application and capacity of the PV system. Chart 9.2 summarizes PV consumption for 2008 There are three types of clients for PV systems, the electricity companies that sell to the users, the private users (persons or companies) that purchase and install the systems for personal consumption and those that use the system to generate energy to sell to the power grid. Likewise, a PV project connected to the grid could be classified in distributed or centralized. The electricity companies can find benefits in a centralized system such as a conventional electricity generation plant as well as in PV systems distributed in the city.

9.4.3 Prices

The prices of PV systems dropped exponentially between the decade of the 70´s until the end of the 20th century and sistolically during the first decade of the new century. This reduction has been guided by such factors as economies of scale (provoked by the increase in demand due to incentives) and by the industries learning curve (with such optimization variables as silisium total consumption and efficiency) (Bradford, 2006). The following figure shows module and installed systems market prices.

One way to calculate the benefits obtained from the investment in a PV system is to perform a cash-flow analysis that includes a projection of up to 25 years (to include the modules performance guarantee). From the PV project side, the initial investment, the maintaining investment and the financial costs (including interest) must be considered. The maintenance cost of an on-grid system is very low and therefore, is not included in the analysis. From the conventional project standpoint, the cost of supplying electricity and, if it exists, the initial connection investment must be considered. The cash-flows are calculated at present value using a discount rate set by the investor. With this practice it is possible to calculate financial indicators such as the Net Present Value (NPV), the Internal Rate of Return (IRR), the Payback Period and the Cost-Benefit Ratio among other variables used to take a decision regarding the viability of the projects.

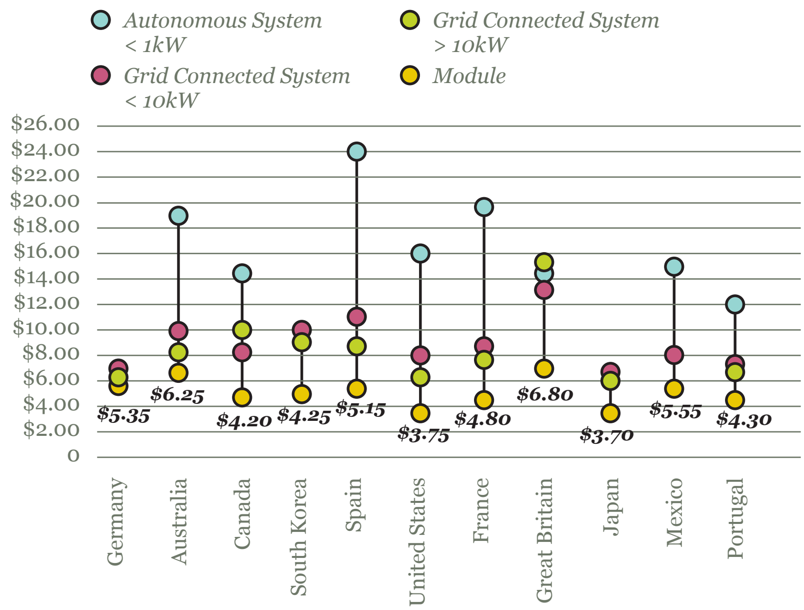


Figure 9.16
Modules and Installed Systems Median Prices (US$/W) in 2007 per Selected Cities

Source: IEA, 2008

Another way to compare the two projects is to calculate the equivalent electricity costs from the solar energy source as if it were a conventional source. A payback period between one or two years is set, the price of the system is divided by the energy (kWh) the PV system will produce during the established payback period. In this manner, the short-term cost of the solar generated electricity is calculated. The following chart reflects the projected costs of photovoltaic electricity.

Currently, major projects exist such as the one carried out in 2008 by the Juwi Group in Waldpolenz, Germany. The photovoltaic capacity of this plant is 40 MWp and at the time that it as announced and planned, it was the largest and lowest cost project in the world ($4.20 dollars/Wp installed). This system is an interesting example of economies of scale in solar energy and the ensuing price reduction. The system, if installed in the southwest region of the United States which receives double the solar radiation than Germany would generate electricity for over 20 years at a cost of $0.16/kWh without one subsidized dollar (Sun & Wind Energy, 4/2008).

City	Hours of sun/year	2007	2010	2020	2030
Berlin	900	€ 0.44	€ 0.35	€ 0.20	€ 0.13
Paris	1,000	€ 0.39	€ 0.31	€ 0.18	€ 0.12
Washington	1,200	€ 0.33	€ 0.26	€ 0.15	€ 0.10
Hong Kong	1,300	€ 0.30	€ 0.24	€ 0.14	€ 0.09
Sydney/Buenos Aires/ Bombay/Madrid	1,400	€ 0.28	€ 0.22	€ 0.13	€ 0.08
Bangkok	1,600	€ 0.25	€ 0.20	€ 0.11	€ 0.07
Los Angeles/Dubai/ Mexico City	1,800	€ 0.22	€ 0.17	€ 0.10	€ 0.07

Chart 9.3
Estimated costs of generation of PV rooftop systems, per kWh.

Source: EPIA and Greenpeace, 2008.

9.4.4 Evaluation of PV Projects in Mexico

The economic feasibility of off-grid PV systems depends on their proximity to an electrical energy power station and the price of the electricity supplied by the competing power grid. For example, if we consider that the residential application consumes, on a daily basis, 10,000 Wh of electrical energy (Ec), that the total electrical efficiency (ηt) of the system is 74% and the average daily solar radiation (T) is equal to 5 kWh/m2 or 5 hours of sun at maximum power, the formula to calculate the photovoltaic power (PPV) of the panel or the peak Watts required to cover the electrical energy needs of the house would be the following:

$$PPV = Ec/(T \times \eta t)$$

In the example, power is equal to 2,696 Wp or 2.7 kWp. Therefore, efficiency (ηt) is calculated multiplying all the electrical efficiencies in the system by the integrator of the system. Among the energy losses is the charge-discharge cycle of the batteries, the conversion of direct current into alternate current inside the inverter, the losses at the cables, among others.

If the average price of an off-grid PV system is $13 dollars or $175 (at an exchange rate of $13.5 Mexican pesos/US dollar) per peak watt of the panel, the total price of the installed system would be approximately $471, 666 Mexican pesos. At this price, in reality, the fiscal benefit must be subtracted as it is deductible the first year. Therefore, with a tax rate of 28%, the investment in the system would be $339,600 Mexican pesos. Now, let us consider that the installed cost per kilometer of a low-tension power line is $800,000 Mexican pesos. In this case, at less than 0.5 kilometers to the power station the investment is lower in solar energy than in the connection to the power grid. In this example, the off-grid PV systems in houses with moderate consumption could represent a lower initial cost beginning at a distance of 100 meters to the power station.

The real financial challenge to solar energy is in the cities or in the areas that have easy access to the conventional electrical grid. At present, the non-subsidized photovoltaic technology cannot compete against the traditional subsidized electricity as it offers investment payback periods of 7 years. Notwithstanding, the expectations for the coming years are positive with respect to an improved comparative economic outlook for solar generated electricity. It could be said the only carbon-based energy source that offers certainty vis´ a vis´ future costs is coal although it is the energy source that emits the most carbon bioxide.

The speculation surrounding the decrease of the proven reserves of oil as well as the political pressure that results from importing natural gas or oil forecast a constant increase in the real price of the supply of electrical power worldwide. Meanwhile, the photovoltaic materials are produced on a larger scale, are increasingly more efficient, are used in lower amounts per Wp, their manufacturing processes are more efficient in terms of cost and their financing schemes adapt to their needs. Given this, it is expected that in some countries price parity (excluding subsidies) with conventional electricity will be achieved during the next decade.

In the case of Mexico, the mean price of electricity has grown an average of 11.4% per year in the period 2000-2008 y registered an increase of 16.5% in 2008 (SENER, 2009). If the expected prices for solar energy in Mexico City shown in the chart 9.3 are considered applying an annual inflation rate of 5 to 11 percent for conventional electricity, it is possible to project, for the average user, that price parity between both power sources will be achieved between 2014 and 2017.

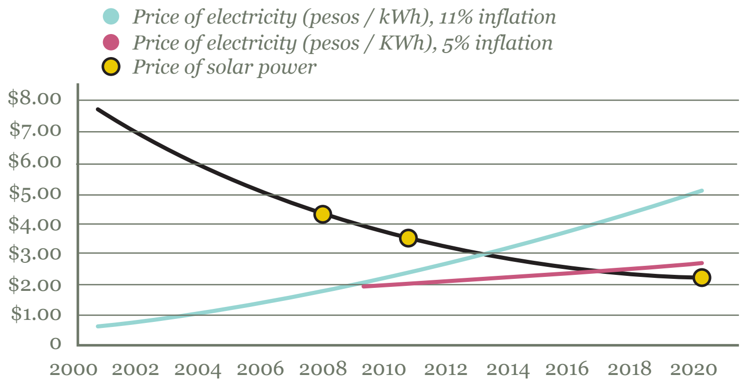


Figure 9.17

Source: EPIA & Greenpeace, 2008 and SENER, 2009

9.5 Perspectives and Opportunities for Mexico

In the period 2009 – 2014, the installed capacity of the national electrical sector will increase 26.5% or 13,544 MW according to the CFE´s expansion program (SENER, 2006). Afterwards, while the population and the Gross National Product (GNP) increases, national electrical power consumption will also grow. The country, the same as the rest of the world, needs to reduce as much as possible the environmental impact associated with this energy. When the generation costs of photovoltaic energy equal the cost of thermoelectric generation without a doubt, solar energy will assume a prominent role in the energy market. The countries that have a well developed market will have greater international competitiveness. Therefore, they will benefit to a greater extent from this technology and energy source.

9.5.1 Photovoltaic potential and its applications

Mexico is a country that benefits from solar radiation as it receives for example double the amount received by Germany. Daily across the Mexican territory there is solar energy that fluctuates between 4.4 kWh/m2 and 6.3 kWh/m2 which only compares with some regions in Africa, the Andes and parts of Oceania. (Official gazette, 06/08/09). On average, with crystalline photovoltaic panels, a surface of close to 100,000 hectares or 1,000 square kilometers would be required to cover the total electric consumption supplied in 2008 by the two state-owned companies (CFE & LyFC). In Germany and Canada, double this area and double the investment would be required to supply an equal amount of energy (184 TWH) (SIE SENER, 2009).

Among the photovoltaic applications, rural electrification as a secure spot in the short term with the approximately 5 MWp (100 WP photovoltaics per home) that will be installed during the next years through the Energy Integral Services Project. The commercial on-grid PV systems will also be promoted by companies such as Wal-Mart which plans to continue to install panels in more of its stores in the country. The tourist sector, especially eco-tourism, is a natural for photovoltaic applications which include from hotels and cabins to arquelogical zones. An important number of tourist installations are located at great distances from the electrical power grid. Solar energy is a great tool to achieve sustainable growth of this economic sector and above all, of the communities where these tourist projects are located.

With the appearance in the market of more efficient alternative products such as the ones that operate based on light emissions diodes (LED) the applications related to lighted signs has become an area of opportunity for the use photovoltaic technology. The solar panels supply energy to an ever growing number of traffic lights, detour signs, airport runway signs and warning lights on towers and buildings. Public lighting, in its different modes, is also a growth area for photovoltaic applications with the new fluorescent and LED lights the same as for the luminous publicity signs.

The photovoltaic technology has been traditionally used in the telecommunications sector. The low-power repeaters, the rural telephone systems and the recharging of radios and cellular phones consume low amounts of electrical power making solar energy an economical option.

On the other hand, BIPV panels offer many advantages: environmental protection, thermal isolation, protection against the sun and noise, daylight modulation and security. The photovoltaic modules and sheets are used on roofs, building external walls, semitransparent facades, daylight filters and shadow systems.

9.5.2 Tendencies in Investigation and Development

In Mexico the universities, investigation institutes, companies in different sectors, inventors and the public sector have the opportunity to contribute to achieve a competitive positioning of the country within the “green” energy market. The areas of opportunity in photovoltaic D+I are listed in the European Community´s Strategic Agenda for the Investigation of Photovoltaic Solar Energy Technology and their descriptions follow (EU PV Tech, 2007):

Cells and Modules

Each PV technology (crystalline silisium, “thin film”, etcetera) has its own challenges and improvement needs but the D+I areas common to all are the following:

- Efficiency, energy relation (kWh/kWp), stability and useful life.
- High efficiency manufacturing including the monitoring and control of the processes..
- Environmental sustainability, to ensure the recycling of PV products.

PV System Components

The challenges in this area are as follows:

- Increase inverter durability and reliability.
- Increase the use of modules, multi-functionality and minimize losses at the component.
- Produce concepts that will maintain the stability of the electric power grid ahead of the high penetration of PV systems.
- Develop components and concepts for the hybrid PV systems

Socio-economic Aspects

Some important activities that remain to be developed are the following:

- Identify and quantify the non-technical costs and benefits (social, economic, environmental) related to photovoltaic solar energy.
- Establish the regulatory requirements and identify obstacles to the application of large-scale photovoltaic technology.
- Establish the basic skills required by the long-term PV associated industries and a plan to develop these skills.

- Develop schemes to increase public awareness and knowledge regarding PV technology.

9.5.3 Perspectives for the PV Market

The European Photovoltaic Industry Association (EPIA) estimates that the European market will grow from 4.5 GW in 2008 to 11 GW in 2013. During the same period, it projects that the United States of America will grow from 0.3 GW to 4.5 GW, Japan from 0.23 GW to 1.7 GW and the rest of the world from 0.5 GW to 5 GW. This will occur in a favorable environment as a result of the continuity and the development of the current policies (EPIA, 2009). For 2030, the European Community Center for Joint Investigation projects that Europe will have an installed photovoltaic capacity of between 1,100 GW and 2,600 GW, the United States of America will be at between 520 GW and 780 GW, Japan at 205 GW and the rest of the world between 920 GW and 1,830 GW. Once again, this depends on the international political scenarios (EC, JRC, 2008)..
Regarding the installed capacity in the value chain, the EPIA estimates that it will grow worldwide at a rate between 20 and 30 percent per year in the period 2009-2013. Given the strong and continuous growth of the PV market demand since 2005, the solar-grade silisium continues to be the bottleneck in the supply chain. It is hoped that the supply deficit will end in 2010 which could signal a drop in solar energy prices. The supply deficit has afforded a development opportunity for the "thin film" industry which is expected to grow versus its crystalline competition. Given this, for 2010, it is expected that this industry will represent close to 22% of PV module production or a little more than 4 GW and that it will reach 25% or 9 GW by 2013 (EPIA, 2008).

Mexico has the potential to begin to develop the PV market as it has the installations and the companies. For example, electronic engineering is well looked upon in the country to the extent that Freescale Semiconductor (one of the principal producers in the world of integrated circuits) set up an D+I center in Guadalajara and is hiring hundreds of Mexican engineers. In addition, there is a strong glass industry as well as diversification of the plastics sector. As a matter of fact, Japanese, German and American companies that fabricate PV modules now operate in the country however, other players are expected on the national scene and it is time to take advantage of their demand for labor and their knowhow. Likewise, it is important to take advantage of the great number of international financing programs aimed at the D+I activities and installation activities of renewable energy projects in order to have sustainable economic growth in Latin America. For example there is a $2 billion dollar fund that the Inter-American Development Bank could set up and the Import/Export Bank of Korea could set up to invest in “green” projects in Latin America and the Caribbean (Greenmomentum, 07,05,09).

9.6 CONCLUSIONS

The photovoltaic solar energy is an important tool in order to achieve sustainable growth in Mexico. Compared with others, it is a source of electrical energy that does not require combustibles or consumables, it does not lead to emissions during the generation process, its maintenance is practically zero during more than 25 years, its installation is very quick and economical, among other advantages. In addition, it is the most visible way to achieve rural electrification goals, a way of generating “clean” energy in the cities, an opportunity to diversify the CFE energy portfolio, a high value-added industry which requires multiple products and services from other sectors and it is an opportunity to create quality employment. The international example has been successful in all these categories. From an economic, environmental and energy security perspective, the Mexican government must define what it wants to achieve regarding the use of photovoltaic technology.

Long-term Photovoltaic Strategy

Clear and concise short, medium and long term goals must be established regarding installed photovoltaic capacity. The projected capacity can relate to objectives in terms of electrification projects for the population, to diversification criterion of the energy portfolio, to the promotion of the PV national industry, among others. The strategic planning must include the definition of the areas of opportunity or implementation, objectives regarding the development of a national industrial capacity. Goals for scientific and technological investigation, among other variables. For its part, the action plan must quantify the previous objectives and set fixed completion dates.

Regulatory Framework

The Mexican legislation already allows for the self-supply of energy as well as for the connection to the network of PV systems in the private sector. What is missing are clear and simple administrative procedures which will be established as a result of the LAERFTE regulations. Likewise, it is necessary to write an Official Mexican Norm to certify the quality of the photovoltaic installations and their components.

Financial Support Schemes

Of the two most popular PV system finance schemes in the world, the analysts agree that the feed-in-tariffs are the ones that promote consumption and entail greater economic benefits. The solar energy tariffs can be subsidized by the governments or prorated based on the consumption of the other electricity users. Likewise, another financial support scheme consists of the inclusion of external factors in the generation costs of all the sources.

Promotional Measures

As a first step, all government agencies must be informed of the benefits that can be derived from the photovoltaic energy programs. It is also necessary to promote detail promotion mechanisms that respond to federal government objectives for the private industry, academic sector and the general public. This must be done with the express purpose of promoting the consumption and investigation of renewable energy sources specifically, solar photovoltaic. On the other hand, the capacity of the production chain that could participate with PV technology and carry out the construction of manufacturing plants that are needed to achieve the strategic goals must be qualified.

Monitoring

It would not be healthy to allow the political mechanisms to act without a follow-up. The efficiency of the policies must be monitored as well as it is necessary to continually review the market and industry indicators in order to evaluate and improve its effectiveness.

In order for renewable energy to be a reality in Mexico and a motor for sustainable growth, an innovative and integral approach is required. It is necessary to establish clear goals, promote and direct investigation and development and increase the industrial competitiveness of Mexican industry.

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10.
Thermal solar energy

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10.1 Introduction

Solar energy is the primary source of all energy on Earth. Plants and microorganisms absorb it and convert it in the form of chemical energy. (Lehninger et al 1995). Oil and coal are formed through a process of millions of years starting with the solar radiation absorbed by the plants, along with carbon dioxide, to transform it into carbohydrates and oxygen. This process generates a large amount of biomass which stores energy in chemical form (Sanchez N.2008). Reserves of energy as carbohydrates remain in the leaves and are ingested by herbivorous animals, and these in turn are eaten by carnivorous animals which at the end of their life cycle, are the food for scavengers, worms and bacteria. When all these organisms die, their bodies undergo degradation and leave elements like carbon, oxygen and nitrogen, among others, and simple organic compounds. By subjecting the compounds to an environment of high pressure and temperature by the earth's geothermic elements (for example, in oil wells) become oil and coal.

These compounds have a high heat capacity. However, they also are the basic elements for the production of millions of products in the form of polymers or plastics. These are essential in order to manufacture sterile surgical instruments and tanks, get low costs of production by injection and to develop strong, noncorrosive materials at reasonable prices. The development of these is a way to tap oil. If oil was just burnt, it we would have to wait millions of years to recover it.

At the end of the nineteenth century, coal began to be used massively to generate steam to power engines, machines and systems. In addition, water heating systems were designed to produce process heat, with or without concentration of sunlight.

Works to understand solar radiation and develop systems for its exploitation were professionalized with the International Solar Energy Society (ISES by its acronym in English), in 1954. In Mexico the National Solar Energy Association was established in 1980.

10.2 The sun

10.2.1 Astronomical and physical aspects

The sun (Picture10.1) is a yellow dwarf star which releases an enormous amount of energy as electromagnetic waves. Every second, 564 megatons (Mton) of hydrogen are transformed into 560 Mton of helium and 4 MTton of matter in the form of radiation by thermonuclear fusion of 4 protons of hydrogen per 1 atom of helium (Muhlia, 2006).

