3-15-2006

Social sustainability of hybrid electricity generation systems in Mexico

Pablo Federico Blackmore
Florida International University

DOI: 10.25148/etd.FI14051162

FLORIDA INTERNATIONAL UNIVERSITY

Miami, Florida

SOCIAL SUSTAINABILITY OF HYBRID ELECTRICITY GENERATION SYSTEMS IN MEXICO

A thesis submitted in partial fulfillment of the

requirements for the degree of

MASTER OF SCIENCE

in

ENVIRONMENTAL STUDIES

by

Pablo Federico Gottfried Blackmore

2006

To: Interim Dean Mark Szuchman
College of Arts and Sciences

This thesis, written by Pablo Federico Gottfried Blackmore, and entitled Social Sustainability of Hybrid Electricity Generation Systems in Mexico, having been approved in respect to style and intellectual content, is referred to you for judgment.

We have read this thesis and recommend that it be approved.

Dr. John H. Parker

Dr. David B. Bray

Dr. Mahadev Bhat, Major Professor

Date of Defense: March 15, 2006

The thesis of Pablo Federico Gottfried Blackmore is approved

Interim Dean Mark Szuchman
College of Arts and Sciences

Interim Dean Stephan L. Mintz
University Graduate School

Florida International University, 2006

DEDICATION

I dedicate this thesis to my family. To my wife, for her good advice and patience. To my son, for whom I work. To my Father for his dreams of a better world. To my Mother for her unyielding support and love. To my Parents in law for their guidance and generosity.

ACKNOWLEDGMENTS

I wish to thank the members of my committee for their support. Their continued direction has been most appreciated. Dr. David Bray helped me frame the context of rural communities in Mexico within this thesis. Dr. John Parker's interest in renewable energy and sense of competence was the impetus for this subject matter. Finally, I would like to thank my major professor, Dr. Mahadev Bhat. From the beginning, he had confidence in my abilities to not only complete a degree, but to complete in with excellence. I thank him for his continued enthusiasm.

I have found my coursework throughout the Curriculum and Instruction program at the Environmental Studies Department to be stimulating and thoughtful, providing me with the tools with which to explore both past and present ideas and issues in Sustainable Development.

ABSTRACT OF THE THESIS

SOCIAL SUSTAINABILITY OF HYBRID ELECTRICITY GENERATION SYSTEMS IN MEXICO

by

Pablo Federico Gottfried Blackmore

Florida International University, 2006

Miami, Florida

Professor Mahadev Bhat, Major Professor

This thesis tried to determine the socioeconomic contributions of a renewable-hybrid energy system in San Juanico, Mexico. It also tried to analyze if the hybrid system was designed based on sustainable development principles. A survey of 91 electrified homes was conducted in San Juanico to gather information on consumer satisfaction and data analyzed using simple means and group mean comparisons, with suitable tests as needed. A binomial probit model for two dependent variables was applied to survey data. An energy price-comparison exercise was conducted as well. Findings showed the hybrid system had suffered from weak institutional frameworks, low community participation and a lack of long-term system and financial planning. Although the system made improvements in quality of life, it had not been reliable and lacked organizational ability to supply rural electricity in a sustainable fashion.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