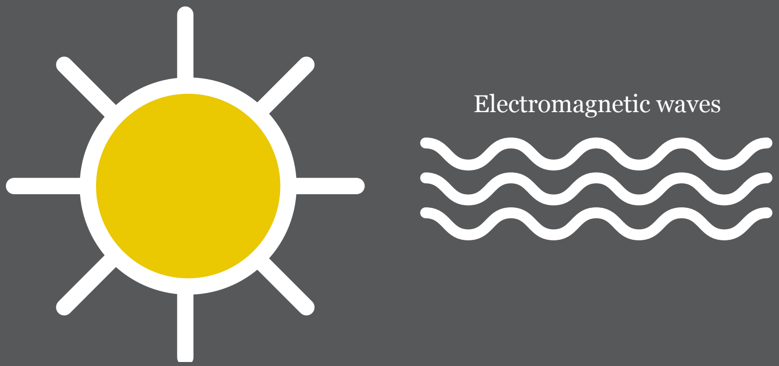

Figure 10.1
The sun, star that releases large amounts of energy..

The power of 4 Mton of matter power is, according to Einsteins´s Law (E=mc2), approximately 3.6 x 1026 J/s. If you divide this by the total energy consumption in 2005, which was 500 exajoules, you get the number of times a second that energy released by the Sun covers the energy needs of the Earth: a total of 720,000 times.

Only a small part of this power (energy per unit of time) reaches the top of the Earth's atmosphere with a constant of 1,367 W/m2, according to the World Meteorological Organization (WMO). There are small variations, since there are higher or lower periods of solar activity and due to the elliptical orbit of the earth, which leads to a standard deviation of 1.6W/m2 in the measurements (Muhlia, 2006). The average solar constant on the earth's surface is 342 W/m2, a quarter of the total amount, due to the effect of rotation of the Earth and the difference in areas between the solar disk and the spheroid surface of the Earth. (Glynn and Heinke, 1999).

The sun moves throughout the year on a path described by two angles: zenith and azimuth. The zenith angle is one that follows the sun throughout the year because of the decline of 23.45 ± that the Earth has with respect to the normal angle of the ecliptic which leads to the different seasons. These angular changes can be seen when the sun is lower in winter and very high in the summer. The Azimuth angle is the one that describes the sun every day due to the rotation of the earth. The sun rises in the East and sets in the West.

10.2.2 The solar radiation that reaches the surface of the Earth.

The solar radiation consists of a spectrum of electromagnetic waves of different wavelengths that is measured in micrometers (um). Waves with a shorter length or short wave are those containing higher spectral irradiation, which indicates high energy content; among them are gamma rays, X rays and C, B and A ultraviolet rays (0.2μm to 0.4μm). The visible spectrum ranges from blues to reds going through greens, yellows, and oranges (0.4μm to 0.7μm). The wavelength continues to grow to cover the spectrum of infrared, microwaves, radio waves and audio (> 0.7μm) (Sutton and Harmon, 1980).

DGiven the different wavelengths that the solar spectrum has, the Earth's atmosphere acts as a filter of some portions of these waves to protect the life that inhabits it (the ozone layer stops UV and gamma rays). It also stimulates the development of wind cycles, water evaporation, moisture and rain through thermal absorption (Theron and Vallin, 1979). Solar energy lights up the earth's surface through dispersion or diffusion to collide with suspended particles of dust, ash, aerosol and humidity. Furthermore, it energizes living creatures through the life cycles of photosynthesis and food chains. (picture 10.2)

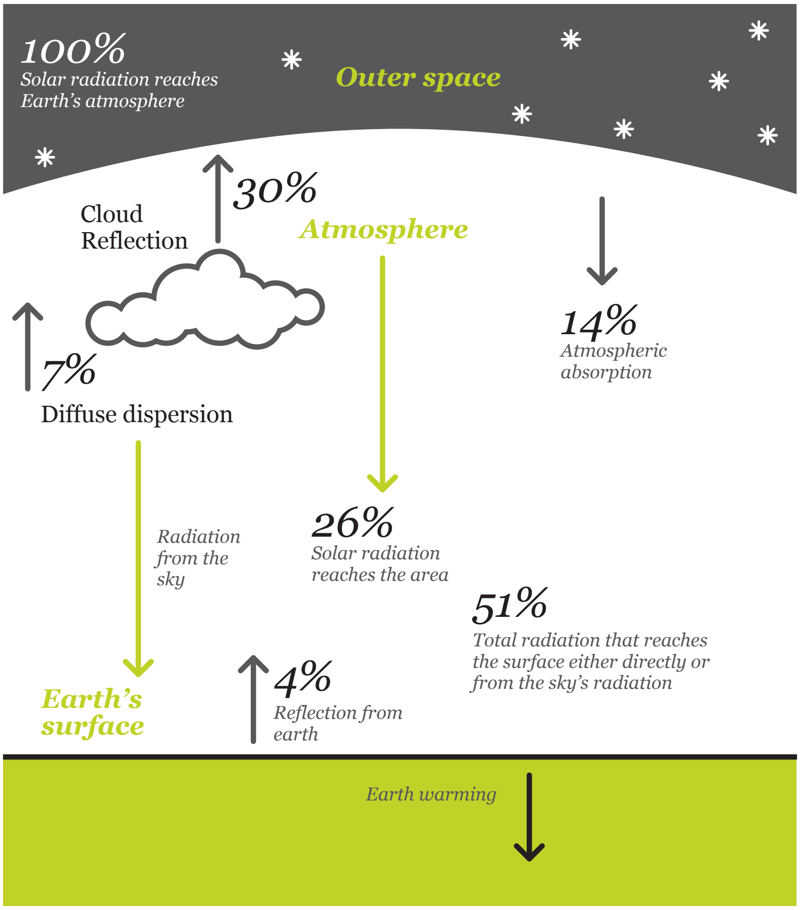

Figure 10.2
Energy input to the Earth's surface at noon.

Source: Sutton and Harmon, 1980.

The solar radiation that falls on the earth's surface is called global solar radiation and is subdivided into direct sunlight, which is what generates shadows and comes from the solar disk, and diffuse solar radiation, which is what makes the sky blue and illuminates cloudy days.

10.2
Solar thermal technology

10.2.1 Principles of converting solar radiation to heat

Heat (Q) is an energy that crosses borders and something bodies do not posses. A body yields or captures heat only when there is a temperature flow in a hot-cold direction. Energy in the form of radiation from the sun is energy as heat. This enters the solar thermal system, so that later the black body or receiver transmits it by conduction, convection and radiation to the transfer fluid.

In order to calculate the approximate efficiency of a solar thermal system, we can use a simple mathematical model, as shown below:

$$Q = mC_x\Delta T$$

Where C x is the specific heat capacity, ΔT is the temperature differential in Kelvin or Celsius degrees between the initial and final temperature and m is the mass in kilograms of transfer fluid. The constant C × expresses the required energy in kilojoules to change the temperature of one kilogram of the X transfer fluid by one degree Celsius or Kelvin (in proportional scales).

If the first equation is divided between the solar radiation accumulated in the collector area during the period in which the initial and final temperatures were taken, we will get the approximate equation of the solar collector efficiency:

$$\eta = \frac{Q}{I}$$

Where η is the efficiency of the collector, with a dimensionless value between 0 and 1, while I is the accumulated solar radiation in the collector area during the test period.

10.2.2 Passive and active devices

A solar thermal collector absorbs the maximum amount of energy radiated by the sun in the form of thermal energy for its use in functional applicators.

These include the heating of water, the mechanical movement of hydrogen Stirling engines, evaporation of water for desalinization in desert areas or where water is scarce, seed drying, food preparation, electric power generation with steam turbines, heating and even with its concentration at the same point, casting of metals. The basic elements of all solar thermal collectors are:

- Black body or receptor means any receptor in any physical state which, by its chemical composition and attributes such as color, light refraction, absorbance, and specific heat capacity, will be able to retain or absorb part or all of the energy radiated by the solar electromagnetic spectrum.
- Thermo tank or thermal storage unit: Receptacle that usually has some thermal insulation, corrosion and thermal shock resistance and whose function is to store the energy captured by the black body for its use.
- Conductor or fluid transfer: All gaseous or liquid fluid which is in contact with the black body and which, by means of convection and thermal conduction, absorbs heat from the same until thermal equilibrium is reached according to the zero thermodynamics law; then this transfer fluid reaches the thermo tank, where it is stored until it is used directly (eg, homes) or indirectly in the generation of electricity.

Solar thermal collectors are classified into passive and active. Each is classified according to the technology they use as indicated below (Gutierrez 2001).

Passive collectors

Use solar energy, store it and distribute it naturally. They contain no mechanical parts. They are divided into structural collection or flat panel collection.

Structural Collection

It refers to the architectural design of buildings where solar radiation is used to control the internal temperature, lighting and natural ventilation. The basic elements of these systems are the following: (Gutierrez 2001):

- Translucent materials: allow the passage of solar radiation, but not their exit through the greenhouse effect. Some examples are glass, acrylic and polycarbonate.

- Thermal mass: store thermal energy in a structural element or deposit for its use during periods of cold or overnight. Examples include concrete, brick, cement, volcanic stone tiles and water.
- Thermal insulation: is material with a low thermal conductivity and filter systems such as blinds, net curtains and eaves. Examples of insulators are air (as in the double glazing or triple), polyurethane foam, polystyrene or styrofoam and fiberglass.
- Reflective Elements: used to increase or decrease the radiation entering the building according to its orientation. They can be made of aluminum and acrylic sheets, and even mirrors or the backs of CDs.

When strategically placed in a building these materials it's possible to obtain surprising energy savings. In the industrialized nations, buildings consume between 35% and 40% of their total primary energy and generate about 33% of greenhouse gas emissions (GHG) like CO2 (Aitken, 2003). There are 3 types of systems in which structural collection is developed.

- Direct Gain: The sun's radiant energy enters the building through translucent materials (windows, skylights, domes, etc.) and is stored and distributed internally.
- Indirect Gain: The sun's radiant energy enters the system through thermal conduction or convection of materials located outside the building that are normally covered by translucent material.
- Mixed Gain: A combination of the two.

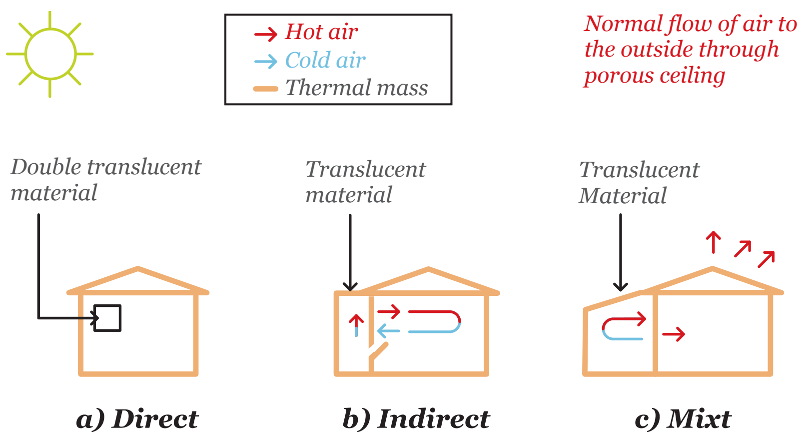

Figure 10.3
Structural passive systems.

Source: Own elaboration by Peter H. Brailovsky and Sergio Romero. Note: The appendix presents the figure as prepared by the authors.

Obviously it is easier to install such systems during the construction of a building than once it has been completed. However, various low-cost modifications can be made (isolate exterior walls, domes and install natural ventilation systems) with a significant energy saving. Among other advantages, studies have shown that children's learning curve in classrooms with solar light is better than those with artificial light. There has also been an increase in productivity and job satisfaction in buildings and even an increase of up to 15% in sales at shops with natural light (The Economist, 2009).

Collecting with natural convection flat panel

They are devices that are formed by one or two layers of a transparent material such as glass or plastics, an irradiation-receiving layer, a transfer fluid such as air or water and a thermo-tank. They have an average size of 2m^2 (Deaf, 2009). They can be 3 types:

- Serpentined metal tube: use iron, copper or aluminum serrated plates as the host material (Picture 10.4). They reach a temperature of 40° C and are used to heat swimming pools and water for showers. (Deaf, 2009).

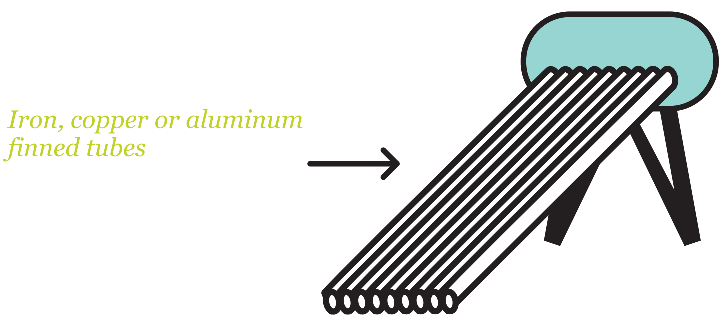

Figure 10.4
Flat coil heater.

Source: Own elaboration by Peter H. Brailovsky and José A. Sordo. Note: The appendix presents the figure as prepared by the authors.

- Tezontle Collector: It uses porous volcanic stones such as black volcanic rock, to heat water to 60°C. It reaches efficiency ratings of up to 58% and is a very economical alternative to the market of solar heaters in Mexico. At present, it is being developed at the Technological Development Center at the Autonomous Technological Institute of Mexico (ITAM, initials in Spanish) (Picture 10.5).

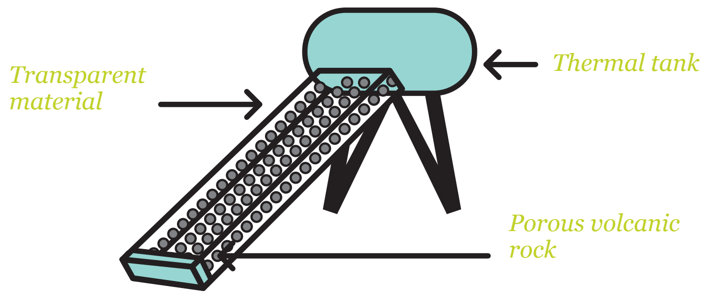

Figure 10.5
Solar volcanic rock (tezontle) heater.

Source: Own elaboration by Peter H. Brailovsky and José A. Sordo. Note: The appendix presents the figure as prepared by the authors.

- Vacuum tubes: They are 2 borosilicate glass tubes separated by a vacuum and covered with aluminum nitrate in the inner tube as a material receiver (ANES, 2006) (Pictures 10.6 A and 10.6 B). They reach temperatures of 80°C and represent a proven home gas consumption saving of up to 60%.

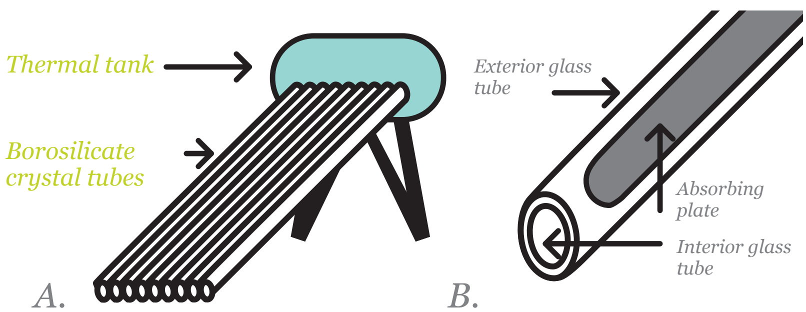

Figure 10.6 A
Vacuum tube solar heater.

Figure 10.6 B
Vacuum tube details.

Source: Own elaboration by Peter H. Brailovsky and José A. Sordo (10.6 A) and Thermosol, 2008 (10.6 B). Note: The appendix presents the figure as prepared by the authors.

Active collectors

They use mechanical devices such as pumps, solar trackers, electro-valves, among others. They are divided into fixed collectors and mobile collectors.

Fixed collector

The collector is in a fixed position throughout the day and the year. They can be two types:

- Flat panel: It has the same components and operating characteristics as the natural convection flat plate collectors, but these devices use pumps or fans to force the flow of transfer fluid (water, oil or air). When oil or water is used and refrigerants are added as transfer fluid, a closed system is required as well as the use of a heat exchanger to transfer energy for its final use (Picture 10.7).

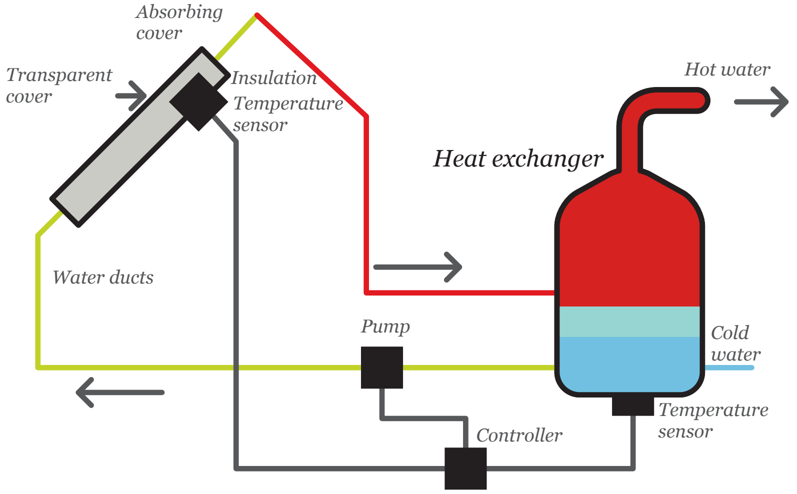

Figure 10.7
Active flat collector system.

Source: Own elaboration by Peter H. Brailovsky.

- Solar Pond: It consists of a body of natural or artificial shallow water with high salt content, forming a layer of non- convective water; this layer is formed by increasing the salt density in the water. Since hot water cannot connectively flow to the surface, it is trapped at the bottom and reaches temperatures of 90 °C. This technology was developed in Israel and it is 20 times cheaper than flat collectors (Covantes 1989).

Mobile collector approach

Use reflective surfaces or Fresnel lenses to concentrate captured sunlight on a smaller absorption area (Covantes 1989).

This type of device has manual or automatic operating mechanisms using servo or stepper motors with a control system operated by light sensors or by the upgrade of a mathematical model as follows (Almanza et al 2003):

$$\delta = \left[23.45 * \sin\left(\frac{360(284+N)}{365}\right)\right] - \phi$$

Where ϕ is the solar declination for each day of the year with respect to latitude, δ is the latitude (positive north of Ecuador) and N is the Julian day of the year, where N = 1 is the first of January.

In this model, the optimal orientation of the collector is given by but this kind of guidance only follows the sun in its zenith trajectory. A solar tracking mechanism increases 30% the energy produced by a system that operates with direct and diffuse radiation, and represents a 25% increase in total system cost (Carmona, 2005). Any concentration solar device can only take advantage of direct sunlight, so it is essential that it has a sun tracking mechanism. The movement that the collectors can have is classified according to the number of axis:

- Follow up on one axis: Follow the sun on its Azimuth angle and concentrate energy up to 50 times at one point. They are used at solar thermal plants with parabolic channels, which are medium temperature (350 ° C) concentrators (Covantes, 1989).
- Follow-up on two axes: Track the sun on its Zenith and Azimuth angles and concentrate energy up to 1,000 times at one point. They are used at parabolic dish plants and in the heliostats at central tower solar plants that concentrate high temperatures (2.000 ° C) (Covantes, 1989).

10.2.3 Thermo-solar plants

These are also known as helioelectric plants, and are responsible for transforming solar energy into electrical energy. This process is carried out by the reception and the capture of solar radiation in a boiler. Subsequently, directly or indirectly (through a heat exchanger), the water or an organic element (isobutene, isopentene) evaporates, is heated and is forced under pressure into a Rankine cycle turbine (except on parabolic dish), whose shaft is connected to an electromagnetic generator. The electrical energy exits the generator at a low voltage and is sent to a transformer to increase the voltage and then to an electrical substation for its distribution. The types of solar plants and their characteristics are shown below.