Growth and development are fundamental aspirations of nations in Latin America. As countries in this area strive to pull themselves out of poverty and underdevelopment, the expansion of electricity infrastructure will play a pivotal role in their ability to provide a better future for their populations. This expansion will be vast over the next few years. Countries will not only have to provide infrastructure to satisfy urban demand, but also expand access to electricity in underserved rural areas. If properly provided, access to electricity in these settings is major stimulus to development. This is especially true when it is aimed at increasing communities' productivity, raising education levels and increasing access to health services. However, supplying this access is often an economic and political impossibility because little purchasing power exists for electrical services and appliances in remote rural communities. Further complicating the delivery of energy infrastructure to underdeveloped remote regions are the traditional characteristics which accompany centrally-controlled, bureaucratic national institutions; a category into which electricity companies in developing countries fall, albeit with some exceptions. These characteristics range from economic inefficiency, insufficient access to current technology, pervasive mismanagement, inadequate expertise and resource limitations due to monopolistic behavior, cronyism and corruption. The ability of nations to launch optimal and sustainable electrification development programs is severely undermined by these shortcomings. However, if developing countries are to succeed, they will have to soon find ways to provide electricity for the millions in their ranks who now live without it. Electricity coverage in Mexico reaches 96% of its populated areas, leaving approximately 5 million people without electricity [Instituto Nacional de Estadística, 2005 #78]. Most of the communities in which this sector of the population inhabit are located in isolated rural areas where grid extension is not economically feasible. The installed capacity for Mexico's Interconnected Grid as of 2003 was 49,672 MW. The yearly average growth rate for installed capacity during the 1993-2003 period was 4.3% while the yearly average growth rate for electricity generation was 4.9% [Energía, 2004 #77]. During this period, investments by the national utility Comisión Federal de Electricidad (CFE) in combined cycle plants increased this technology's participation in Mexico's energy portfolio by 44.4%. The hydroelectric contribution during this period was reduced from 28% in 1993 to 22% in 2003 [Energía, 2004 #77]. Table1 [Energía, 2004 #77] describes Mexico's electricity portfolio's development during this period:

TABLE 1. Mexico's energy portfolio 1993 - 2003

TECHNOLOGY	1993 (3.070 TeraJoules/day)	2003 (4.578 TeraJoules/day)
Nuclear	3.9%	5.2%
Dual	1.7%	6.8%
Coal	8.3%	8.2%
Geothermal + wind	4.6%	3.1%
Combined Cycle	6.3%	27%
Vapor + turbogas + Internal Combustion	54.4%	40%
Hydroelectric	20.7%	9.7%

(Source: Secretaría de Energía, 2004.)

During the 1993-2003 period Mexico's average yearly growth rate for electricity consumption in Mexico was 4.7%. Industrial consumption represented the largest demand sector, while the services and agricultural sectors remain the lowest demand sectors. Table 2 [Energía, 2004 #77] describes how electricity demand was distributed in Mexico during this period:

TABLE 2. Electricity demand in Mexico by Sector

DEMAND SECTOR	1993 (101,277 GWh)	2003 (160,384 GWh)
Agricultural	6%	5%
Industrial	54%	59%
Services	5%	4%
Commercial	9%	8%
Residential	25%	25%

(Source: Secretaría de Energía, 2004.)

Projected average yearly growth rates for electricity consumption in Mexico for the 2004-2013 period is 5.7% [Energía, 2004 #77]. Given the associated investment requirements to meet this growing demand, decision makers need appropriate evaluation tools for different energy options. However, there still exists a significant sector of the population living in remote rural communities whose electricity demand is not being met through programmed investments in the electricity grid.

This study will focus on the perceived impact of a renewable/diesel hybrid system in San Juanico, Baja California Sur Mexico as an alternative electrical "off-grid" system for remote rural areas. The term *hybrid* will be used to describe any power system with more than one type of electricity generator. It is common for hybrids to be constituted by a conventional generator powered by a diesel or gas engine, and a renewable energy source such as photovoltaic (PV), wind, or hydroelectric power system. A well-designed hybrid system can exploit the strong points of different sources to provide a flexible and reliable power system. These include the use of free resources, low operation and maintenance costs and high reliability[Sandia National Laboratories, 2002 #47].

Challenges for this energy option stem from two main sources. Those in the first category are those that limit renewable energy deployment, while those in the second address limiting factors to conventional off-grid energy systems. In the case of renewable technologies in developing countries, these include the relatively high initial capital cost, the unfamiliarity of the receiving parties with the technology, the inexperience of equipment installers, and a high degree of difficulty in procuring parts and maintenance service and the lack of any functional institution-building model to secure the long life of the projects. In the case of conventional off-grid technologies, the main challenges include the high cost of fuel transportation and difficulty in securing parts and service in remote areas [Marquand, 1998 #39]. In the future, systems operating with a diesel component will undergo pressure to eliminate this part of the system because of the large developing body of evidence of diesel's harmful effects on the health of people and the environment [Goldemberg, 1998 #38]. In short, the main limitations are lack of access to financing, relatively high initial cost, lack of awareness and/or involvement in rural communities and absence of appropriate technical support institutions, institutional drivers and safeguard structures.