Parabolic Channel

They are tracked on one axis and consist of elongated metallic structures that are installed in the reflective surfaces with a parabolic profile (in the form of a crescent moon) and are responsible for concentrating the sunlight at one point. They have a dark absorbent tube through which the transfer fluid passes (trimethylbenzoyl-diphenyl phosphinoxide or non-polluting oils, according to U.S. standards), as seen in Figure 10.8 (IEA, 2003). It is the most mature thermal solar technology, but the success of the central tower plants is rapidly replacing it. The Israeli company, Luz International Ltd. installed nine such plants in the desert at Mojave, California, with a capacity of 354 MW. Eight of the plants operate in a hybrid way, with a maximum support of 25% natural gas, and the other uses a thermal storage system (IEA, 2003).

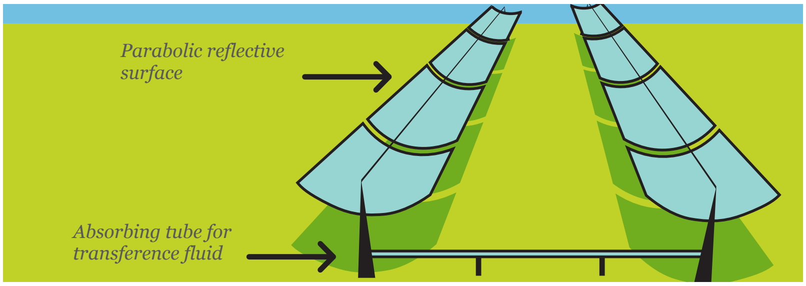

Figure 10.8
Parabolic trough plant.

Source: Energisol NG, 2009.

Central tower or central receiver

It is tracked on two axes and consists of a fixed structure of steel or reinforced concrete in the shape of a tower, whose top houses a receiver that transfers the energy to the transfer fluid. A series of mirrors or moving heliostats is radially distributed around the tower and oriented to project sunlight directly to the receiver (Figure 10.9). These are the thermal solar plants with the highest plant factor (Chart 10.1) since a thermal storage system of molten salt has been successfully adapted. This can overcome the limitation of solar intermittency and generate electricity at a constant rate and with a smaller turbine.

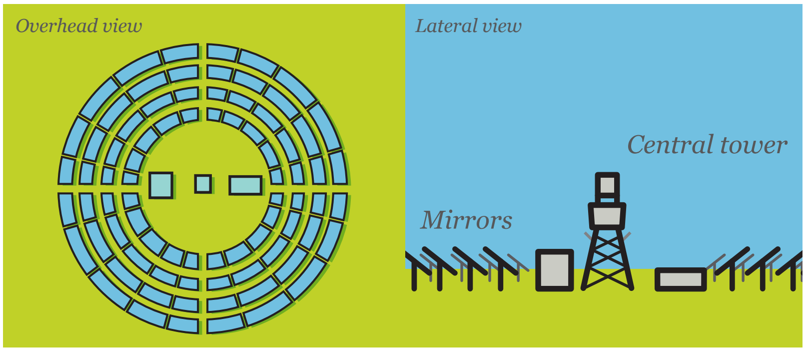

Figure 10.9
Central tower plant.

Source: Bitdrain, 2009.

Parabolic dish, plate or paraboloide.

This is tracked on two axes and consists of a similar structure to that of the parabolic antennas. However, the paraboloide is formed by multiple mirrors which focus the energy on the absorbent point where there is a Stirling engine to generate electricity (Figure 10.10). With respect to the previous two, they have the advantage of not requiring large expanses of territory and can be installed in areas where there is no connection to the national electric grid. Currently, they have a higher cost per kW installed, and there are no commercial plants using this technology. Its peak efficiency is the highest of all the thermal solar technologies (Chart 10.1).

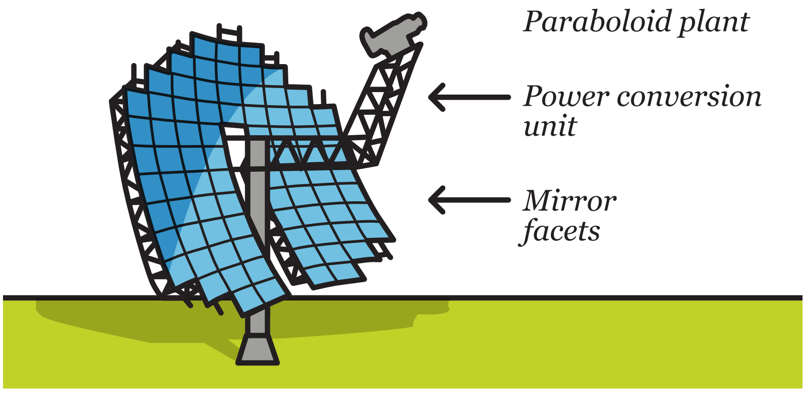

Figure 10.10
Parabolic dish plant.

Source: Solúcar, 2007.

Solar Pond

These plants can reach temperatures close to 90 ˚C, and their construction is economical. Organic fluids, through a series of heat exchangers, and with a low evaporation point, are overheated by the layer of hot water at the bottom of the solar pond. Then, the overheated steam is introduced into a low pressure turbine and electricity is generated. The surplus steam from the turbine is condensed in cooling towers or in a sump (upper layer of the pond) and pumped back into the heat exchanger (Fig. 10.11). This type of technology has practically not been used for generating electric power, since the low temperature turbines for the Rankine cycle were manufactured again in 1973. They have a conversion efficiency of solar energy to electricity of 20% and are suitable for installation in regions located at 40˚ latitude, without a significant loss of efficiency. Notwithstanding, it is preferable to install them near salt mines or in coastal areas (Covantes, 1989).

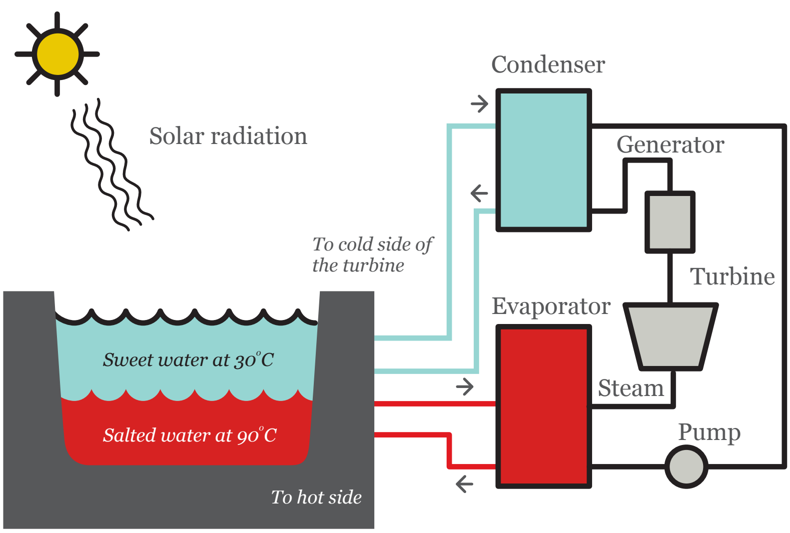

Figure 10.11
Solar pond plant.

Source: Own elaboration by Peter H. Brailovsky.

Hybrids

They are any combination of the above plants with conventional power plants or combined cycle power plants (gas turbine and steam). They increase supply capacity and utilize existing infrastructure in locations with high solar irradiation. The central tower plants can become hybrid plants with combined plants of natural gas, coal and oil, which burn using the

Rankine cycle (IEA, 2003). In Mexico, the solar combined-cycle plant, Agua Prieta II is being built in Sonora, and it will have a 25 MW solar field (Torres and Gomez, 2006).

Chart 10.1
Peak efficiency and annual plant factor by type of technology.

Source: IEA, 2003.

	Parabolic trough	Central tower	Parabolic dish
Peak efficiency	25%	23%	29%
Annual plant factor (with and without thermal storage)	24%	25%-60%	25%

A solar thermal plant requires about 3,561 m2/GWh generated, slightly less than that required by a carbon electric plant, including the land for the mines.

There are other types of solar thermal plants, like solar chimneys. An example of this is the 50 kW plant in Manzanares, Spain, built in 1981, occupying a collection area measuring a diameter of 240 meters and with a stack that is 195 meters high. These plants operate by heating air in a flat base covered with glass or plastic, which then rotates an air turbine at the base of the stack.

They are very inefficient (1.3%) and occupy a large space (100 MV would require a collection area of 3.6 km in diameter and a stack of 950 meters). (Boyle 2004)

10.3 Useful energy generated by solar thermal systems

Solar thermal and geothermal energy share many similarities in their use or application, since, regardless of the source generator, both work with thermal energy. The heat may be generated in the following ways:

Process heat at a low temperature (less than 100 ° C)

It is generated by all passive or active flat devices (except some of vacuum tubes). It is used in the following sectors:

- Domestic: water heating (for residential use and swimming pools) and hydronic heating or conditioning of dwellings.
- Agriculture: for aquaculture, greenhouses and silos, it helps control temperature and allows for the low-cost drying of grains (coffee and cereals), fruits, vegetables and tobacco without contaminating the products (Covantes 1989).
- Industrial: for thermal resorts and spas, heat pumps for fluid pre-heaters and for conditioning industrial or commercial buildings. (Gutiérrez 2001).

Process heat at medium temperature (between 100 °C and 350 °C)

It is generated in vacuum tube systems and in axis concentration devices (parabolic channels). It is used in the following sectors:

- Domestic: for absorption refrigeration systems (the sun´s thermal energy helps separate water from ammonium in order to re-start the absorption cycle) and by compression (the compressor is powered by solar energy); for concentration solar stoves (pyramid, parabolic and flat collector, and for electricity micro-generation in rural areas which are not connected to the electric power grid (Covantes 1989).
- Agriculture: for wood drying, electric power generation, water pumping, etc.
- Industrial: for refrigeration (Mexican fisheries are an important niche for this type of application) (Covantes 1989) concrete curing, milk pasteurization, CO2 production, salt extraction, distillation (evaporation and condensation of water) and sterilization of medical instruments, solutions, dairy products, treated water, etc. (by raising its temperature above 90 ° C, because at this temperature bacteria and larvae cannot survive) (Sacchi and Testard, 1971).

Process heat at high temperature (between 350 °C and 2000°C)

It is generated in two axes concentrator systems, in particular tower or central receivers. It is mainly used in the industrial sector, in foundries, and for the generation of mechanical energy and electricity.

10.4 Current and potential solar thermal energy use in the world and in Mexico

The potential consumption of solar thermal energy in the world depends directly on the average irradiance levels on the earth's surface. Figure 10.12 shows the levels of direct radiation in the world, indicating the potential of concentrated solar power:

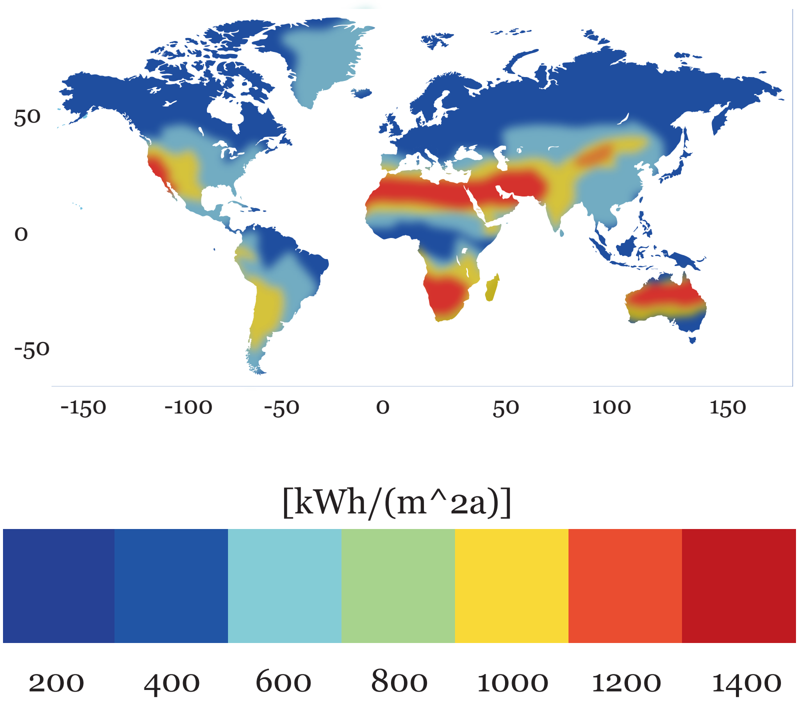

Figure 10.12
World direct solar radiation heat map.

Source: IEA, 2003.

Clearly, northern Mexico has enviable levels of direct solar radiation much higher than Europe, which already uses solar thermal technology.

10.5
Limitations and advantages of solar thermal technology

10.5.1 Intermittency, low concentration of solar radiation and storage systems

Solar radiation is subject to the seasonal cycle, the cycle of day and night, and natural phenomena like rain and clouds; all this makes it an intermittent energy source (one cannot count on it all the time and its intensity is variable .) In the case of solar thermal plants, this only represents a problem for the systems not connected to the grid. However, with the inclusion of new and proven thermal storage systems using molten salt (common salt or nitrate salt which has a higher efficiency) or with molten metals such as sodium (Na), this problem is being solved. Solar pond plants, through the non-convective brine layer and the upper-convective water layer, have the ability to store and isolate hot water for several days without being affected by intermittence. The plants connected to the grid can deliver the generated energy in various ways, and the CFE only has to regulate the system by partially opening and closing the gates at the large hydroelectric plants (which run as an inventory or energy buffer).

For residential water heating systems, the operation of hybrid systems with traditional gas or electric heaters already installed in the homes, solves the problem of intermittency, even some thermal storage solutions can work for 12 hours and new ones that can work up to 16 hours are already being developed.

The amount of energy per area unit radiated by the sun has a low concentration that requires systems to have good thermal insulation (such as air, vacuum, fiberglass and polyurethane foam) that facilitate energy storage until it reaches useful levels. In the case of the systems for generating electricity or mechanical energy, it is necessary to concentrate the solar radiation to solve this problem. Storage systems increase the supply and commercialization capacity of solar plants, which satisfies the electric demand and lowers system installation costs by using smaller turbines (IEA 2003). There are two forms of thermal storage:

- Sensitive heat: Stores energy with increasing temperature. The demonstration plant at the Mojave Desert in California, named Solar Two, with 10 MW of central tower type energy, successfully tested the use of molten salt as thermal storage with a 12 hour capacity. The Spanish commercial plant, Solar Three with 15 MW, also uses this system (IEA, 2003).
- Latent heat: Stores energy without increasing temperature due to the enthalpy of phase changes.

Thermal storage systems for parabolic plants are under development. Currently, electric storage systems have been installed using capacitors (batteries), which are very expensive.

10.5.2 Energy efficiency at local and distributed systems

A great advantage of solar thermal systems is that the power source can be utilized on-site; this allows for the use of installations distributed in geographical areas where the national power grid has not yet arrived or where road infrastructure hinders the transport of fossil fuels for their traditional generation. The distribution of electrical power generation systems minimizes the costs associated with transmission.

Although solar thermal plants and residential water heating systems based on the combustion of fossil products have a higher average energy efficiency (around 75%) than solar thermal systems (average efficiency of 25% for thermal plants and 40 % for flat plate collectors) the sun's energy is free and the costs associated with installation and generation of solar thermal plants are becoming increasingly competitive versus traditional generation and other renewable energy sources.

10.5.3 Maturity of different systems and devices

Although passive structural collection systems have not been sufficiently promoted, they are in a maturation period as prior to the invention of electric energy in 1831, they were the basis for interior lighting designs (courtyards at haciendas and colonial buildings in Mexico), ventilation and temperature control (high ceilings in hot areas).

Flat collectors are also well positioned in Mexico and the world. This is an industry with an annual growth rate of 18.3% in Mexico for 2008, and there are approximately 50 companies that manufacture, import and market these technologies, some of them for at least half a century (Deaf, 2009).

Parabolic solar plants are still in the development and pilot plants installation phase (40 MW by 2005, but with an annual growth rate of 40% for systems which are not connected to the grid). The situation of parabolic channel plants is very different, since there are already commercial and "show-room" plants that by 2005 had a worldwide capacity totaling 650 MW, with an annual growth rate of 20%. Similarly, although less mature due to their installation costs, are solar tower plants that have commercial and "show-room" facilities in the U.S., Spain, Japan, Russia, Germany and France, totaling by 2005, a worldwide capacity of 135 MW. It is expected that 4,000 MW will be reached by 2020, with an annual growth rate of 25% (Chart 10.2). In the world there are 25 companies that design, sell and operate these plants (IEA, 2003).

	2002	2005	2010	2020
Parabolic trough	354	650	1,600	10,050
Central tower	25	135	410	3,850
Parabolic dish	1	40	215	6,250

Chart 10.2
Installed capacity, planned and predicted by technology, units in electrical MW.

Source: IEA, 2003.

Some materials with improved thermal properties, optical and chemical resistance, which include polycarbonate fiberglass and neoprene seals, have been developed. However, science and engineering must continue studying and producing materials with improved properties (Chart 10.3) in order to increase the efficiency of solar thermal systems and lower its costs as well as those of its components'(central tower heliostats, nitrate salts, stainless steel pipes, among others).

Transparent container	Materials	Optimal level
Properties	Reflection	Low
	Transparency	High
	Weatherproof	High
	Thermal insulation capacity	High
	Shock resistance	High
	Temperature Resistance	>°C
	Permeability	High
	Fluvial chemical resistance	High
	Growth of bacteria and algae	Low
	Cost	Low

Black body	Materials	Optimal level
Properties	Absorbance	High
	Specific heat capacity	Low
	Cost	Low

Chart 10.3
Properties of transparent container and black body with optimum levels.

10.6 Opportunities for Mexico

10.6.1 Geographical location and amount of energy received

Mexico is geographically located between 14° and 33° northern latitude (N. Sánchez, 2008). This is ideal for harnessing solar energy, since nationwide average irradiation is around 5kWh/m^2-day, placing the country in the forefront worldwide. The average radiation changes throughout the Republic and also depends on the month in question, descending slightly below 3kWh/m^2-day, and reaching values higher than 8.5 kWh/m^2-day (see Annex 10.1). Figure 13 shows the annual average daily global radiation in MJ/m^2 (Almanza R, et al, 2003).

Numbers in parentheses in daytime langleys

* Values for US are from Bennet, 1965 and Hulstrom, 1981

(1 Langley = 1 calorie / cm^2)

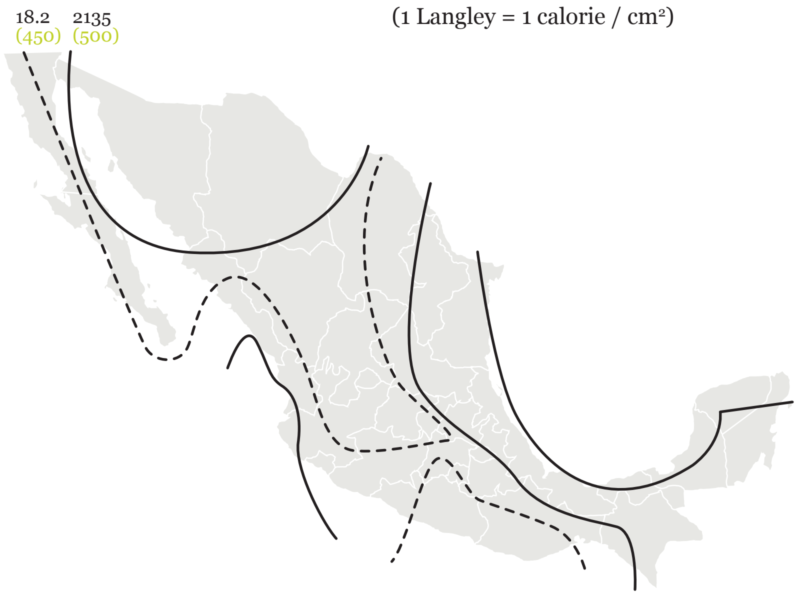

Figure 10.13
Annual average of daily global irradiation in MJ/m^2.

Average monthly global irradiation values for the Mexican Republic can be seen in Chart 4, while the monthly irradiation range in Mexico can be seen in Figure 14.

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Min*	*Max*	*Med*
Minimum	3.1	3.3	3.1	3.8	4.1	4.4	4.5	4.5	4.1	3.5	3.1	2.8	2.8	4.5	3.7
Maximum	5.4	6.3	6.6	7.5	8.3	8.6	7	6.6	6.7	6	5.7	5.6	5.4	8.6	6.7
Average	4.1	4.7	5.3	5.7	5.9	5.6	5.6	5.5	5.1	4.7	4.3	3.8	3.8	5.9	5

Chart 10.4
Source: CONUEE, 2008.

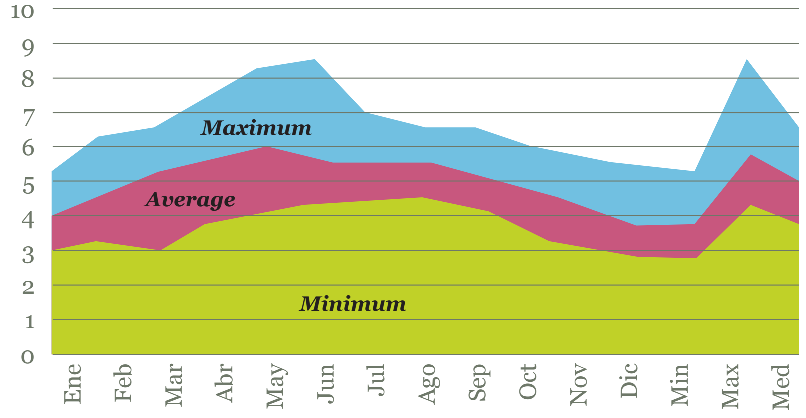

Figure 10.14
Monthly irradiation range in Mexico

Source: CONUEE, 2008.

The insolation distribution (period when solar radiation heats the Earth's surface) in the country must consider the average number of clear and cloudy days for each region. The northwest and north (states of Sonora, Chihuahua and Baja California) have the highest insolation, it is lower in the highlands and even lower in the southeast and the Gulf Coast of Mexico (due to the great number of cloudy days) (Ayllon and Chavez, 1992).

10.6.2 Appropriate technology for the country's industrial capacity

The domestic industry could manufacture most solar thermal systems components, as there are many companies producing and working iron, steel, aluminum, copper, glass, plastics, or polymers (polycarbonate), acrylic with aluminum, mirrors, concrete, organic fluids and salts (salt mines or salt flats). The manufacture of solar thermal systems does not require such accurate processes, compared to the photovoltaic industry, nor a degree of process automation, which the country does not possess. The most specialized components, which at first would have to be imported, are servomotors, stepper motors, and heliostat and Fresnel concentrator lenses.

10.6.3 Laws that promote renewable energy

There are various regulations that regulate and promote the use of renewable energies in Mexico. For example, the Law to take Advantage of Renewable Sources of Energy (LAFRE) issued by the Energy Secretary (SENER) (Mata, 2005) seeks to complement the existent legislation in order to establish the conditions for individuals and state-run companies to generate electric power from renewable sources and to take advantage of solar thermal energy, geothermal energy or pumping using wind energy, among others. Moreover, The Interconnection Agreement for Renewable Energy Sources (IEA, 2009) issued by the Energy Regulatory Commission (CRE) sets the requirements, terms and conditions for interconnection of renewable energy sources to the national grid, applicable to intermittent sources of energy (such as solar) at installations with smaller storage capacities than those needed independently. Therefore, excess energy can be sent to the grid to be used later when needed. The SEMARNAT and the SHCP have a program allowing for accelerated depreciation on investments that protect the environment (IEA, 2009).

Likewise, there are programs designed specifically for the use of solar energy. The Program for Promotion of Solar Water Heaters for the Residential Sector in Mexico (2005) issued by the National Commission for Efficient Energy Use (CONUEE) seeks to “promote” the sale of solar water heaters in the domestic sector in Mexico, showing that it is a viable option to have hot water in Mexican households, which reduces pollution and helps conserve natural resources like gas (CONUEE, 2005). The Program promotes the sale and installation of solar heaters and follows up on the gas savings by participants. It offers a performance warranty that includes respectively, one, three, and five years for manufacturing and installation defects and useful life.

Currently, Mexico has a program for the Promotion of Water Heaters (PROCASOL 2007-2012) (SENER, 2009) for residential, commercial, industrial and agricultural sectors, so that by 2012 Mexico will have installed 1.8 million square meters of water heaters. Besides, due to the support by the World Bank, the Federal Government’s has been able to implement the project “Integrated Energy Services” to promote rural electrification with renewable sources, mainly solar energy (SENER 2008).

There is also international support. The project “Mexico Renewable Energy Program” (IEA 2009 Sandia National Laboratories (SNL) - with the collaboration of the Office of Solar Technologies of the U.S. Department of Energy and the United States Agency for International Development (USAID) - seeks to promote the use of renewable energy in off grid applications in Mexico as well as at small systems that use solar and wind power.

There are also official norms in Mexico aimed at harnessing solar energy. The Norm PROY-NMX-EN-002-NORMEX-2006 was published in September 2006, which defines the terms and language that will be used in various rules to regulate solar thermal energy, as well as standard techniques to measure irradiation and what the different types of solar heating systems and solar collectors are (NORMEX, 2006). The Norm NMX-ES-001-NORMEX-2005, "Solar-Thermal performance and functionality of solar collectors for water heating test methods and labeling" was published in October 2005. It establishes the procedure to determine the thermal performance of solar collectors with the only aim to use solar radiation as an alternative source of energy (NORMEX 2005). The Technical Norm for Labor Competency (NTCL) NUSIM005.01, "Installing solar hot water" was published in February 2009. It regulates the assessment and certification of solar water heater installations (SENER 2009).

10.7 Main barriers to its widespread use

10.7.1 Lack of regulatory laws and standards

There is a regulation relating to solar water heaters particularly in the residential sector. However, a more general framework is needed to regulate the use of large-scale solar thermal power. The incentives and regulatory framework needed to encourage private investment in this industry should be generated, so that society can collect the fruits of both, power supply and cleaner generation.

10.7.2 Social ignorance of its benefits

Ignorance on the part of decision makers about the state of development, costs and benefits of this technology has limited its widespread use, being restricted to small-scale use. For example, most of the population is unaware of the savings in energy and money a solar heater represents. That is why this technology´s market penetration has been difficult.

Moreover, the environmental benefits are difficult to discern. The effect of the reduction of GHG emissions in the local area is very difficult to assess on a global scale, as only the accumulation of reductions in different parts of the world and for a long period of time reports a global result. However, it is possible that after the meeting held on climate change in Cancun, the value of reducing GHG emissions will be expressed in economic terms, thanks to efficient mechanisms such as carbon credits. Thus, society will see the real benefit of power generation based on renewable sources. The carbon dioxide emissions per kWh generated by source used are shown in Chart 10.4.

Conventional systems		Renewable systems	
System	g-CO2/kWh	System	g-CO2/kWh
Coal	975.3	Wind	9.7-123.7
Oil	742.1	Photovoltaic	53.4-250
Natural gas	607.6	Biomass	35-178
Nuclear	24.2	Thermo solar	13.6-202
-	-	Hydraulic	3.7-237

Chart 10.5
Carbon dioxide emissions per kWh generated by source: comparison of life cycle engineering analysis (g-CO2/kWh) of different sources of energy.

Source: Varun, 2009.

The various types of solar thermal energy offer higher or lower reductions in carbon dioxide emissions. This depends on the type of technology and the efficiency of the equipment used, as shown in Chart 10.5

Year	Location	Type	Lifespan (years)	Power (MW)	g-CO2/kWh
2006	Italy	Parabolic (dish)	30	1	13.6
2006	Spain	Central tower	25	17	202
2006	Spain	Parabolic trough	25	50	196
1990	United States	Central receptor	30	100	43

Chart 10.6
Carbon dioxide emissions per kWh generated by technology.

Source: Varun, 2009.

Another social benefit offered by solar thermal energy is that it provides energy to communities or regions that lack electricity. It also creates jobs in these regions and elsewhere in the Republic. For this reason, the creation and support of society´s awareness programs and information on the benefits of renewable energy sources becomes essential. Good programs such as PROCASOL, require more publicity so that society becomes familiar with them.

10.7.3 Lack of appropriate funding mechanisms

Due to its geographical location, Mexico has a great advantage in terms of return on investment in solar energy. In northern Europe, the time required to recover investments in solar collectors is usually over 10 years and can even reach 30 years (Boyle, 2004). In Mexico, however, solar energy applications may leave a positive economic balance over a period of five to 10 years. Most applications are considered economically viable if we consider the profits made over its lifetime which means, in the long run. Despite this, most of Mexico's population lacks the resources to make the necessary investment. Financing mechanisms are needed in Mexico to eliminate this barrier. At present, we only have accelerated depreciation schemes which even when they help reduce the initial investment, do not solve the problem of the lack of financing mechanisms.

10.8 Strategic instrumentation

10.8.1 Science, Technology and Innovation

Solar thermal technology is in a period of great growth and development. Therefore, it is necessary to invest in research to improve the energy efficiency of solar energy collection systems and reduce the costs of various components such as mirrors, heliostats, collectors and electric generators. A decrease in costs would establish power generation fields that can compete directly with traditional sources (fossil fuels), but representing a vast improvement in terms of environmental protection and providing energy security to the country.

Currently, these fields require a large area to place the mirrors and have the disadvantage, with respect to wind energy, that this area cannot be used simultaneously for other activities (including agriculture). Because of this, the desert areas in the north of the country are ideal, but investment is required in transmission lines to send power to the CFE grid.

Another area in which shows great potential for development is the storage of collected thermal energy. The aim is to improve thermal energy collectors so that they work for up to 12 hours. If achieved, we could use solar energy collected and stored throughout the day (Aitken, 2003) during the night and morning, which would allow solar energy to heat water in homes.

Likewise, the implementation of efficient construction techniques allows for the use of solar energy for heating homes at a very low cost. This is useful in regions with extreme climates such as in the north, as it keeps the inside of buildings cool in hot weather and prevents heat from escaping in cold weather (Boyle, 2004).

10.8.2 Promotion and Industrial Development

On the use of large-scale solar thermal energy, the 171 CC Agua Prieta II Project with a solar field operated by the CFE is currently under development, in Sonora (SENER, 2008). The main goal is to have a combined cycle gas plant (SENER, 2009) with a gross capacity of 477 MW, and 25 MW of heat generated by a parabolic solar thermal system.

Moreover, Mexico is a world leader in small-scale solar thermal power generation with more than 1 million square meters of collectors installed and with a total generating capacity of more than 4.5 PJ per year. Mexico's position in the world can be seen in Figure 10.15.

To continue taking advantage of the thermal energy it is necessary to promote targeted programs in both, residential and industrial sectors.

10.8.3 Public Policy

The design and implementation of public policies that consider the external positive impact that solar thermal energy utilization has in the economic,

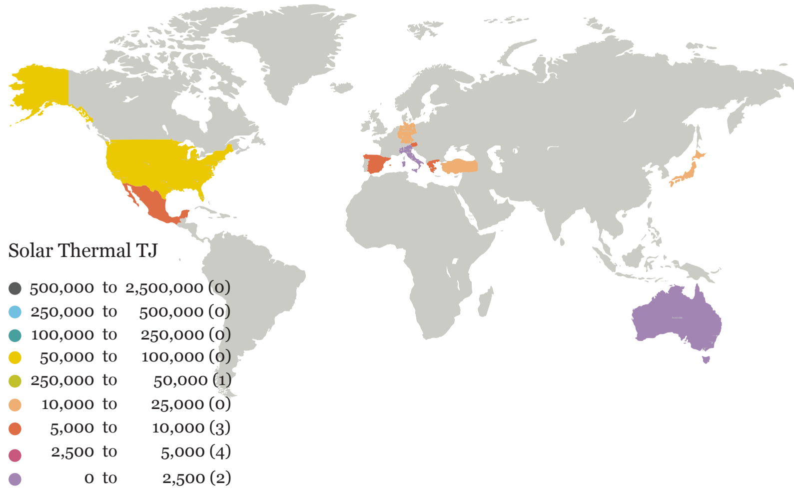

Figure 10.15
Countries with higher solar thermal energy production (TJ).

Source: SENER, 2008.

social and environmental areas is a topic of great relevance today. On the production side, incentives are needed, such as preferential rates for the incorporation to the national grid of power plants using solar thermal energy, or tax credits for its generation, accompanied by funding mechanisms, such as bonds, loans at preferential interest rates, tax exemptions or accelerated depreciation on investments. These measures would help reduce investment costs and the recovery time of the same, leading the private sector to channel resources towards renewable energy and solar energy in particular. Another way would be to establish an obligation to generate a certain percentage of energy from specific renewable energy at the municipal, state and federal levels. However, this is a less flexible mechanism, and therefore requires more care when setting goals in order to avoid an excessive achievement cost, which could even exceed the added benefit of having a higher percentage of renewable energy.

Internationally, the mechanisms described in the Kyoto Protocol, expected to be expanded on at Cancun, will help to reflect the positive external effect in the form of carbon credits, which will provide a great incentive for investment in clean technologies.

As for the residential sector, public policy should be focused on spreading the benefits of solar water heaters and on financing programs. Specific actions SENER has adopted to promote the development of solar energy in the country include the following (SENER, 2008):

- To establish optimal conditions for productivity and competitiveness of the solar energy industry, attracting investment and generating formal and quality jobs.
- To achieve the social, economic and technological of the communities to the solar energy systems in order to raise the level of development of the population and to promote and encourage training for its use.
- Preferably use electricity produced from solar systems for energy supply in areas currently not served by the national electricity system (SEN).
- Ensure compliance with environmental standards in all production stages in the solar energy industry.
- Evaluate, on a cost-benefit basis, the construction of infrastructures for large-scale solar power.
- Publish the laws under which activities related to this industry must be carried out, and where appropriate, provide technical advice.

10.9 Socio-economic and environmental impact of its widespread use

10.9.1 Increased job creation per unit of generated useful energy

Studies conducted to determine the effect of investment in solar energy technology on the labor market have concluded that the creation of jobs is greater than an equivalent investment in conventional technologies. For example, an analysis of the UP Public Interest Research Group shows that an investment that allows for the generation of 20% of the energy required by the U.S. from renewable sources would help create three to five times more jobs than a similar investment in fossil fuels (Aitken, 2003).

On the other hand, the U.S. Worldwatch Institute conducted a study that concluded that investing in solar energy would generate between 100 and 150 percent more jobs than using coal or nuclear power. This helps justify public investment in these new energy sources, as not only does job creation increase the wealth available for investment and consumption, resulting in a multiplier effect of spending, but also reduces the marginal costs of electricity generation (Aitken, 2003)

10.9.2 Economic feasibility of the incorporation of solar thermal systems.

The biggest problem with solar technology is its cost, so investment in research and development to achieve technological advances that allow for their reduction is required (SENER, 2008). However, solar thermal technology has a much higher yield than that of photovoltaic systems, so that even if the price of PV systems fell by one half, it would still be more expensive (per unit of energy generated) than solar thermal systems.

Note that the systems are economically viable in a planning horizon of five to ten years due to high irradiation in the country.

The International Energy Agency (IEA) presented a study on the costs of investment and generation of various renewable energy sources, projected to 2010 and based on a discount rate of 6% and a payback period of investment of 15 to 25 years with scenarios of low and high cost. The information is summarized in Chart 10.6.

Chart 10.7
Investment and generation costs by renewable source (values in dollar per kW). Source: IEA, 2003.

	Investment (low cost)	Investment (high cost)	Generation (low cost)	Generation (high cost)
Mini hydro	950	4500	0.2	0.8 - 0.13
Photovoltaic	3000	4500	0.10 - 0.15	0.18 - 0.40
Thermo solar	2000	4000	0.6 - 0.8	0.10 - 0.12
Biofuels	400	3000	0.2	0.8 - 0.12
Geothermal	1000	3500	0.2 -0. 3	0.5 - 0.10
Wind	700	1300	0.2 - 0.4	0.6 - 0.9

Source: IEA, 2003.

It can be seen that solar energy has advantages in terms of its cost with respect to the photovoltaic solar technology, although at its current development stage, which is lower than other renewable sources, it is more expensive.

Another advantage is that the useful energy can be produced where it is to be consumed, thereby reducing costs considerably. Transport and distribution of secondary energy, as well as the transmission and distribution of electricity, increase the costs and decrease the overall efficiency of the energy systems. This can be avoided by placing the energy generation fields close to the demand centers, or using solar energy on a smaller scale in the residential sector with solar water heaters.

10.10 Conclusions and recommendations

The use of solar energy is recommended in arid or semiarid regions with a 1.700 kWh/m2 (IEA, 2003) average annual irradiation in the states of Sonora, Baja California, Chihuahua, Durango, Zacatecas, Coahuila, Sinaloa and Aguascalientes mainly.

The installation of hybrid systems is highly recommended in the country's thermoelectric power plants located at sites with the irradiation characteristics and climate mentioned above (in the north of the country). The most efficient plants are built of both, combined and solar cycle (with central tower or parabolic canals); a thermal storage system by molten salts or molten nitrate salt (with 16 hour-storage) can be installed to increase supply capacity and the plant factor, (from 22% to 60%) and diminish the size of the turbine, thus reducing the share generated by burning fossil fuels.

Installation of paraboloide plants is recommended in areas located ar from the national grid, because they are more economical than photovoltaic systems, in applications from 10kW to 10MW (Gevorkian, 2007). We also recommend the installation of large solar thermal power plants (over 400 MW) which are close to each other in order to reduce generation costs due to maintenance and operation. The specialized literature indicates that doubling the size of the plant, reduces the cost of capital between 12% and 14% (IEA, 2003).

The installation of solar pond thermal power plants near the salt mines, the salt marshes and coastal areas is advisable, since the cost of these plants is very low and they have a great energy generation potential in our country and for its use in direct heat applications at temperatures below 90 ° C.

Lastly, we need to promote the purchase and installation of passive systems for flat plate collectors (tezontle or vacuum due to their cost and efficiency) and structural collection systems in the domestic and industrial sector. Development programs that include solar applications in agriculture and aquaculture should also be established, with the aim of promoting their development at a low cost.

In general, we need to modify the legal framework and create financing mechanisms in order to change incentives to encourage private investment in renewable generation technologies. In the case of Mexico, solar energy has great unexploited potential with the consequent economic and environmental costs. However, it is expected that with the United Nations conference in Cancun this topic will become more relevant and that public policies will emerge to encourage solar energy use.

Finally, the use of solar energy sources should be maximized bearing in mind the privileged location of the country in terms of solar energy collection. Proper implementation of solar thermal projects to provide some of the base demand for the national electricity sector can be a key player in reducing the carbon footprint associated with energy use in Mexico. This would increase energy security by basing production in an inexhaustible and permanently available “fuel”.