As more and more technological improvements take place in the arena of renewable energy, the acceleration in the learning curve, emerging higher efficiencies, and the implementation of more economic solutions present the need to analyze changing investment requirements in renewable components. The continued reliance on the hybrid system in San Juanico and places like it in the future, therefore, requires a clear understanding of whether the system would still remain socially acceptable and viable given people's experience with the system. Further, future investments on alternative energy systems need to be justified based on the positive social and economic contributions that the existing hybrid system might have made to the rural community. This is especially true if developers of these systems are looking to gain funds from international finance institutions such as the World Bank. Consequently, research is needed to evaluate the potentials of said hybrid system in providing an economically- and socially sustainable source of energy in rural Mexico.

This study will be conducted within the conceptual framework of sustainable development. For this purpose, sustainable development means improving the quality of human life while living within the carrying capacity of supporting ecosystems[Reed, 1996 #51}. This definition embraces three interdependent components - the economic, the social and the environmental. The economic component of sustainability urges societies to choose growth paths that sustain true long-term income while reducing dramatic inequities in income distribution instead of shortsighted policies that perpetuate long-term poverty and resource degradation. In generating an "optimal flow of income", societies must maintain their basic capital stock, which includes man-made capital, human capital and natural capital. Finally, it calls for the internalization of all costs associated with development and growth, particularly environmental pollution.

The social dimension of sustainable development is based on social equity; all people should have access to education and the opportunity to be productive and be fairly remunerated for their work. The characteristics that define the social component of sustainability include active political participation, slower population growth rates, local population's knowledge (human capital) and participation and the strengthening of civic groups (social capital). Institutions that support local-level sustainable management practices. Finally, the environmental component of sustainable development is founded on maintaining the long-term integrity and productivity of the planet's life-support systems and environmental infrastructure [Reed, 1996 #51].

In the context of the implementation of a hybrid energy system for rural electrification, sustainability could be defined as the process by which said energy system is developed, the ethical and policy standards applied to its implementation and institutional operation, the technical processes that relate to the proper operation of the system itself, and the impact the system has on the local economic and environmental context [Hackett, 1998 #49]. A successfully designed hybrid system will necessarily be people centered in that the aim of system installation is ultimately the improvement of the quality of human life within the community it serves, while respecting nature's carrying capacity [Reed, 1996 #51]. Local capacity to maintain the system should be a major planning issue, so the system should be relatively simple and training of locals thorough.

In an effort to launch renewable energies, several national and international organizations have set up pilot projects in Mexico [Energía, 2002 #79]. Some of them, such as the Xcalac, el Junco, and Santa María Magdalena are hybrid technologies. A definition of these types of technologies will be provided below. It is important to realize that most of these pilot hybrid projects have failed. These observed systemic failures stem from several shortcomings in the development and execution of these aforementioned projects. Mainly, components were selected without taking into consideration environmental site conditions, poor local resource assessment, poor system sizing and failure to forecast local load growth, all of which contributed to shorter systems lifetimes and reliability [Agredano, 2000 #20]. These failed pilots have clearly not contributed to sustainable development.

Previous research that attempted to address this question mostly focused on the technological drawbacks of the hybrid solution. Research focused on the sustainability of these systems in rural communities is needed to analyze how they have improved the lives of their recipients insofar as their productive capabilities and quality of life. Also, based on the systems' costs and institutional structures; how likely is it that they will continue to do so in the future?

Specific Objectives

The proposed research will analyze the social and economic factors surrounding a renewable-hybrid power system in the rural community of San Juanico, Baja California Sur, Mexico. The specific objectives of this study are:

1. Evaluate the economic and social contributions of the hybrid energy system to the community of San Juanico.
2. Evaluate the institutional framework available for the operation and maintenance of the hybrid energy system of San Juanico.
3. Provide policy insight on the applicability and sustainability of hybrid systems for rural electrification.

II. LITERATURE REVIEW

Energy and sustainable development

This chapter will provide a summary of reviewed literature addressing sustainability of energy policy, energy and development, renewable energy development in the international and Mexican contexts, and existing information on rural electrification using hybrid and renewable energy sources in Mexico. Information contained in this chapter stems from a wide range of sources such as journal articles, textbooks, scholarly papers, websites, governmental information, magazines, reports and specialized books.