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Anexo

State	City	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mín.	Max.	Med.
Sonora	Hermosillo	4	4.6	5.4	6.6	8.3	8.6	6.9	6.6	6.7	6	4.7	3.9	3.9	8.6	6
Sonora	San Luis Río Colorado	3.4	3.8	4.9	6.2	7.3	7.4	6.9	6.1	5.1	4.05	3.3	2.8	2.8	7.4	6
Sonora	Guaymas	4.5	5.7	6.5	7.2	7.3	6.8	5.9	5.8	6.3	5.9	5.1	5.6	4.5	7.3	6
Jalisco	Colotlán	4.6	5.7	6.5	7.5	8.2	6.6	5.8	5.6	5.8	5.3	4.9	4.1	4.1	8.2	5.9
Chihuahua	Chihuahua	4.1	4.9	6	7.4	8.2	8.1	6.8	6.2	5.7	5.2	4.6	3.8	3.8	8.2	5.9
Querétaro	Querétaro	5	5.7	6.4	6.8	6.9	6.4	6.4	6.4	6.3	5.4	5	4.4	4.4	6.9	5.9
Zacatecas	Zacatecas (La Bufa)	4.9	5.7	6.6	7.5	7.8	6.2	6.2	5.9	5.4	4.8	4.8	4.1	4.1	7.8	5.8
Oaxaca	Salina Cruz	5.4	6.3	6.6	6.4	6.1	5	5.6	5.9	5.2	5.9	5.7	5.2	5	6.6	5.8
Sonora	Cd. Obregón	3.6	4.5	5.9	7.1	7.7	7.5	6.07	5.8	5.6	4.9	4.09	3.4	3.4	7.7	5.7
Durango	Durango	4.4	5.4	6.5	7	7.5	6.8	6	5.6	5.7	5.1	4.8	3.9	3.9	7.5	5.7
Baja California	La Paz	4.4	5.5	6	6.6	6.5	6.6	6.3	6.2	5.9	5.8	4.9	4.2	4.2	6.6	5.7
Jalisco	Guadalajara	4.6	5.5	6.3	7.4	7.7	5.9	5.3	5.3	5.2	4.9	4.8	4	4	7.7	5.6
Aguascalientes	Aguascalientes	4.5	5.2	5.9	6.6	7.2	6.3	6.1	5.9	5.7	5.1	4.8	4	4	7.2	5.6
Guerrero	Cd. Altamirano	4.8	5.5	6.4	6.7	6.6	5.7	5.9	5.8	5.2	5.3	5	4.1	4.1	6.7	5.6
Guanajuato	Guanajuato	4.4	5.1	6.1	6.3	6.6	6	6	5.9	5.8	5.2	4.8	4.6	4.4	6.6	5.6
Baja California	Mexicali	4.1	4.4	5	5.6	6.6	7.3	7	6.1	6.1	5.5	4.5	3.9	3.9	7.3	5.5
Jalisco	Lagos de Moreno	4.5	5.3	6.1	6.7	7.2	6.1	5.8	5.6	5.5	5	4.7	4	4	7.2	5.5
Baja California	San Javier	4.2	4.6	5.3	6.2	6.5	7.1	6.4	6.3	6.4	5.1	4.7	3.7	3.7	7.1	5.5
Tamaulipas	Matamoros	2.9	3.9	5.3	6	6.7	7	6.8	6.7	5.5	5.1	3.7	2.8	2.8	7	5.5
Puebla	Puebla	4.9	5.5	6.2	6.4	6.1	5.7	5.8	5.8	5.2	5	4.7	4.4	4.4	6.4	5.5
Hidalgo	Pachuca	4.6	5.1	5.6	6.8	6	5.7	5.9	5.8	5.3	4.9	4.6	4.2	4.2	6.8	5.4
San Luis Potosí	San Luis Potosí	4.3	5.3	5.8	6.4	6.3	6.1	6.4	6	5.5	4.7	4.2	3.7	3.7	6.4	5.4
Chiapas	Arraiga	5.1	5.4	5.5	5.9	5.6	5.2	5.9	5.5	5.1	5.3	5.1	4.7	4.7	5.9	5.4
Quintana Roo	Playa del Carmen	4.1	5	5.8	6.6	6.3	6.1	6.1	6	5.3	4.8	4.3	3.9	3.9	6.6	5.3
Guerrero	Acapulco	4.8	5.3	6.1	5.9	5.6	5.1	5.3	5.4	4.9	5.2	5	4.7	4.7	6.1	5.3
Oaxaca	Oaxaca	4.9	5.7	5.8	5.5	6	5.4	5.9	5.6	5	4.9	4.8	4.4	4.4	6	5.3
Sonora	Nogales	3.1	3.9	5.2	6.5	7	7	6.1	5.6	5.2	4.3	3.5	2.9	2.9	7	5.2
Veracruz	San Andrés Tuxtla	3.5	4.4	5.6	6.6	6.5	5.8	5.8	5.6	4.9	4.6	3.9	3.4	3.4	6.6	5.2
México	Chapingo	4.5	5.1	5.6	5.8	5.9	5.4	5.2	5.2	5	4.7	4.6	3.9	3.9	5.9	5.1

Tlaxcala	Tlaxcala	4.6	5.1	5.5	5.4	5.6	5.2	5.3	5.2	5.1	4.9	4.7	4	4	5.6	5.1
Chihuahua	Cd. Juárez	3.1	3.9	5.2	6.4	6.9	7	6.4	5.6	5	4.2	3.5	2.9	2.9	7	5
Veracruz	Poza Rica	3.1	4	5	5.9	6.4	6.1	5.8	5.9	5.1	4.8	3.3	3.1	3.1	6.4	5
Sinaloa	Culiacán	3.6	4.2	4.8	5.4	6.2	6.2	5.4	5.1	5.2	4.6	4.2	3.4	3.4	6.2	4.9
Colima	Colima	4.4	5.1	5.3	5.8	6	5.2	4.9	5	4.6	4.4	4.4	3.9	3.9	6	4.9
Michoacán	Morelia	4.2	4.9	5.5	5.8	5.9	5.2	5	5.1	4.9	4.6	4.3	3.7	3.7	5.9	4.9
DF	Tacubaya	4.4	5.2	5.8	5.8	5.7	5.1	4.9	4.9	4.7	4.4	4.2	3.8	3.8	5.8	4.9
Sinaloa	Mazatlán	3.9	4.8	5.4	5.7	5.7	5.6	4.8	4.9	4.7	5	4.5	3.9	3.9	5.7	4.9
Yucatán	Progreso	4.1	4.9	5.4	5.5	5.3	5.1	5.3	5.3	5	5	4.4	4	4	5.5	4.9
Nayarit	Tepic	3.9	4.3	4.8	5.5	6.1	5.3	4.9	5.3	4.4	4.4	4	4.8	3.9	6.1	4.8
Coahuila	Saltillo	3.8	4.2	4.8	5.1	5.6	5.9	5.9	5.6	5.2	4.4	3.6	3.3	3.3	5.9	4.8
México	Toluca	4.4	4.9	5.3	5.4	5.2	5.2	4.9	4.9	4.6	4.4	4.2	3.9	3.9	5.4	4.8
Campeche	Campeche	4	4.1	5.5	5.8	5.5	4.9	4.9	5.1	4.7	4.4	4.2	3.7	3.7	5.8	4.7
San Luis Potosí	Río Verde	3.6	4	4.6	4.9	5.4	5.6	5.8	5.8	5.1	4.3	3.7	3.3	3.3	5.8	4.7
Quintana Roo	Cozumel	3.9	4.6	5.3	5.7	5.2	4.8	4.9	4.9	4.6	4.4	4	3.8	3.8	5.7	4.7
Quintana Roo	Chetumal	3.9	4.7	5.4	5.7	5.3	4.7	4.9	5	4.5	4.4	4	3.7	3.7	5.7	4.7
Yucatán	Mérida	3.7	4	4.6	5.2	5.7	5.5	5.7	5.5	5	4.2	3.8	3.4	3.4	5.7	4.7
Chiapas	Tapachula	5.4	4.9	4.8	4.6	4.7	4.7	5.2	5.1	4.6	4.1	4.3	4.1	4.1	5.4	4.7
Chiapas	Tuxtla Gutiérrez	3.8	4.4	4.6	4.8	5.3	5.1	5.4	5.3	4.9	4.4	4.1	3.7	3.7	5.4	4.7
Guerrero	Chilpancingo	4.1	4.5	4.9	5.2	5.2	5.2	5.1	5.1	4.7	4.4	4.1	3.8	3.8	5.2	4.7
Morelos	Cuautla	3.2	3.9	4.7	5.5	5.7	5.4	5.4	5.3	4.6	4.4	3.7	3.1	3.1	5.7	4.6
Chiapas	Comitán	4.1	4.4	4.8	4.9	5.1	4.8	5.5	5.5	4.8	4	4	3.7	3.7	5.5	4.6
Tamaulipas	Soto la Marina	3.4	4.2	4.9	4.9	5.1	5.3	5.4	5.4	4.9	4.6	3.7	3.2	3.2	5.4	4.6
Veracruz	Veracruz	3.7	4.5	4.9	5.1	5.1	4.8	4.7	5.1	4.6	4.8	4.1	3.6	3.6	5.1	4.6
Coahuila	Piedras Negras	3.1	3.6	4.2	4.5	4.8	6	6.7	6.3	4.9	4.1	3.3	2.9	2.9	6.7	4.5
Tamaulipas	Tampico	3.3	4.1	4.7	6.4	5	4.9	4.9	4.9	4.6	4.6	3.7	3.2	3.2	6.4	4.5
Tamaulipas	Reynosa	2.6	3.5	4.6	5.3	5.7	6	6.1	5.7	4.8	4.4	3.3	2.5	2.5	6.1	4.5
Yucatán	Valladolid	3.7	4.1	3.1	5.4	5.7	5.3	5.4	5.4	4.9	4.2	3.8	3.5	3.1	5.7	4.5
Chiapas	San Cristóbal	4	4.3	4.5	4.5	4.8	4.7	5.4	5.3	4.6	4.2	3.9	3.7	3.7	5.4	4.5
Nuevo León	Monterrey	3.2	3.6	4.1	4.3	4.8	5.5	6.1	5.6	5	3.8	3.3	3	3	6.1	4.4
Veracruz	Tuxpan	3.1	3.8	4.4	4.8	4.7	4.4	4.7	5.5	4.4	4.1	3.4	3.1	3.1	5.5	4.2
Veracruz	Jalapa	3.2	3.5	3.8	4.3	4.6	4.4	4.9	5	4.4	3.7	3.3	3	3	5	4
Veracruz	Orizaba	3.3	3.5	3.9	4.2	4.9	4.4	4.5	4.6	4.3	3.6	3.3	3.1	3.1	4.9	4
Veracruz	Córdoba	3.1	3.3	3.6	3.8	4.1	4.4	4.6	4.5	4.1	3.5	3.1	2.8	2.8	4.6	3.7

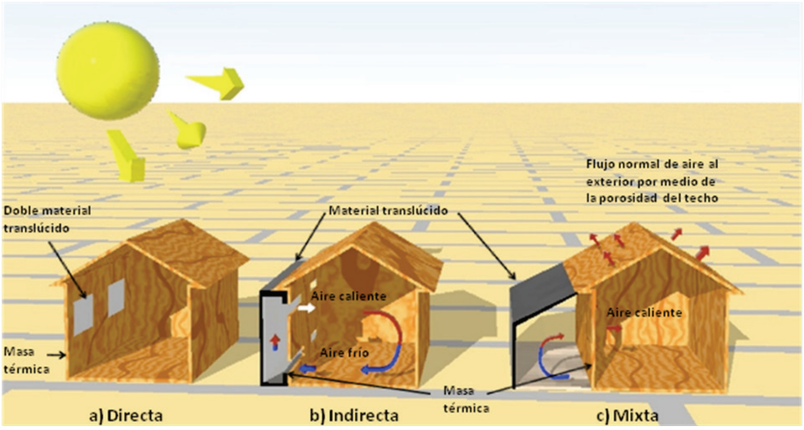

Figure 10.3
Structural passive systems.

Source: Own elaboration by Peter H. Brailovsky and Sergio Romero. Note: The appendix presents the figure as prepared by the authors.

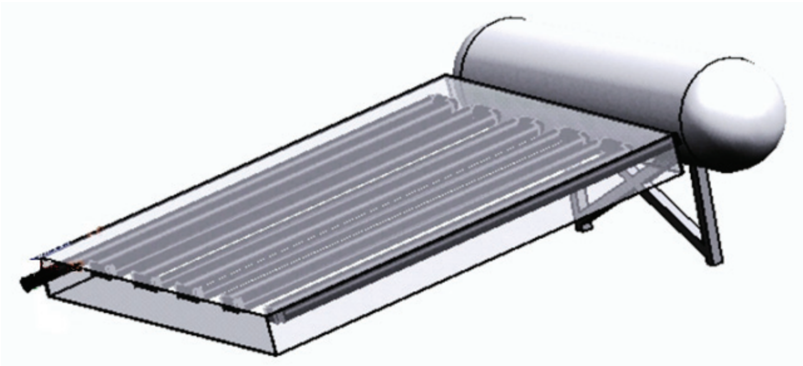

Figure 10.4
Flat coil heater.

Source: Own elaboration by Peter H. Brailovsky and José A. Sordo. Note: The appendix presents the figure as prepared by the authors.

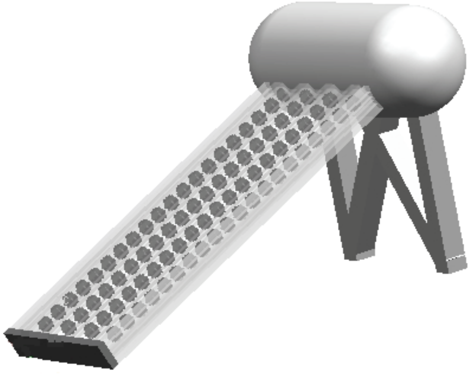

Figure 10.5
Solar volcanic rock (tezontle) heater.

Source: Own elaboration by Peter H. Brailovsky and José A. Sordo. Note: The appendix presents the figure as prepared by the authors.

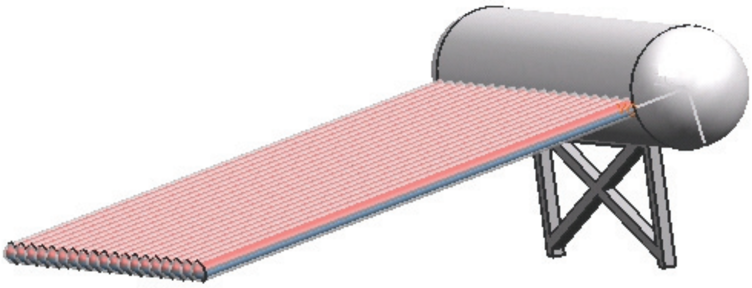

Figure 10.6 A
Vacuum tube solar heater.

Source: Own elaboration by Peter H. Brailovsky and José A. Sordo (10.6 A) and Thermosol, 2008 (10.6 B).
Note: The appendix presents the figure as prepared by the authors.

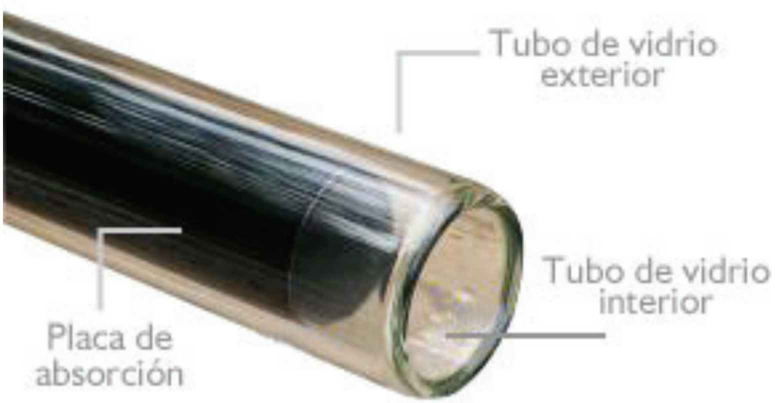

Figure 10.6 B
Vacuum tube details.

Source: Own elaboration by Peter H. Brailovsky and José A. Sordo (10.6 A) and Thermosol, 2008 (10.6 B).
Note: The appendix presents the figure as prepared by the authors.

11. Micro Generation

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11.1 Introduction

In the previous chapters different sources of renewable energy which is used or could be used in Mexico on a large scale were described in detail. In general, all these technologies have in common that they are renewable and are so abundant that they will last for hundreds of years.

An increase in the use of renewable energy insures the generation of a sustainable source of electricity in the long term and reduces the emission of green-house effect gases (GHEG). Notwithstanding, the adoption of projects to improve energy sources from renewable sources must take into consideration important factors before they are launched. On the one hand, the strong geographic component which characterizes these (the amount of solar radiation, wind velocity, the availability of geothermic resources, etcetera, varies from location to location) and, on the other hand, the low density of energy generated per unit of area (dozens of hectares of solar panels or wind-powered turbines to generate the same amount of energy as one conventional thermo-electric plant).

The great projects in the world designed to improve the use and effectiveness of renewable energy sources have had to develop, on an individual basis, the best strategy in economic, technical and social terms in order to be carried out. Another aspect which must be evaluated in these types of projects is the distance that exists between the source of renewable energy and the point of consumption. Traditionally, the giant electrical generation plants are located at a great distance from the consumption centers which makes it necessary to transform the energy at giant substations in order to subsequently transfer and distribute the electrical energy through the use of high-voltage cables until the point of consumption is reached. Additionally, the implementation of any project for the generation of energy from renewable sources must take into consideration that it will eventually be integrated into the national electrical energy grid.

The existing challenges for the development of the national electrical energy grid are reflected in several strategic questions that must be answered in order to satisfy the increasing energy demand. Therefore, a change in the fuels that are used, the installation of new transmission and distribution lines as well as, an increase in energy transformation capacity is required. Although the Federal Energy Commission (FEC) is the only organism responsible for the national electrical energy grid, other methods are available that can contribute to a reduction in the enormous investment required by this company. One of the available methods is micro generation.

11.2 Micro generation

Micro generation is defined as the capacity to produce useful energy (thermal or electrical) in a small scale. Micro generation varies according to the geographical region. Generally, a generation of 100 kW (kilo-watts) of electrical energy is considered the ceiling in order to be classified as a micro generation source although, this can be increased to 5 MW (mega watts) in line with the existing legislation. The energy sources most commonly identified with micro generation are solar-thermal, solar-photovoltaic, and wind-generation, bio-gas, bio-mass and hydro-electric among others. Although it appears that the energy options for micro generation are principally renewable sources, existing energy sources such LP gas or natural gas which can be converted into combined heat and power (CHP) sources can be used that allow for a reduction in energy costs as well as for the implementation of programs to increase energy efficiency.

Contrasting with the giant electrical energy plants which use conventional methods (thermo-electric, carbon-electric, etcetera) which are usually located hundreds of kilometers from the consumption centers, the micro generation systems utilize energy sources found in the same area where the energy is produced. This reduces the high transmission costs associated with energy distribution. As a result, losses associated with energy transmissions and distributions are eliminated.

The majority of the technologies associated with micro generation are renewable, which reduces the environmental impact associated with energy generation. Moreover, when renewable sources are used, the emission of GHEG is reduced.

Micro generation is not a technology rather a method for the generation of useful energy through different sources capitalizing on the energy potential of each region at the source in order to obtain an economic and social benefit. It must be pointed out that it is not an option to substitute the existing methods implemented in the national electrical energy generation plan but rather, an option to complement the existing methods.

Mexico is in a favorable position with respect to the rest of the world thanks to the diversity of energy sources available. A large solar capacity is available throughout the whole country; various regions have strong and constant wind currents; and in others, small water-falls exist which represent a considerable hydro-electric potential; vast areas have a strong geothermic potential; the bio-mass production is present throughout the country and the supply of natural gas is so great that its utilization for micro generation in urban centers could be considered.

The challenges present for the use of micro generation as a method within the national energy plan are not solely of a technical nature but also center around its implementation. Although CFE has strived to assure a sufficient supply and quality of electrical energy for the whole country, problems still exist in regions that are isolated and remote from the energy sources.

In some remote locations the light bulbs do not shine brightly, the electronic equipment does not operate correctly or the voltage spikes provoke an abnormal behavior of the equipment connected to the grid. These abnormalities are generally attributed to the losses along the distribution lines which can be either “natural” (losses in the transmission of energy) or as a result of an illegal connection by the users to the grid. If micro generated sources could be found at the end of the distribution lines this could increase the quality of the energy supplied at these locations.

A great part of the potential that micro generation represents depends on the efficient development of the utilization potential of the renewable sources. Following is a brief summary of these sources.

11.3 Renewable Energy

The principal characteristic of the renewable energy sources is that they regenerate and are so abundant that they will last for hundreds of years. These energy sources use the natural resources such as the sun, the wind, and the ocean tides, the agricultural or organic residues among others. An increase in the use of renewable energy would insure the sustainable generation of electrical energy for the long term and would reduce CO2 emissions. The following is a list of the main renewable energy sources:

Wind-generated energy. According to the Institute for Electrical Energy Investigation (IIE, 2009), wind-generated energy in the world increased starting in 1980 and highlights the leadership shown by Germany, United States, Denmark, India and Spain. The wind contains kinetic energy (from air masses in movement) which can be transformed into mechanical or electrical energy using aero-turbines which include rotors (blades), a generator and a tower. The electrical energy which is generated must be transformed at substations before it can be transmitted or utilized.

Solar energy. The solar energy received by our planet results from a process of nuclear fusion which occurs within the sun. A small fraction of the energy which is released by the sun travels through space and reaches Earth as radiation. This solar radiation can be transformed directly into electrical energy (photovoltaic solar energy) or into heat (thermal solar energy). The heat can then be used in thermal applications where a temperature differential is required or to produce steam or generate electricity.

Geothermal energy. Geothermal energy comes from the use of the heat which emanates from below the Earth´s surface. Our country is among the countries which produce more geothermal energy in the world with approximately 1 GW of installed potential. Geothermal energy is produced when the steam is transmitted through pipes and after being processed, a mixture of water and dry steam is obtained which is then used to move turbines which generate electricity. It is considered renewable energy as it is generated by a natural activity of the planet, it is available in great quantities and it is a clean source of energy which requires minimal maintenance. The heat can also be used for thermal uses. After hydro-electrical generation, geothermal energy generation represents the major source of renewable energy for the country.

Hydrogen. In the hydrogen cells a molecule of water (H2O) is broken to obtain hydrogen and through this process electricity is produced. The only remaining by-products are oxygen and steam (water). These cells are used in homes and businesses in developed countries; some automobile manufacturers are producing vehicles using this technology. Notwithstanding, this technology presents some technical and scientific difficulties as it represents a new technology which has not been developed commercially. (For this reason it was not considered in this book).

Bio-mass. Bio-mass or biological mass is living material produced in a determined area of the Earth´s surface or by specific organisms. This term is more frequently used when referring to the bio-mass energy or combustible energy which is obtained directly or indirectly from biological resources. Bio-mass in its broader definition, is all organic material either animal or vegetable and includes materials that come from its natural or artificial transformation. Natural bio-mass is that which is produced naturally without human intervention while residual bio-mass is generated by human activity in agricultural or livestock processes such as wastes and residual waters. Produced bio-mass is that which is cultivated with the express purpose of its transformation into combustible energy instead of for food such as the sugar cane in Brazil, oriented towards the production of ethanol. In energy terms, it is used as renewable energy such as wood, bio-diesel, bio-alcohol, bio-gas and bio-fuels. The bio-mass could provide energy which would substitute fossil fuels thanks to the bio-carburant liquids and solids such as bio-diesel and bio-ethanol. Bio-mass can be generated or can be obtained from by-products or residuals such as vegetation, aqua-cultures, forest and agricultural residuals, urban residuals and animal waste among others.

From an energy outlook, bio-mass can be utilized in two different ways: to produce heat through combustion or transforming it into fuel for transportation and warehousing. Solid fuels such as (wood, wood chips, carbon vegetable), liquids (bio-carburant, oils, alcohols, organic acids) and gaseous (bio-gas, hydrogen) can be produced.

°Bio-mass is potentially neutral in terms of its carbon emissions as the carbon bi-oxide which is emitted when it is burned is the same as the amount absorbed while the plant was growing. This is important in terms of global warming and its effects.

Hydro-electrical energy. This is the most mature technology. It functions using the potential energy from a river and it transforms this energy into kinetic energy which powers a hydraulic turbine in order to turn an electrical generator. Major hydroelectric projects exist in the world with an installed capacity of several GW; nevertheless, small projects also exist with great potential for micro generation. There is no consensus worldwide regarding the definition of a small, mini and micro hydrogenation plant; however, the upper limit varies between 2.5 MW and 30 MW for the small hydro-electric plant. The most common definitions for these types of installations are the following:

- Small hydroelectric: capacity of 1 MW to 5 MW.
- Mini hydroelectric: capacity of 100 kW to 1 MW.
- Micro hydroelectric: capacity under 100 kW.

In general, the micro, mini and small plants are structures built at water level where the required fall is provided by a natural cleavage along the river such as “rapids” or a “waterfall”.

At present, some technologies to develop renewable energy are in the investigation or develop stage which implies the need for investment in the short term. On the other hand, there are technologies which today represent a real alternative in terms of cost and efficiency. The International Energy Agency (IEA) carries out frequent studies in order to reevaluate the viability of different technologies. Graph 11.1 shows the perspectives for cost and competitiveness of different renewable energy technology.

As Graph 11.1 illustrates, hydroelectric energy generation (small & big) represents an excellent option in terms of cost as in the medium and long term it represents a competitive solution which does not require incentives due to a reduction of carbon bi-oxide emissions or from the government in order to be implemented. Electrical energy generation via primary sources such as bio-mass, geothermal or wind-generated methods are still in development although with certain energy intensive conditions, geographic advantages or capacity which make them economically viable and they use mature technologies. In other scenarios in which conditions differ, the afore-

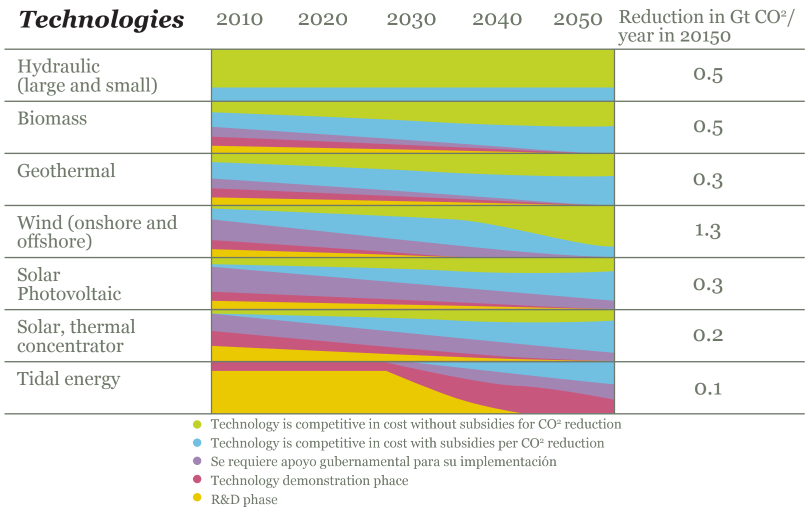


Figure 11.1
Cost and competitiveness prospectives for renewable energy generation technologies. Source: IEA, 2007.

Source: IEA, 2007.

mentioned technologies as well as the photovoltaic are economically viable if financial support is available in the form of carbon bonds, government subsidies or other mechanisms.

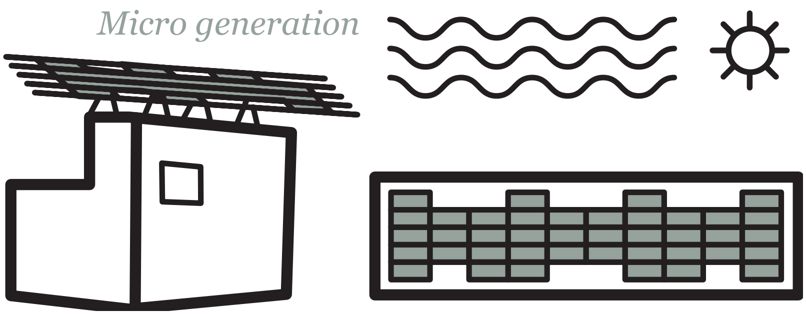
11.4 Micro generation - Utilization Schemes

Micro generation can use several of the technologies previously described. However, the “simple generation of energy” is not enough to provide the benefits of micro generation. This energy source needs to be associated to a utilization scheme which allows the greatest economic, social and environmental benefit possible. A system of micro generation could be utilized with two different schemes: independent of the electrical energy grid (off-grid) or as part of a hybrid system in which the grid can be accessed (on-grid systems). Each one of these has different scopes and applications, described as follows.

11.4.1 Systems Independent of the Electrical Energy Grid (Off-grid)

The most common applications of off-grid systems are located in areas where the FEC or a natural gas line do not satisfy the useful energy needs (thermal or electrical) – for example, in rural areas that require energy for lighting, to power fresh water pumping systems, to power electrical equipment or small sawmills, among other activities -. Mexico is a clear example of a country where these types of applications proliferate. Notwithstanding, the tremendous effort made by the FEC to expand the electrical energy grid to the remotest locations in the country, at least 2.9 million Mexicans do not have electrical service according to estimates of 2009 by the National Institute of Statistics and Geography (INEGI).

Micro generation also offers solutions for the energy supply to remote installations such as the ones dedicated to eco-tourism, community or education centers and for public street lighting. The small installations using solar panels have demonstrated that they are reliable and productive with useful lives of greater than 30 years. An example of this is shown in graph 11.2, which shows an independent installation for an eco-tourist hotel.



Graph 11.2

One limitation that these systems present is a reduced capacity to store great quantities of electrical energy (more than 400 kWh/day), as required by an industrial building making it necessary to accumulate the electrical energy in battery banks. This implies a higher cost and the need for more space. Moreover, care must be taken to avoid an excessive use of batteries as this can lead to problems with the balancing of charges and the accumulation of explosive gases where the batteries are installed.

Other options are available for the accumulation of energy such as compressing air in tanks under pressure (CAES) and afterwards discharging these through the use of air turbines which are coupled to an electric generator. However, this type of accumulation is less efficient than the charge-discharge cycle of electrolyte batteries (hypothetically 70% in a process at constant temperature, compared to approximately 90% efficiency when using batteries) (BNIE, 2007). Also, new technology is being developed to make longer-lasting, more efficient and smaller batteries however; the actual costs indicate that this is not an economically viable alternative.

Another important factor which must be considered is the fact that the majority of the renewable energy sources generate voltage as direct current (DC) which needs to be transformed into alternating current (AC) in order to use the existing market applications. This can be accomplished by way of investments in equipment that converts the continuous discharge from a DC source into an AC signal. The investment capacity in off-grid systems is limited, by manufacturer´s recommendations, to no more than 15 kVA per battery bank. This implies that if greater daily electrical energy capacity is required, it would be necessary to set-up several battery-generation and inverter systems working in parallel. This, in turn, would lead to higher investment and operation costs which would reduce the installation´s utilization factor. For example, the small buildings (less than 10 apartments) and the small industries could consume the charge provided by one module while the medium and large structures require more modules and, as a result, a greater investment.

11.4.2 Hybrid On-grid Micro Generation Systems

These systems are characterized by the fact that they do not have battery banks where energy is stored and are permanently connected to the energy provider (FEC). These systems are installed on the roofs, basements, walls and windows of the buildings and the houses as well as in their proximity; therefore, they are geographically dispersed in relation to the national electrical grid. Regardless of the technology used to generate the energy, an on-grid system is characterized by the following:

- The primary sources for energy generation are installed with an “electrical generator” (photovoltaic panels, micro hydro-electrical, wind-generation electrical turbines, and bio-digesters with combustion motors, etcetera).

- The energy generated from these sources is controlled, modulated and transformed in function of the consumption requirements (in Mexico, AC at 60 Hz and 110 v) using an inverter.
- It is important to mention that all the energy from the local sources must be consumed at the same time as it is generated (in real-time).
- If the energy requirements at the point of consumption are greater than the energy provided by the local sources at the site, the shortfall in supply can be demanded from the electrical grid. If the installed capacity of the system is permanently lower than the demand at the point of consumption, no additional elements can be considered.
- If the energy demand at the point of consumption is lower than the energy installed capacity, the surplus must be disposed of, opening the way to several options.
- The energy surplus has only one way to exit the generation point, the national electrical energy grid. This makes it necessary to control, modulate and transform the surplus electrical energy (modulate means not only converting the voltage and frequency of the grid but also synchronizing this with the energy wave found at the time in the grid).
- The electrical energy consumption meter at the generation point must be bi-directional which means it must account for the energy consumed at this point as well as discount the energy provided by the grid automatically calculating the energy balance for the installation. In that sense, the alternative would be to use two conventional meters, one at the entry point and one at the exit point and manually calculate the energy consumed and provided by the grid establishing the energy balance for the installation. This method is clearly inefficient.

The micro generation systems have proliferated in response to the necessity to increase energy efficiency at the buildings in the great urban centers. One example of this is photovoltaic integration in buildings (BIPV, Building Integrated Photovoltaics), a tendency which is acquiring greater popularity. This is due to the fact that in the European Community, United States and Mexico, the authorities are standardizing (this is obligatory to a certain extent) the energy savings and the utilization of renewable energy sources in new buildings and one of the most viable options is precisely BIPV. Throughout the world auto-generation systems can be found in many buildings. In several urban centers in Scotland, the buildings have wind-generated micro-turbines on the roofs and in the walls. The energy provided by these systems is frequently used in low-consumption applications such as lighting.

The energy efficiency of a building depends on its consumption. For example: in a government installation, the higher consumption is between Monday and Friday during working hours; afterwards, consumption drops significantly during the night and at dawn. In a building used for educational purposes (schools, universities, etcetera), the consumption is different as the higher consumption takes place during the afternoon when classes and other activities lead to a need to maintain the lighting systems, computers and other auxiliary equipment functioning and consumption drops significantly at night. Something similar occurs at the shopping centers where the higher consumption is incurred between the last hours of the working day and the close of the shopping center; however, during the week-ends electrical energy consumption is at its maximum as commercial activity increases. In this manner, energy efficiency could increase considerably based on the variations in consumption patterns and the utilization of electricity – if usage sequences are developed, electricity usage spikes (peaks) and energy demand would be reduced.

Besides the space required for the components, an on-grid micro generation system has an important limitation: when an energy surplus is present, it is necessary to use the grid to receive the energy provided by the system. The grid must support the injection of new energy as well as be sufficiently stable to perform real energy measurements of the energy being supplied (and ideally register the hour at which the energy injection is carried out). For this to occur, the building and the energy system must have the necessary infrastructure. The building must have inverter and modulators that integrate the energy into that which is currently in the existing electrical system while the cables at the grid must allow for the influx of the surplus to the system.

11.4.3 Government Support to Developers of Small Hydroelectric Plants

Since the changes in 1992 to the law governing the supply of electrical energy, the government has provided support to companies that wish to develop small hydroelectric plants. The following presents the main government supports that have been provided:

- Creation of the Contract for the Interconnection of Renewable Energy Sources which stipulates that the surplus energy will be stored at the

FEC Energy Bank for its use or sale during the following 12 months.

- The investments carried out for machinery and equipment for renewable energy generation will be 100% deductible in one exercise.
- The FEC will pay the surplus kWh at 85% of the short-term median cost at the delivery point or 70% if the plant is still in a test period– in January 2009 the average short-term median cost for Veracruz amounted to USD$0.048/kWh-.
- The small producers are paid at 95% of the short-term median cost.

11.4.4 Challenges to the Development of Small Hydroelectric Plants

Regardless of the progress reported to date, challenges still exist in order to achieve the proliferation of Mexican mini hydroelectric plants. For example, for 2012 plans call for the mini hydroelectric plants to provide 3% of the national electrical energy installed capacity (1,700 MW); however, this seems difficult to achieve. The Law for the Good Use of Renewable Energy and Financing for the Energy Transition states that the generation installations will not exceed a capacity of 30 MW which represents a limitation.

Action must be taken to promote the development of small hydroelectric plants as follows:

- Coordinate the activity of all the institutions involved in the process in order to achieve within a reasonable timeframe the publication of the existing national resources that can be economically exploited.
- Allow for the development of mini-hydroelectric plants on rivers where it is shown that agricultural activity is not negatively affected and the environmental impact is minimal.
- The CFE together with the INEGI must publish plans outlining by state the distribution lines and substations that comprise the electrical energy grid.
- Adapt or adopt norms to regulate the safe interconnection or the energy generation distributed up to 10 MW.

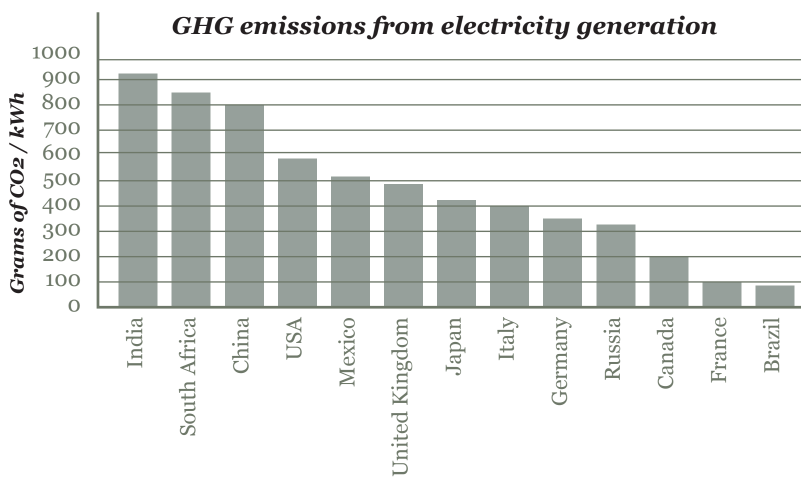
In addition, the FEC must analyze and show, case by case, how it determined the interconnection point and the voltage for the distribution lines.

11.5 Micro Generation - Advantages and Limitations

The correct usage of the different available micro generation schemes present several benefits which must be considered. The benefits can be as follows: environmental, economic and social.

11.5.1 Environmental Benefits

The different micro generation systems offer direct or indirect environmental benefits. When the energy source is clean (solar, wind, geothermal), there is a direct environmental benefit associated with the decrease in greenhouse effect gas emissions (GHEG) into the atmosphere as a result of the generation of electricity. It is estimated that in Mexico, up to 2008, each kWh of electricity represents the equivalent emission of 515 grams of CO2 into the atmosphere (WWF, 2008). The generation of energy for immediate consumption at the site where it is generated eliminates all emissions associated with the transmission of the energy to that location.



Graph 11.3
GHEG Emissions due to electrical generation.

Source: IEA, 2009.

Additionally, several indirect environmental benefits exist as a result of the conservation of the ecosystems. Since no construction work has to be carried out relating to transmission or distribution lines, the deforestation associated with the construction of roads and clearings for the high-voltage power line towers is avoided.

11.5.2 Economic Benefits

In the current highly competitive global economic environment, a reduction in the costs associated with any productive activity is very important.The different micro generation schemes can, if correctly implemented, reduce energy costs for compañies and communities.

In case electrical energy is required at a locality outside of the FEC distribution grid, the costs for towers, posts and cables (as well as for transformers, if necessary) are absorbed by the consumers. This means that, from a financial point of view, it is necessary to make an initial investment, as well as cover the actual consumption costs. In these situations, a well planned micro generation project offers an immediate Return-On-Investment (ROI) if the investment in infrastructure es lower than that which is required to be able to interconnect to the national electrical grid. When the initial investment for micro generation es greater than the grid interconnection costs, the ROI period is very short due to the immediate savings achieved as the cost for electrical raw material is not incurred.

When access to the grid already exists, the installation of a micro generation project is a little more complicated. For the residencial consumer it is very difficult to find a micro generation scheme in which economic benefits are attained as the residencial tariffs only conatin seasonal and consumption components but do not consider the hours in which the consumption is incurred. Due to this, the micro generation options are only complementary to the grid or a partial backup when the grid fails. Notwithstanding, for consumers with higher energy demands (more than 100 kW) it is commonplace that the tariff includes an hourly component with three different tariffs: base, intermediate and peak. The energy consumption cost will depend on the hour at which the energy is consumed, with scenarios as shown in graph 11.4.