The purpose of this review is twofold. First, to provide the reader with a selective review of above mentioned concepts. Second, to identify some existing gaps in literature that this study will try to answer. Although the entire body of knowledge for each concept has not been covered here, the selection of literature is representative of current knowledge on these subjects.

Conventional wisdom states that economic growth should be roughly proportional to increasing consumption of raw materials and energy. Many even argue that "high energy consumption is associated not only with physical comfort, economic well-being, and military strength, but has been identified with civilization itself" [Basalla, 1979 #65]. In short, there is the "energy = civilization" equation which can be recognized as a pervasive, if often implicit, element in both popular and scholarly approaches to energy and society. Nevertheless, this is but a crude formula. It does not ask who got to use the energy, if the energy was squandered on trivialities, wasted in destructive wars or utilized to advance the social, moral, and cultural accomplishments we identify with civilization. However incomplete and blunt this idea might be, it has had a markedly large impact in the way countries shape and pursue energy policy. In short, those countries with high rates of energy consumption are ideologically committed to maintaining them and those with lower rates are motivated to copy their energy-hungry, civilized superiors. This ideological component helps explain why so many of the less industrialized nations felt it necessary to have their own nuclear reactors. It was not necessity that drove them to acquire them but the feeling that they might be left behind in the race towards civilization [Basalla, 1979 #65].

If one takes global warming seriously, this belief creates a conflict between environmental well being and economic development. Energy sectors in industrialized nations are credited as being the greatest contributors of greenhouse gases which aggravate global warming (among other negative contributions). "There is now a broad scientific consensus that human-induced climate change is under way and accelerating, with a number of projected impacts of warming already occurring. These changes include glacier shrinkage, permafrost thawing, later freezing and earlier buildup of ice on rivers and lakes, lengthening of mid- to high-latitude growing seasons, shifts of plant and animal ranges, declines of plant and animal populations, and earlier flowering of trees, emergence of insects and egg-laying birds"[Starke, 2002 #54]. Further research is being directed into the vulnerability of ecosystem services on which humans depend and potential impacts on human systems of their degradation. These include water resources, agriculture, forestry, coastal zones and marine systems, human settlements, energy, industry, insurance and other financial services, and human health. Few outcomes being modeled in these areas hold a positive outlook for human livelihoods; For example, the IPCC concluded that "the effects of climate change are expected to be greatest in developing countries in terms of loss of life and relative effects on investment and the economy"[Starke, 2002 #54]. In short, those who will be hit hardest have contributed least to the problem.

However contentious further contributions might be from an environmental perspective, global growth in commercial energy consumption is inevitable. This growth will happen primarily in developing countries. Fortunately, new technologies exist which either bypass old energy conversion systems dependent of fossil fuels, or are significantly superior in the way they utilize these fuels.

Developing countries face a choice regarding the development of their energy infrastructure. "They can mimic the industrialized nations, and go through an economic development phase that is dirty, wasteful, and creates an enormous legacy of environmental pollution; or they can leapfrog over some of the steps originally followed by industrialized countries, and incorporate currently-available modern and efficient technologies into their development process"[Goldemberg, 1998 #38]. Basically, they can choose between two paths, what Amory Lovins (1977) has termed the "hard path" and the "soft path".

The hard path is based on the rapid expansion of three centralized high technology mega-sectors to increase supply in energy, especially in the form of electricity: coal, gas and oil. In short, this path is eventually destined to fail for several reasons. "Despite intensive electrification, consuming more than half the total fuel input in 2000, we are still short of gaseous and liquid fuels, acutely so from 1980 and on, because of slow and incomplete substitution of electricity for the two-thirds of fuel use that is now direct"[Lovins, 1977 #33]. Furthermore, "shortages in gas and oil only deepen; at least half of the energy growth never reaches the consumer because it is lost earlier in elaborate conversions in an increasingly inefficient fuel chain dominated by electricity generation[Lovins, 1977 #33]. These central mega-systems are not only inefficient and environmentally unfriendly but are also particularly ill suited in meeting the electrification needs of millions of people who live in remote areas.