As shown, consumption is concentrated with 76% in the intermediate tariff range while in the peak tariff range only 10% consumption was recorded;

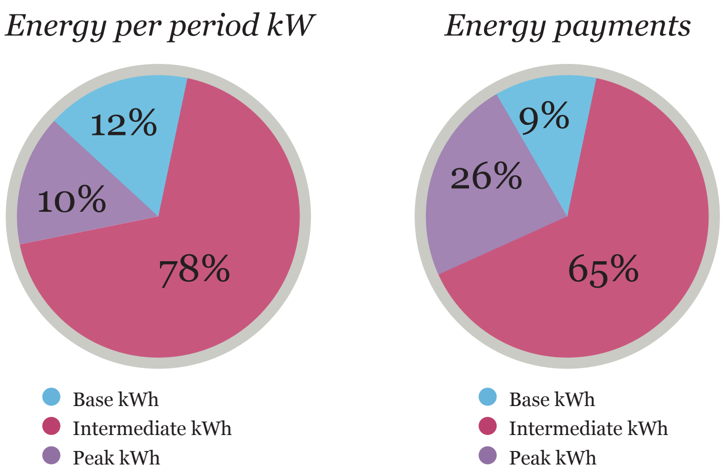


Figure 11.4
Payment consumption hour impact on the energy bill

Source: Elaboración propia.

however, this last range absorbed 26% of the payments for electrical consumption. This is due to the fact that the cost per kWh at the peak tariff is double the base tariff (it can reach 4 times greater depending on the region). This represents a business opportunity, as a micro generation system can be installed which will supply energy during the peak period at a lower cost than offered by the FEC. Several companies already use this scheme with natural gas motors and micro-turbines with generators. In these cases, an additional benefit exists if a heat exchanger is utilized so that the combustion gases heat the water required by the installation, deriving in a CHP system.

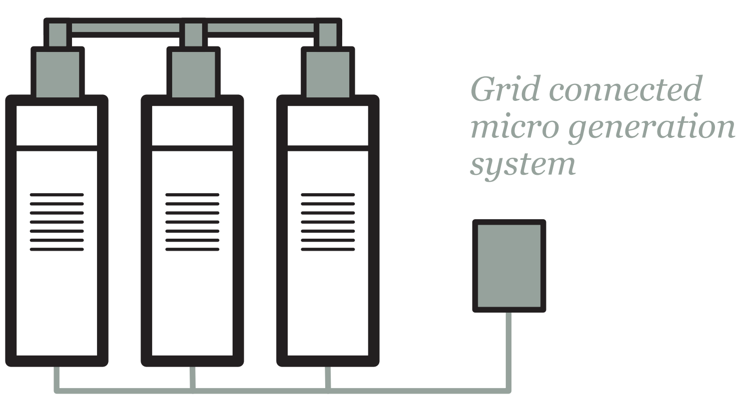


Figure 11.5
Example of a micro generation system connected to the grid..

11.5.3 Social Benefits

The use of micro generation schemes is an option which can provide electrical energy to communities isolated from the distribution grid as these usually have vast renewable energy sources (rivers, waterfalls, constant wind or strong solar radiation) which are susceptible to conversion into energy sources which translates into economic development for its population.

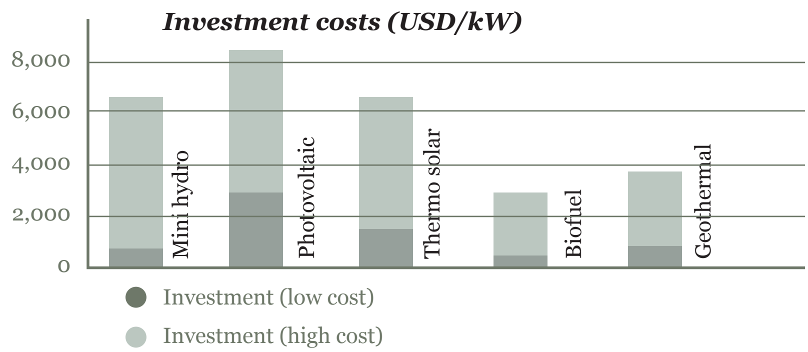
Additionally, the micro generation schemes have the capacity to mesh with applications designed ex-professo such as pumps for efficient irrigation, sawmills or mills, refrigerators for rural clinics, Public Street lighting, among others. This illustrates that having electrical energy in remote areas stimulates the growth of small industries and generates a clear social benefit.

In urban or industrial localities, the micro generation systems allow for an increase in the reliability of the energy in specific areas where the failures, albeit by only a few seconds or minutes, result in significant consequences (for example, in telecommunications and computer systems). The FEC indicated that in 2008, the interruption time per user was approximately 132 minutes per year which results in a reliability factor of 99.97%. However, for the cases that were presented, the international “best practices” indicate that a reliability factor of 99.99% is required which is equivalent to 5 minutes per year. Availability of a micro generation system provides a back-up system capable of providing this level of reliability.

11.5.4 Limitations

The clearest limitation that the micro generation systems present is the availability of renewable energy sources at the point of consumption as these sources have a geographical component. Additionally, a conflict between the hour that the energy is generated and the hour that the energy is consumed could present itself. For example, in a solar energy system, the energy is produced during the day; however, it is generally consumed at night. The inclusion of battery banks would solve this problem although it implies an additional acquisition and maintenance cost.

In addition to this, the solutions based on micro generation systems imply a costly initial investment which leads to the need for its planning to require an integral financial evaluation in order to insure adequate financial returns periods thus allowing the projects to be financially viable. On the other hand, it is important to mention the correct implementation of the micro generation projects requires the participation of experts that understand the different technical, financial and strategic variables.



Graph 11.6
Source: IEA, 2003.

There also exists a refusal by the native communities to depend on energy schemes based on renewable sources. This is due to what occurred during the presidential period 1988 to1994, when a great many photovoltaic units were installed as part of the government program "Solidarity" although proper maintenance and service was not provided. Consequently, the communities prefer their energy to be supplied by the national grid in order to insure reliability of the service.

11.6 Conclusions and Recommendations

Micro generation is an alternative available to complement the national electrical energy grid. Given the lack of fiscal incentives as exist in other countries, the micro generation projects need to present a clear economic or social advantage in order to justify their implementation. For example, they could be used to reduce the costs and the consumption of electricity as part of an on-grid system. Also, they are an alternative when energy interruptions affect industrial productivity. In some cases, they represent a viable idea if conceived as an emergency plant in-line during the peak tariff periods (in some cases they could be viable during the intermediate tariff period). This leads to the conclusion that the micro generation alternative would help increase energy supplies when the energy supplier does not have the capacity to cover extraordinary energy demands.

Finally, it is important to note that the micro generation schemes are not a substitute for a national electrical energy grid but a complement to the same and should be studied and utilized when required.

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12. Conclusions

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We thank Prof. Francisco Torres for his collaboration.

In December 2010, in the 16th edition of the United Nations Conference Regarding Climate Change (COP16) held in Cancun, Mexico, the government of Felipe Calderon achieved a great triumph when it convinced the major powers that a road does exist and can be followed regarding negotiations over climate change and that a significant follow-up agreement to the Kyoto Protocol can be achieved in the foreseeable future. The arduous work and long hours put in by Patricia Espinosa and her team was critical in achieving the consensus that the Kyoto Protocol can be followed by an international regimen regarding climate change which contains significant agreements by the principal economies of the world, developed as well as developing nations, to reduce their emissions and accept the economic and financial cost of slowing the impact of climate change. Given this, Mexico must evolve towards a harmonic and sustainable development viewing the renewable energy sector as a high-potential alternative to help reduce its dependence on fossil fuels. As mentioned in the introduction, Mexico the same as other countries in the world, enjoys a privileged position in terms of its resources and its geography, which makes the use of renewable energy sources an attractive option. However, there are several obstacles that need to be eliminated before the renewable energy sector can be fully developed in the country.

In each one of the chapters of this book, diverse specialists and experts have analyzed the potential of the renewable energy technology and what it means for Mexico in terms of jobs, investment, development and of course the reduction in the emissions of green-house effect gas. In addition, the authors were asked to identify the shortfalls in terms of regulations and investments that impede the exploitation and use of the renewable sources.

This book offers an integral image of the current state of renewable energy in Mexico at the end of the first decade of the 21st century. Much work and effort needs to take place in all the areas in order to develop the resources; moreover, greater incentives are needed to promote investigation, generate business opportunities and attract investments from the national private sector as well as foreign investments.

An interest to increase knowledge about this topic among the political and social elite and to generate national applications based on internationally developed technology is present throughout all the chapters of this book. It would seem that Mexican society requires more help in order to overcome its perception that Mexico is a nation that must depend on hydrocarbon energy sources. In recent years, several debates regarding energy reforms have taken place with positive results although the creation of specific regulations regarding renewable energy in 2007 as well as the creation of a development fund for new initiatives has also helped.

In addition, all the chapters repeat the fact that development of the renewable energy potential in Mexico would provide a boost to the social and economic development of the rural areas. For the people living in these areas as well as for the small businessmen in the rural areas that do not have access to the national electrical grid, a small solar generator or wind-powered or hydroelectric energy sources offer an opportunity to radically change their life style providing the means for applications for lighting, refrigeration and irrigation.

In the following conclusions, we offer a summary of the investigations that have been presented and explained in this body of work as well as a synthesis of the main ideas presented by the authors.

12.1 Renewable Energy as a Catalyst to Achieve Competitiveness and Development

The optimum use of the different sources of energy can have a significant social, economic and environmental impact therefore, it is very important to establish policies and outline strategies that allow for the selection of energy sources and appropriate technology for the development of our nation.

In this context, the optimum use of the renewable energy sources is a critical element for the development of the country with the use of regional matrices that allow for the maximization of the cost-benefit relation in the economic and social environments.

The resources that are invested to obtain the optimum use of the renewable energy sources will contribute to the improvement of the standard of living in some of the regions as they will generate permanent jobs and improved salaries in the areas where these sources are found as well as, contribute to the proliferation of diverse industries. One example is the construction industry that can use the local labor force and resources which will indirectly benefit other economic sectors.

In addition, the sustainable use of renewable energy sources will lead to the possibility of the creation of new industries or subsidiaries of existing ones leading to additional permanent jobs and at the same time, generating a demand for skilled professional labor to operate the new businesses thus contributing to the development of a more highly skilled labor force and offering new investment opportunities.

The expansion of the renewable energy sources in line with the generation sources contributes to an improved labor force and income distribution in the different areas of the country. Usually, these energy sources are found in areas with a low rate of industrialization which not only allows for support of the economic and industrial development policies in the different states but also facilitates the achievement of the accords established by our country to protect the eco-environment.

During the last two decades, technologies that take advantage of renewable energy sources to generate electricity, thermal or mechanical energy have progressed significantly as they have improved their economic competitiveness, level of reliability and efficiency. Additionally, they have penetrated into new markets, in some cases with direct government support through prices, subsidies and economic stimulus or through the recognition by society of the need to use clean energy sources in order to reduce the generation of green-house effect gases. This is reflected in the willingness to pay a premium for the use of clean energy sources; a situation which needs to be evaluated in our country.

Compared with the other countries members of the Organization for Cooperation and Economic Development (OCED), Mexico has maintained a low profile in terms of the establishment of national industries dedicated to the development of renewable energy sources that have in-house basic engineering or local patents for the development of sustainable energy technology. In addition, Mexico has faced important social problems during the development of the infrastructure programs required for the expansion of renewable energy sources.

Although Mexico has a tremendous potential in the use of renewable energy sources, very little has been taken advantage of with exception of the giant hydroelectric and geothermic plants. Notwithstanding, wind-powered electrical energy generation has received an important boost during the last few years.

Clearly now is the moment to invest in these and other renewable technologies. In recent years, the price increase of oil and gas has had a tremendous real impact in the development of renewable energy sources throughout the world and even though oil prices fell in 2008 and 2009, in the long term, an increase in the price of fossil fuels is possible. Notwithstanding, when the real prices associated to the emission of green-house effect gases appear, new incentives to develop alternative energy sources in Mexico will be proposed. At that moment, the disadvantages presented by the use of fossil fuel energy compared to renewable energy sources will be evident forcing the government and private sector to take note of this new scenario.

It is worrisome to note that Mexican society is not conscience of the grave effects that the intensive use of conventional energy has on the eco-environment and that people think that the use of renewable energy is too expensive. This translates into a resistant at all government levels, Legislative and Executive, to the establishment of the necessary support mechanisms to take advantage of these energy sources.

However, it should be noted that some positive signs have appeared. Some positive changes have been enacted in the legal structure – although they could be improved -, mechanisms have been set-up to provide a rational use of the energy sources and there are many projects being developed. Government statistics show some improvement although this must be taken with some precaution as almost one third of the renewable energy reported used corresponds to the traditional use of firewood which cannot be considered as sustainable, efficient or beneficial to the eco-environment.

Although it is a fact that renewable energy sources are an abundant resource in Mexico, the lack of precise and detailed information regarding their location limits its development. It is imperative to have national maps pinpointing where the renewable energy sources are found.

For example, the case of solar radiation can be mentioned as some experts think that its use could be tripled while others think that its potential is much greater. Similarly, the use of the bio-mass can be mentioned as some indicate that Mexico could use this source to generate 2,000 MW of electrical energy and others think that this number could reach 12,000 MW.

Support of national projects for the development of new technology is basic in the use of the numerous sources of renewable energy. Currently there are very few small-scale projects that use technology developed in Mexico and even less large-scale projects that prefer the use of imported technology.

The Sectorial Energy Program states that one way to increase energy security is to balance the use of primary energy sources promoting the use of the sustainable natural resources. To guarantee stability in quality and security in the supply of electrical energy, the generation portfolio must be in balance in terms of its source, the type of technology and price volatility; however, balance in real terms will be achieved when all external elements associated with each case are factored into the generation cost. Another factor that must be considered is that the use of renewable energy sources allows for the use of new technologies which will define the future options for electrical energy generation.

A determining factor in the development of these sources is the government policies and their legal framework as up to just recently; energy from renewable sources was not competitively transmitted to the electrical grid. At present, the energy generated from some of these sources has some benefits such as net usage which allows for the use of the national power grid as a “bank” in which surplus generated energy is “deposited” and “withdrawals” are made based on energy demand. This is valid for the energy which is generated on an intermittent basis such as wind-powered energy which is produced during the hours that the wind blows with greater force and intensity and for photovoltaic energy which takes advantage of the hours of greater luminosity or greater solar radiation and for the mini-hydroelectric plants at which the electrical energy generator cannot control the water flow gates.

Renewable energy can benefit the country supporting the generation of energy especially electrical energy. In addition, it offers other advantages such as jobs creation, an economic infusion in the area, the clean handling of municipal, industrial and agricultural waste materials and the reclaiming of land currently lying fallow.

Although the increase in the price of fossil fuels has driven the development of renewable energy, an improvement in the financial payback would allow the different economic sectors to discover additional elements that favor the use of renewable energy sources. For example, the use and distribution of water as well as its recovery and recycling could find in the mini-hydro electrical plants elements that favor an improved financial payback such as occurred previously in the mining industry which requires a continuous supply of electricity. In the same manner, the wind-powered propellers and turbines could provide support to the agricultural activity assuring the supply of water for irrigation and for the livestock.

12.2
Recommendations to Bolster the Optimum Use of Renewable Energy

12.2.1 Mexican Regulatory Framework

The use of renewable energy sources has increased worldwide. Mexico, due to its geographical location, faces a niche market in expansion and with great opportunities. For the year 2020, Report REN21 states that the American continent will have close to 29% of the total installed capacity of renewable energy on the planet.

On the other hand, the institutional and judicial framework changes which have recently been authorized such as the Law for the Optimum Use of Renewable Energy Sources and its Regulation have improved the conditions for the development and the optimum use of these sources. Notwithstanding, several important aspects remain unsolved such as the regulation of land ownership and the definition of territorial reserves which provide judicial assurances for the investments in this area.

To promote the adoption of renewable energy sources, on November 28, 2008, the government published in the Official Daily Gazette of the Federation the Law for the Optimum Use of Renewable Energy Sources and for the Financing of the Energy Transition (LAERTFE). This law has hit its mark, as it has filled the legislative vacuum which existed regarding renewable energy and addresses several Mexican international obligations concerning sustainable growth.

What is striking about LAERTFE is that it has very few articles that address this topic. The conditions for the implementation of renewable energy projects are not included but will be addressed in other regulations such as the norms dictated by the Energy Regulatory Commission (ERC) and which are stated in article 7 of the LAERTFE. This means that these articles will represent either an obstacle or a catalyst to the development of the project.

The chapter regarding the regulatory framework clearly states some of the pending legislation among which the following four are worth noting. First, the ERC needs to define, prior a ruling by the Mexican government taxing authority (SHCP), the permits and contract models and the rights and obligations which must be adhered to by the project sponsor and supplier. These are legal instruments that in order to become incentives must conform to the conditions dictated by the ERC and the SHCP. Second, a calculation of the contribution made by the projects to the total capacity of the national electrical energy grid will be carried out following the directives for interconnection and the methodology dictated by the ERC. This topic together with the operation norms is a fundamental question which affects project cost and financial payback. Third, official government norms (NOM) must be written and published in order to allow for a national energy plan which will incorporate the integration of the project components and equipment. Fourth, the final beneficiaries of the fund as well as the conditions under which any stimulus package would be implemented must be determined through the Standard Operating Procedures of the Energy Transition Fund.

For example, the LAERFTE in its Article 14 states that the benefits must include payments related to the costs derived from the generation capacity as well as from the energy generated by the project. The benefits may depend upon the technology used and the geographical location of the projects. In conjunction with this, Articles 16 and 17 of the LAERFTE allow for the contract models and the benefits between suppliers and sponsors to be determined by the norms as published by the ERC.

The promotion of the investment in renewable energy requires that clear judicial assurances are provided. Therefore, it is important that all methodologies, regulations and procedures as stated in the LAERFTE are published a soon as possible.

12.2.2 The Hydroelectricity Potential

The technology implemented by the hydroelectric plants is mature. The worldwide development of important hydroelectric plants started at the beginning of the 20th century. In Mexico, the first major hydroelectric plants for the integrated national system were built in the 1950´s however, optimum use of these resources has not been reached. The macro-hydro electrical potential reached worldwide is 38% while in Mexico it is only 22%. Similarly, the micro-hydro electrical potential reached worldwide is 36% while in Mexico it is only 6%.

A coordinated effort to finish evaluating the national micro-hydro electric economic potential must be carried out. In the following 10 years, between 500 and 800 MW could be developed from this energy source. The same as with other technologies, a good national integration of the mini-hydraulic industry can be reached thus providing support to the economic development of the country.

Besides the technological aspects it is very important to address the social aspects related to the optimum use of the hydraulic resource. The National Electricity Commission (NEC) is developing large capacity projects of which, some have faced major opposition from the local communities. This means that the government needs to get close to and negotiate with the social groups in the different areas. There are also several private sector projects designed to establish small hydroelectric plants in several states in Mexico which combine the interest of the agricultural sector with the industrial sector. It is worth remembering that a similar format gave rise to the hydroelectric plant at Necaxa and the ensuing residential electrification more than a century ago.

The development of small hydroelectric plants reduces costs and improves electrical conditions of the medium tension grid. The judicial and regulatory framework allows for the development of mini-hydraulics in Mexico (174 MW) although actions are pending related to the normativity, paperwork and number of people that need to be involved in order to obtain a permit.

12.2.3 Bio-combustibles: on the road to the second generation

Sustainable growth and adoption of the bio-combustibles represent a starting point to detain the environmental deterioration. However, Mexico has diverse limitations for the development of the bio-combustibles although it also has opportunities that must be capitalized.

At present, several technological alternatives exist that will improve the production of plants that are used for the production of ethanol, of trans-genetic seeds that are resistant to unfavorable growing conditions and of close-circuit refineries that can promote alternative uses of the sub-products generated during the production of bio-ethanol. Notwithstanding, a large investment by the public and private sector will be required. Likewise, subsidies must be implemented in order for bio-ethanol to compete in the international market and for it to have a positive impact on the eco-environment.