A different approach, under present economic and technological circumstances, can be found in solutions provided by the "soft path". The soft path is characterized by five main attributes. It is important to remember that the distinction between hard and soft energy paths rests on the technical and sociopolitical structure of the energy system, not on how much energy is used. Soft energy technologies depend on the flow of renewable energy sources, such as solar, wind and vegetation, as opposed to a fixed (and therefore depleatable) energy capital [Lovins, 1977 #33]. In this sense both sets of technologies can be considered as economic stock or flows. Soft technologies can be considered as an economic flow in that its value may change at given periods in time, but it will always fluctuate around an average value. Hard technologies, on the other hand, can be equated to an economic stock because it holds true that from one time period to the next its value can only increase or decrease (accumulate or deplete). For hydrocarbons, since the rate of extraction far exceeds the rate of deposit formation, we can safely say that these sources can only be depleted as their demand continues to increase. Soft energy technologies are diverse. These systems are composed of the aggregate of very many small energy contributions, each matching the specific load for which it was designed with maximum effectiveness, integrating a distributed generation system [Lovins, 2002 #80].

They are also flexible. Soft energy systems are easy to understand and use. They do not use overly complicated technology, which is not to say it is unsophisticated. Furthermore, they "are matched in scale and geographic distribution to end-use needs, taking advantage of the free distribution of most natural energy flows"[Lovins, 1977 #33].

Finally, soft energy technologies are matched in energy quality to end-use needs. This is perhaps one of their most important attributes. Traditional systems are characterized by their energy inefficiency when it comes to end use applications. In layman's terms, generating electricity at a big nuclear or coal fired plant for lighting or household appliances is "like cutting butter with a chainsaw". For instance, over 95% of the energy used by a light bulb is lost in the long chain of inefficient conversions. Renewable energy systems can be designed specifically for different tasks. This is an enormous advantage because much less energy is lost, hence reducing fuel inputs and associated negative effects.

Many countries have started to see renewable energy as a feasible option in the development of their energy infrastructure. The 1990s saw an enormous increase in megawatts generated by renewable technologies. Over the last ten years the fastest growing energy source was wind power. However, the vast majority of these additions were made in industrialized countries. Developing countries are bound to increase their energy consumption in an attempt to catch-up to industrialized nations, but whether or not they are going to shouldn't concern us, it is how they do it that should [Zervos, 2006 #81].

Renewable Energy in Mexico

Some developing countries have half-heartedly placed small wagers on developing renewable electricity systems for certain sectors of their populations. Mexico is one of them and has achieved limited renewable energy implementation with mixed results. Since the early 1990s, renewable energy has been considered as a potential energy portfolio option by Mexican authorities [Energía, 2003 #82]. However, if they are to commit to developing it, the risk level associated with renewables has to be reduced. An important way of reducing inherent risks is to better understand how these technologies are successfully deployed and shape policy based on new understandings. Conversations held between this author and several experts in the field (Mr. Eduardo

Zenteno, General Director for Mexico, EDF Energies Nouvelles; Mr. Oscar Galindo, General Director, Eoliatec de México; Mr. David Horta, President, CISA), support the notion that existing doctrinal and technological inertia within the Mexican Comisión Federal de Electricidad causes it to be generally opposed to the large-scale deployment of small-scale renewable energies for several reasons. Mainly, most renewable energy projects are too small to be considered by such a large institution. This means that most renewable energy projects will be pursued by independent developers or agencies, especially in the case of distributed generation. Furthermore, it also seems that advances in distributed renewable energy are perceived by certain authorities as an erosion of CFE's predominance. Although there are a couple of departments dedicated to the subject, individuals within the institution who are pursue small-scale renewable energy do not receive the necessary funds or corporate backing.

Budget limitations, institutional inefficiencies and rural poverty remain culprits behind the lack of access to electricity of an estimated five million Mexicans. Even though "governments at all levels recognize the productivity and social development benefits of rural electrification, and especially the electrification of farms, these causes still prevent electricity from flowing in 88,000 villages and 600,000 livestock farms"[The InfoShop, 1999 #8]. In addition, more than 100,000 rural communities are in need of potable water [Sandia National Laboratories, 1999 #7].

Although the dissemination of renewable energy technologies in less developed countries (LDCs) has been slow, it is steadily progressing. Renewable energy technologies include wind energy turbines, solar photovoltaic cells, solar thermal, run-of-river minihydro electric plants, and biomass burners and digesters. Some of these are now viewed by many development agencies as a viable solution for rural electrification which, in time, reduces people's dependence on their immediate surroundings for sources of energy(Goldemberg 1998). This dependence, mainly on fuel wood, is a primary driver of environmental degradation in LDCs. Rural settings provide some of the best opportunities to apply renewable energy for: lighting, water-pumping, refrigeration, education, solar ovens, curb respiratory disease incidence amongst women and children, solar hot water heaters, and reduce deforestation rates and associated issues.

The Renewables for Mexico Program, conducted and implemented by Sandia National Laboratories, the Department of Energy and institutions in Mexico such as the FIRCO (Fideicomiso de Riesgo Compartido), has disseminated solar technology projects in 1,400 rural communities in Mexico(Sandia National Laboratories 1999). At this point the largest productive application of solar PV in Mexico is for water pumping. This application encompasses 38% of solar-produced electricity usage in rural communities. There are now 45,000 small solar systems in Mexico. Clear benefits from solar energy technology in rural communities [Sandia National Laboratories, 1999 #7] in Mexico are:

- Less livestock mortality
- Less operation and maintenance costs
- More leisure time
- More water for domestic use
- Better and more efficient irrigation

Barriers to Renewable Energy Implementation

The barriers impeding penetration of solar energy technologies in Mexico's agricultural sector include at it their most basic level the lack of awareness among unelectrified rural communities. However, these barriers are existent across a diverse prism of institutions. Governments, academia and private entrepreneurs must quickly find ways to economically create a market where trained technicians and vendors that can design, install and service units(Foster, Orozco et al. 1999). The lack of technical specifications and certifications processes for equipment adds a tremendous contribution to the uncertainty of developing these technologies, specifically in rural settings where, in the face of equipment breakdown or malfunction, the owner is left completely without recourse.

Further, past experiences of this nature have built a barrier of their own for the penetration of renewables as farmers grow suspicious of renewables and view them as unreliable novelties. Finally, the most perverse barrier can be found with the economics of solar energy systems(Frantzis and Katofsky 2002). The high initial cost of solar technology compared to traditional systems coupled with inexistent or severely deficient financing sources for initial investment make the development of these technologies very difficult in Mexico. However, what is lacking is a discussion on the cost of not electrifying these communities fast enough. Lack of basic rural infrastructure places many pressures on national economies as quality of life, health, security, political and human rights issues stimulate rural-to-urban migration that most Latin American countries suffer from, increasing the demand for services in urban areas.

However hard the road to expanding the market for solar energy technologies in Mexico, there are still important drivers that keep pushing this expansion. In Mexico alone, rural solar-based electrification is valued at 511 million dollars [Sandia National Laboratories, 1999 #7]. There is a clear economic incentive. For example, solar and other renewable energy systems for small-scale irrigation are estimated at 94 million, or 11,700 units [Sandia National Laboratories, 1999 #7]. And this is only one third of the potential found in livestock watering. Livestock watering using solar or other renewable energy driven pumps is estimated at 297 million dollars or 42,430 units [Sandia National Laboratories, 1999 #7]. (Economically speaking, this is the best application for small scale RE because livestock ranchers can often pay for the system without government aid).

Technical and social factors of Hybrid Energy Systems' Sustainability

Several lessons have been gathered from previous incursions in hybrid energy systems. Amongst the lessons that speak of system technical sustainability we find [Foster, 1999 #9], [Jacobsson, 2000 #40]:

1. Maintenance is critical for long-term system survival
2. System ownership and responsibilities need to be established early on
3. Metering (kWh) is key for successful operation of village hybrid systems
4. Local village support and training is crucial for a successful hybrid system

5. Long term planning is needed for all village-use hybrid energy systems
6. For coastal locations, corrosion proof hardware is required
7. Battery charging from the generator is needed to enhance system efficiency and battery life.