To understand the implications of the bio-combustibles in Mexico, it is necessary to carry out a multi-disciplinary investigation. For example, the selection of the primary seed used in the production of ethanol must be based on the knowledge of agricultural conditions, the energy balance (which expresses the relation between demand and energy production for a specific combination of raw materials and its converting process), the availability of sub-products with economic value, the impacts on the eco-environment (on agricultural and industrial production), and the competition with food production. Given all these factors, sugar cane is the most viable option for the production of ethanol in Mexico in the short term. Mexico also has a long history in the use of this crop. Notwithstanding, this does not mean that sugar cane is the only option for the production of ethanol in Mexico.

A major limitation to the use of corn as a raw material in the production of ethanol is that this crop is an important element in the basic diet (foodstuffs) of the Mexican population. Although different studies reveal that its use in the bio-combustibles market has a small impact on its price, some government institutions such as the Department of Agriculture, Livestock, Rural Development, Fishing and Foodstuffs (SAGAPPA) consider it necessary to safeguard the dietary autonomy of the population rather than use corn for other purposes. Based on the studies presented by Romero-Hernandez which include an analysis of the life cycle and energy balance of the ethanol produced in Mexico from corn, it is possible to conclude that the use of corn as the primary source for the production of bio-ethanol should be avoided as the eco-environmental impact is greater than the benefits.

In Mexico, the government has invited private industry to supply on an annual basis 176 million liters of ethanol to PEMEX Refinery. The purchase price is set at a maximum of 8.20 pesos per liter during a 5 year period which represents a risk of an increase in the price of the raw materials and primary resources. Likewise, the use of corn grown nationally is prohibited which leads to the use of sugar cane as the primary resource for the production of ethanol. In conjunction with this, the government prefers to employ companies which have production facilities in the country (Reform in 2009). It will be important to follow-up on this invitation and verify that the bio-combustibles program continues to conform to the economic, social and environmental principles which every sustainable growth project requires.

For this reason, since 2008, laws have been enacted to regulate the investigation and the development of bio-energy sources such as the Law for the Promotion and Development of Bio-Energy Sources and the Law for the Optimum Use of Renewable Energy Sources and the Financing of the Energy Transition. Mexico is in the initial phase of the regulation of this new industry and a long road lies ahead in order to have a strong judicial framework that will correctly support the development of this industry.

The second generation bio-combustibles are better options for Mexico as these do not compete with the foodstuffs; they present a lower growth cycle (plant and harvest) cost and their energy and gas emissions balance is positive. Currently second generation bio-combustibles have 50% higher land-use efficiency when compared to first generation crops in terms of the distance that a transportation unit can travel on what is generated per one hectare of land. In addition, these combustibles are not only used by the transportation sector; they can also be used in the kitchen for cooking principally in those rural areas where the converting plants are located thus avoiding the green-house effect gas emissions.

These types of bio-combustibles are still in the investigation and development stage which means that their commercial use is still years away. Mexico could actively participate in this market due to its great weather diversity and cheap labor force. Additionally, at present, it has very creative investigators that could develop technology that is compatible to the country. This is a very important point as countries that have achieved progress in first and second generation bio-combustibles are highly industrialized and their agricultural, economic and technological conditions are very different to the ones in our country.

This leads to the conclusion that the country must have a great technological system that is innovative and informative in which each step in the supply chain is intercommunicated and actively participates. They must not only be able to produce and export energy crops such as jatrophas and algae but also be able to convert these into liquid combustibles and mix them with gasoline. For this to take place, the fossil-based combustibles market must actively participate allowing this new form of combustibles production to use its already established converting installations and distribution channels. It should be noted that for the foreseeable future, the bio-combustibles are not yet considered perfect substitutes for gasoline but simply represent a transition towards cleaner fuels.

Similarly, it is necessary to have the participation of other countries either for the joint initiation of investigation projects or to invest in ethanol production facilities and automobiles with hybrid motors as well as to share technological advances and establish norms or agreements that will regulate the international use of the bio-energy sources and their international commerce. Mexico is on the right road as it has begun to collaborate with other countries such as the United States of America and Canada sharing information between their Bio-energy Commissions. Promoting cooperation between the three partners in the North American Free Trade Agreement (NAFTA) could provide important benefits.

12.2.4 Bio-Mass and Bio-Gas

The modern bio-mass technologies have the capacity to provide better services based on the available energy and the resources of the residual bio-mass agriculture. The availability of low-cost bio-mass in the rural areas could provide cleaner and more efficient services thus supporting the local development, protecting the eco-environment, improving the domestic combustibles and rural subsistence. Additionally, the modern bio-mass energy technologies can contribute to an improved use of the biological residuals.

The existing studies indicate that compared to other primary energy sources, the potential for the employable generation of modern bio-mass is among the highest. For example, in Brazil, the annual production of 14 million liters of ethanol from sugar cane is responsible for the creation of 462,000 direct and 1,386,000 indirect jobs which is equivalent to an annual job-creation rate of 263,000 jobs. In Mexico, the data regarding the potential of bio-energy sources contrasts with its use. The bio-energy generation potential in Mexico oscillates between 3,035 PJ and 4,055 PJ per year which contrasts significantly with the current scenario in which only 408 PJ are generated (GBEP, 2008).

The impact that the modern bio-mass energy technologies have among the poor is not clear as they can lead to competition between the available bio-mass resources and the land. Large-scale bio-mass energy can lead to a greater marginalization of the poor rural population if care and adequate planning is not applied. However, it is also possible that the growth and development of these technologies could lead to an increase in the income of the poor (for example, the small sugar producers).

Bio-gas is currently a viable and sustainable alternative for energy generation in our country. The road to follow has already been shown by countries that have successfully used this technology for years implementing mechanisms, laws and incentives for its development and growth. This energy source can generate a total of 649 MW in the short term taking advantage of the existing resources. The recent initiatives in our country as well as the latest changes in legislation regarding renewable energy represent a first step. However, there is a long road ahead in order to reach the level achieved by the more developed nations.

Similarly, the waste generated by the large cities represents an important renewable energy source for the generation of electrical power with social, environmental and economic advantages. Its use is viable in sanitary landfills which allow for the formation of bio-gas which is sent to power electric generators although there are methods that implement direct incineration. The use of bio-gas from sanitary landfills is a new application in Mexico which has great potential.

A similar case is the generation of electricity using waste water from municipal sewers which also produce bio-gas. Another important source for the generation of this bio-combustible is the waste from pork and poultry farms as well as from the large dairy farms. All have a great potential that must still be exploited.

12.2.5 Reap the Wind

Although Mexico has one of the greatest potentials in class I and class II wind-powered energy with more than 10,000 MW, based on available information, up to 2009, its development has been limited as it has an installed capacity of less than 500 MW. In addition, the medium term perspectives do not contemplate any significant growth as an installed capacity of less than 4,000 MW is expected for 2017.

The main reason for the slow development of wind-powered energy in Mexico is the lack of public incentives that promote the use of renewable energy sources as well as the lack of a regulatory framework which allows greater participation of the private sector in the development of wind-power generation sites.

Mexico is at a good moment to apply the lessons learned from the development of wind-powered energy in other countries as recently it approved a law to push the development of renewable energy and is currently in the process of defining the details of the different mechanisms contemplated in this law. This allows for an objective evaluation of Mexico and the conclusion is that Mexico faces a long road although it is on the right path.

Other countries apply different strategies in order to promote renewable energy use and the Mexican incentives have had very little impact. The experience in California and Texas (in the United States of America) shows the relevance that certain regulatory schemes can have upon the development of the wind-powered energy industry. In particular, the success that the implementation of temporary subsidies have on the development of renewable generation as well as the setting of minimum goals for the generation of renewable sources should be noted.

Concerning the eco-environment, it cannot be denied that much work needs to done but we should not lose sight of the fact that the means, the strategies and the resources to carry out this work are available. There is no reason to scorn measures that provide protection and mitigate the impacts.

From an economic viewpoint, it has been shown that with plants that have factors under 30% the industries can carry out business in other parts of the world. Mexico has sites with that potential and higher which should be an incentive for the creation of jobs and the strengthening of the local capabilities. Likewise, the speed range of the wind must be widened to maintain a high efficiency of the turbine, improve the infrastructure in order to transfer electrical energy that is generated far from the coast, promote new technologies for the storage of the energy and reinforce the towers that support the turbines in order to increase their resistance and reduce their cost.

12.2.6 Heat from the Earth

Geothermic energy is a renewable resource as the energy obtained is replaced continually by more energy in a timeframe that is similar to the one required for its generation.

In general, the direct uses of geothermic energy for heating, thermal water sites, greenhouses and other agricultural and industrial applications including geothermic heat pumps have been developed more than the indirect uses for the generation of electrical energy. In Mexico the exact opposite has occurred. Currently, Mexico has a geothermic capacity of 958 MW in operation with proven reserves of at least an additional 175 MW and additional probable reserves of a minimum of 3,000 MW. However for the development and exploitation of the geothermic non-conventional reserves such as the ones for low and medium temperature, dry hot rocks and underwater reserves, high-cost technological and economic barriers must be overcome.

To bolster the development of geothermic energy investigation is recommended as well as the application of drilling techniques that allow for the reduction in the costs of the wells as well as the precise development of new materials with a lower cost (piping, pumps, additives, heat exchangers and cooling systems). These need to be integrated using innovative designs in such a manner that the system in its entirety is more efficient and consequently more economical.

In Mexico, it is recommended that specific legislation be enacted which includes initial subsidies for the development and exploitation particularly of the non-conventional geothermal resources using fiscal stimulus or other mechanisms such as ones that are used for environmentally friendly and renewable energies in other parts of the world. These would increase the availability of geothermal energy exploration and exploitation services, attract investments and development and strengthen international cooperation. Additionally, it is recommended that the new geothermal projects, for conventional as well as non-conventional sources, rely on the Mechanisms for Clean Development (MCD) as stated in the Kyoto Protocol in order to obtain carbon credits or certificates of lower emissions which can be utilized to reduce the unitary costs.

All of this would undoubtedly assure the supply of energy for the country, mitigate the effect on climate change and strengthen a diversified energy market in a manner that would be socially, economically and environmentally sustainable. Mexico exports electricity generated from geothermal sources and the potential to increase these exports is available as well as the capability to enter into agreements with the different states as well as the federal government in the United States of America.

12.2.7 Solar Photovoltaic

The solar photovoltaic energy is a great source for the sustainable development and growth in Mexico. Compared to other sources, this is a source of electrical energy which presents many advantages among these that it does not require combustibles or consumables, produces no emissions during the generation process, practically requires no maintenance during 25 years of useful life and can be installed very rapidly and economically. It is the most viable form available to provide electrical energy to the rural communities and to generate "clean" energy in the cities. Also, it is an opportunity to diversify the national energy basket as provided by the Federal Electricity Commission (FEC-CFE), it generates a high "value-added" impact as it requires multiple products and services from other sectors and lastly, it represents an opportunity to create quality employment.

Mexico has an enormous potential for the use of solar energy especially in the northern regions of the country. This potential can satisfy a part of the internal consumption needs as well as be exported. There exists a real possibility to export solar photovoltaic energy to Arizona and California where there exists an increasing demand for green energy. There are many success stories in the world and many of the leading countries in the photovoltaic market would like to have a solar radiation similar to Mexico. The Mexican government needs to define from an economic, environmental and energy security viewpoint, the work to be carried out in photovoltaic energy. To achieve this, clear and specific goals for the short, medium and long term regarding installed photovoltaic energy must be established.

The projected capacity can correspond to the objectives established for electrical energy to be available to the entire population, to the criteria for the diversification of the national energy basket and, to the promotion of the national photovoltaic energy industry among others. The strategic planning should include the definition of areas of opportunity or application, objectives for the development of the national industrial capacity and, scientific investigation and technological objectives among other factors. The action plan should quantitatively detail the aforementioned objectives and set concrete completion dates.

In terms of the regulatory framework, the Mexican legislation already allows for energy self-sufficiency as well as for the connection to existing private sector photovoltaic grids. What is lacking is the establishment of simple and clear administrative procedures which will surely surface as a result of

LAERFTE. Similarly, there exists a need to establish an official Mexican Norm to certify the quality of the photovoltaic installations and their components.

Of the two most popular and existing financial aid schemes in the world providing financial support for the purchase of photovoltaic systems and for the production of solar energy, the analysts concur in that the "feed-in-tariffs" is the scheme that provides greater stimulus for consumption and greater economic benefits. The solar energy tariffs can be subsidized by the governments or prorated based on the consumption by the other users of the electrical energy generated. Likewise, another financial support scheme consists in the inclusion of the external factors that impact the electricity generation costs of all the sources.

To promote the use and application of the photovoltaic technologies in Mexico, all government agencies must be informed of the benefits and of the photovoltaic programs available in the country. Also, it is necessary to bolster detailed promotional schemes that comply with federal government objectives among the industrial and academic sectors as well as the civil population. This should be done with the express purpose of promoting the consumption and the investigation of renewable energy sources and more specifically, solar photovoltaic energy. Likewise, it is necessary to qualify the capacity of the production chain that could utilize the photovoltaic energy that would be generated and promote the construction of the manufacturing facilities needed to achieve the overall photovoltaic strategy. As for the areas of investigation and development, it is necessary to improve the efficiency and simultaneously reduce generation costs, develop new materials and design new energy storage technologies.

12.2.8 Solar Thermal Energy

The use of solar thermal energy is recommended for arid or semi-arid regions with an average annual solar irradiation equivalent to 1,700 kWh per square meter (m2). In Mexico, these regions mainly cover the states of Sonora, Baja California, Chihuahua, Durango, Zacatecas, Coahuila, Sinaloa and Aguascalientes.

The installation of hybrid systems in the current thermoelectric plants located in sites with the aforementioned irradiation and climate conditions is recommended. The most efficient plants are the ones integrated with a combined and solar cycle (with central tower or parabolic canals). A thermal storage system with foundry salts or salt nitrates (with 16 hours of storage capacity) can be installed to increase the supply capacity and the plant factor (from 22% to 60%) and reduce the size of the turbine as well as reduce the percentage generated by the burning of fossil fuels.

The installation of parabolic plants is recommended for regions located far away from the national electrical energy grid as these are more economical than the photovoltaic systems in applications between 10 kW and 10 MW. The installation of giant thermal-solar plants (greater than 400 MW) that are located in near proximity to each other is recommended in order to reduce generation costs as a result of maintenance and operation. Existing literature indicates that doubling the size of the plant will reduce capital costs between 12 and 14 percent.

Similarly, the installation of thermal-solar plants with solar pools near salt mines and coastal areas is recommended as the cost of these plants is very low and they represent a great potential for the generation of electrical energy and for their use in direct heat applications at temperatures of 90o C. Also, the purchase and installation of systems with flat passive collectors (made of shale due to its cost and efficiency) and with structural retention capability is recommended for the domestic and industrial sectors. This represents an opportunity to expand the use of collectors in the residential developments for the lower and medium middle class. On the other hand, programs for the development of the countryside that include solar applications for agricultural use should be established in order to promote its growth at a low cost.

In general, there is a need to modify the legal framework and create financing mechanisms in order to improve the incentives that favor private investments in technologies applied to the generation of renewable energy sources. In the case of Mexico, solar energy presents a great potential which has been sub-utilized with the resulting economic and environmental costs. However, it is expected that after the United Nations Conference in Cancun this topic will be given a higher priority and public policies will surface that will promote the use of thermal solar energy.

Lastly, the use of thermal solar energy sources should be maximized considering the country´s privileged geographical location in terms of solar radiation. The adequate instrumentation of thermal solar projects to satisfy part of the basic demand of the national electrical sector can be a critical agent in achieving a reduction of the carbon footprint associated with the energy currently utilized in Mexico. This would also increase energy security as it would base production on an inexhaustible and permanently available "combustible".

12.2.9 Microgeneración

Micro-generation is an available option to complement the national electrical system. Given the lack of fiscal incentives similar to the ones in other countries, the micro-generation projects must present clear social and economic advantages in order to receive approval. For example, they can be used to reduce costs and consumption of electricity by a system connected to the national grid. They are also an attractive option when energy interruptions affect industrial productivity. Moreover, in some cases, they can be installed as an emergency plant on line during the hours that peak hour tariffs apply (in some cases they may even be economically viable in hours when intermediate tariffs apply).

Analyzing other possible scenarios, the micro-generation options can help to increase the availability of energy when the energy supplier lacks the capacity to supply energy to cover peak demand periods.

Lastly, it is important to point out that the micro-generation schemes should not be considered a substitute to a national electrical power grid but should be viewed as a complement which should be studied and implemented when it is required.

12.3 Final Conclusions

The Law for the Optimum Use of Renewable Energy Sources and the Financing of the Energy Transition contemplated the establishment of a fund totaling $3 billion Mexican pesos per year for the promotion of renewable energy projects and the establishment of a Renewable Energy Consulting Committee with the joint participation of all sectors and the government in the development of public policies.

The natural resources available in our country, its human capital, the development of the national market and its proximity to the largest energy consumer makes it an ideal destination for investments in the energy sector. However, we continue to be subject to technological advances in other nations and to the disadvantages that come from not having local patents or incentives to spur the development of specific solutions for the conditions that exist in our country.

Today, more than ever, it is necessary to examine all strategic options in terms of macroeconomic policy that will allow for the establishment of a proper framework for productive development favoring an increase in investments and jobs, an improved income distribution and sustainable growth. Technological development will no doubt be an indispensable ally in achieving these goals.

Faced with the current world economic situation, a reduction in spending by the government and the lack of liquidity in the industrial sector, we call upon the groups responsible for public policy to maintain and open wider the windows of opportunity that are derived from the activities dedicated to investigation and development.

This includes the implementation of efficient systems of solar energy, wind-power or hybrids, the installation of mini-hydroelectric plants, the installation of new lighting systems, the design and construction of more efficient electro-domestics, the production of a wider and more efficient collection of thermal isolators, the development of second generation bio-combustibles and of hybrid automobiles and in the near future, the design and construction of CO^2 depositories as well as the creation of intelligent electricity transmission and distribution networks (smart grids).

Also, the statistical information and the data bases related to renewable energy sources and its use must be improved thus allowing the industries in operation and the development projects to have better information for decision-making. This will allow for the existence of additional capacity and physical and technical infrastructure as well human capital in order to identify and take advantage of the niches of opportunity in the national market which over time, could attract new investments.

In terms of a balance in the environment and global warming, renewed efforts must be made to utilize renewable energy such as hydraulic, wind-powered, solar and bio-combustibles. The methodologies for the evaluation of development projects must incorporate elements such as green-house effect gas emissions, the assurance of supplies and price scenarios.

In the case of the optimum use of the renewable energy sources, conversion efficiencies could be higher thus contributing to a reduction in fossil fuel dependence. However, the transition to these sources not only has technical implications but also requires an important financial contribution, the re-education of the public regarding the use of these energy resources as well as precise and timely information.

Mexico has the industrial and technological capability to design equipment and projects related to renewable energy sources that present a high potential for development, that represent a niche for the incorporation of a professional labor force as well specialized technicians.

At this stage of the transition toward a cleaner energy generation, the final use of the energy is also important in order to achieve energy security given the importance of an intelligent and efficient use of the resources. This means a significant social change. For example, it will be necessary that residential and commercial construction consider aspects such as natural lighting, thermal isolation and energy recovery. It should be mentioned that this transition is foreseeable even from the viewpoint of the world´s principal energy companies that produce fossil fuels.

The adoption of projects to generate energy from renewable sources and energy efficiency programs represent two of the principal areas of opportunity to continue fortifying the country´s energy security, to reduce the emission of green-house effect gases and to promote economic and social development. This book presents the state of renewable energy in our country and sets the stage for its discussion. We hope that this book will stimulate the debate among experts and legislators showing the imperative need to achieve a collaborative effort among all parties involved in order to create national applications with the existing technologies and to develop new technologies in this country.

Renewable Energy in Mexico:

Policy and Technologies for a Sustainable Future

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