Of equal importance, and often the most difficult to implement, are lessons gathered that have focused on institutional issues that surround the challenges and opportunities of renewable-hybrid technology conclude the following [Marquand, 1998 #39], [Hanley, 2000 #10], [Suding, 1996 #26]:

1. Following technical quality standards is essential. Replication of high-quality systems is the true measure of success for renewable-hybrid system implementation.
2. Building a strong supplier network is important to meet the demands of new implementation programs.
3. Fostering reasonable end-user expectations will ultimately dictate the growth of renewable-hybrid markets in developing countries.
4. Improving end-user and vendor access to financing is crucial. High initial costs of renewable technologies are still a major barrier to market growth.

Although these lessons may provide an evaluative framework, there is still a gap between their understanding and their application in real-life scenarios. Further research focused on monitoring economic and social indicators is needed to justify a sustained investment effort into renewable energy sources. Existing studies have mainly focused on the technical aspect of these systems. Impacts on quality of life, income, women's opportunities, education, productive activities, family life and how local institutions can be adapted to support the systems other indicators of social sustainability have not been addressed in these studies. This study will attempt to provide further understanding on these crucial aspects by directly measuring the perceptions of those whose life has been impacted by a hybrid energy system.

III. METHODOLOGY

In order to evaluate the main study objectives, the following research questions were asked:

1. How has the implementation of the renewable-hybrid system positively/negatively affected the productive capabilities and quality of life of the community?
2. What have been the main problems with the system, its implementation and the institutional structures that control it?

To answer these questions, the following hypotheses were formulated: (1) the renewable-hybrid system has positively affected the life of the community by increasing its productive capabilities and quality of life. (2) The system was designed and implemented under sustainable development guidelines.

Background on the Study Area

San Juanico is an isolated fishing community of approximately 95 homes on the west coast of Baja California. It is located about 350 miles north of the southern tip of the peninsula. In addition to being a fishing community, San Juanico also depends on intermittent tourism for a portion of its income. Famous for having the longest wave pipeline in North America, this town (also known as Scorpion Point) becomes the destination to dozens of California surfers every time strong waves are forecasted for the site.

The town is approximately forty five km away from the nearest utility transmission grid. The costs of expanding the grid to San Juanico were and still continue to be prohibitive. It is important to note that prior to the 1999 installation of the hybrid electricity generation system (HEGS), San Juanico had a 13.2 kV, 60Hz distribution grid and was powered by an oversized and outdated 205kW diesel generator which had been supplied free-of-charge by the state government. The generator was connected to a mini grid that only reached a portion of the town's residences. This arrangement was less than optimal for the community, which had to provide the fuel and the upkeep and could only afford to run this diesel system three to five hours a day in the evening, when the load was at its highest. Local businesses had to provide themselves with their own electricity. The local school had no electricity for classes during the day. At one point prior to the installation of the HEGS, there were over 40 small gas and diesel generators in San Juanico. In short, although San Juanico is a very remote community, its inhabitants had already started taking steps, albeit ineffective, to secure electricity supply.

The hybrid power plant in San Juanico was developed as a pilot project under the US Initiative on Joint Implementation, supporting the U.S. National Action Plan on Global Climate Change to reduce greenhouse gas emissions. Several parties contributed to the design and building of the hybrid power plant. The main players included Arizona Public Service (APS), Niagara Mohawk Power Corp. (NMPC), Comision Federal de Electricidad (CFE), Sandia National Laboratory, National Renewable Energy Laboratory (NREL), state Government of Baja California Sur, municipal Government of Comondu, US Department of Energy and US Agency for International Development and the locally formed *Patronato de Electrificación de San Juanico* (hereafter Patronato). APS and NMPC had a central role up to the installation of the system in 1999 as the main sources of finance for the project. In fact, the project is the result of an emission trade between these two companies and executed under a USAID partnership. After the installation their direct participation has waned off, leaving the Patronato with the responsibility of operating and maintaining the system, albeit with some technical support from CFE.

When the system first came fully operational on June 11, 1999, it provided utility-quality, 24 hour electricity to this town of approximately 400 people. The community immediately started sensing the benefits of 24 hour electricity availability. This condition lasted for two years. Unfortunately, the system has not been fully operational since January, 2002. There are several explanations for this, but one stands out the most: the lack of a formal operation and management institution for the San Juanico power plant and grid. Such an institution was originally formed, the previously mentioned Patronato, a locally elected group of individuals that was to take on the responsibility of operating and maintaining the system. Upon being faced with responsibilities they were hardly prepared to undertake, Patronato members slowly started dropping them altogether until a sole member remained at the time of my site visit. The lack of funds, limited communications availability with the outside world and the fact that nobody at the Patronato spoke sufficient English to deal with component suppliers, amongst other practical factors set the stage for nearly no response capability to system component malfunctions.

System Description and Operation

According to the Feasibility Study and Project Implementation Plan prepared by APS and CFE[Johnston, 1998 #69], the power plant is located in a 32,000 sq. meter area on the North West edge of the community. The wind turbines are arranged in two rows of five machines, while the solar array is positioned in the center of the installation on the south side of the control building. All electronics, batteries and generators are contained within the control building.

This generation system replaced the old diesel generator the town used for basic illumination at night. The design of the system included a new 85kW standby generator, ten Bergey 10kW (100 KW) wind turbines and 60 285W ASE- PV panels (17 KW) with a maximum power point tracker. Energy storage is achieved through the use of five parallel banks consisting of 200 Trojan L16 flooded electrolyte batteries (420 kWh) configured for a nominal 240 volts. The system is controlled by a 90Kw TRACE inverter[Bianchi, 1999 #23]. At the time of installation it was expected that at least two thirds of the power generated would come from renewable resources. Table 3 gives a full description and characteristics of the full power plant installation.

TABLE 3. San Juanico Hybrid System Components

Description	Characteristics
Wind Generators	10 units - 10kW each, 240 vca, 3 BWC Excel-R type phases. Includes a BWC-VCS-10 voltage control system.
Photovoltaic Panel	60 units - ASE-30-DG/50, 285 Watts of maximum power, 50.5 Vdc of maximum voltage, 5.9 Adc of maximum amps, 60 V of circuit voltage, 600 Vdc of maximum system voltage (16.8 Kw).
Battery Bank	200 units - Heavy usage, 75 Amps of reserve capacity, for 190 minutes, mounted on 5 sections of 40 units each, Trojan L-16 (420 Kwh).
Inverter / Rectifier	1 unit - Inverter/rectifier, continuous 90 Kva/70kw, 175 KVA for 5 seconds, single with 3 phase bidirectional bridge, 240 volts, 3 strings, 60 Hz, CD buss of 450 Vdc, including a 15 KVA isolated transformer - Trace Technologies
Auxiliary Distribution Transformer	1 unit - auxiliary control transformer, 15 KVA, 240 VCA, delta primary, 208Y/120 VCA, 60 Hz, cat# 15T12H MCA SQUARED.
Diesel Generator	1 unit - 75 KW/90KVA, Diesel generator, 240 VCA, 60 Hz, three phases, model D90P1 (Kohler~80ROZ5).
Control Building	1 unit - Housing and operating building. Walls of 3" diam. Tridipanel and insulpanel 2" roofing
Grounding System	1 lot consists of fencing and cuadricule formation in housing based on 3/0 cable and extended to all equipment components, their connection and fixation to metal structures, metal caging, buried and connected with 5/8"x8' deep metal rods.
Underground System	1 lot - underground system based on canalizations with conduit 2", 3"IPS ced. 40 PVC plastic tubes.
Potable Water System	1 lot - Installation of 1500 lts tank for potable water and sanitary services and generation equipment. Includes full system, pipes, connectors, etc.
Contaminated Water Drainage System	1 lot - Installation of drainage system, including pipes, discharges and storage tank for acid-contaminated water.
Diesel Fuel Storage System	1 lot - Installation of 3500 lt. diesel fuel system, including pipes, connectors, meters, purge piping, tank respiration, all with black carbon steel ced. 80.
Oil Drainage System	1 lot - Installation of gutters and piping for oil discharge, diesel and contaminated waters; includes PVC 2' diam. Pipe, ced. 40.
Septic Tank	1 unit - one sewage deposit tank (drainage).
Sewage Drainage System	1 lot - Installation of piping and equipment for sewage drainage system, to septic tank: includes 2" diameter PVC - ced. 40.

(Source: Comisión Federal de Electricidad, 1999)

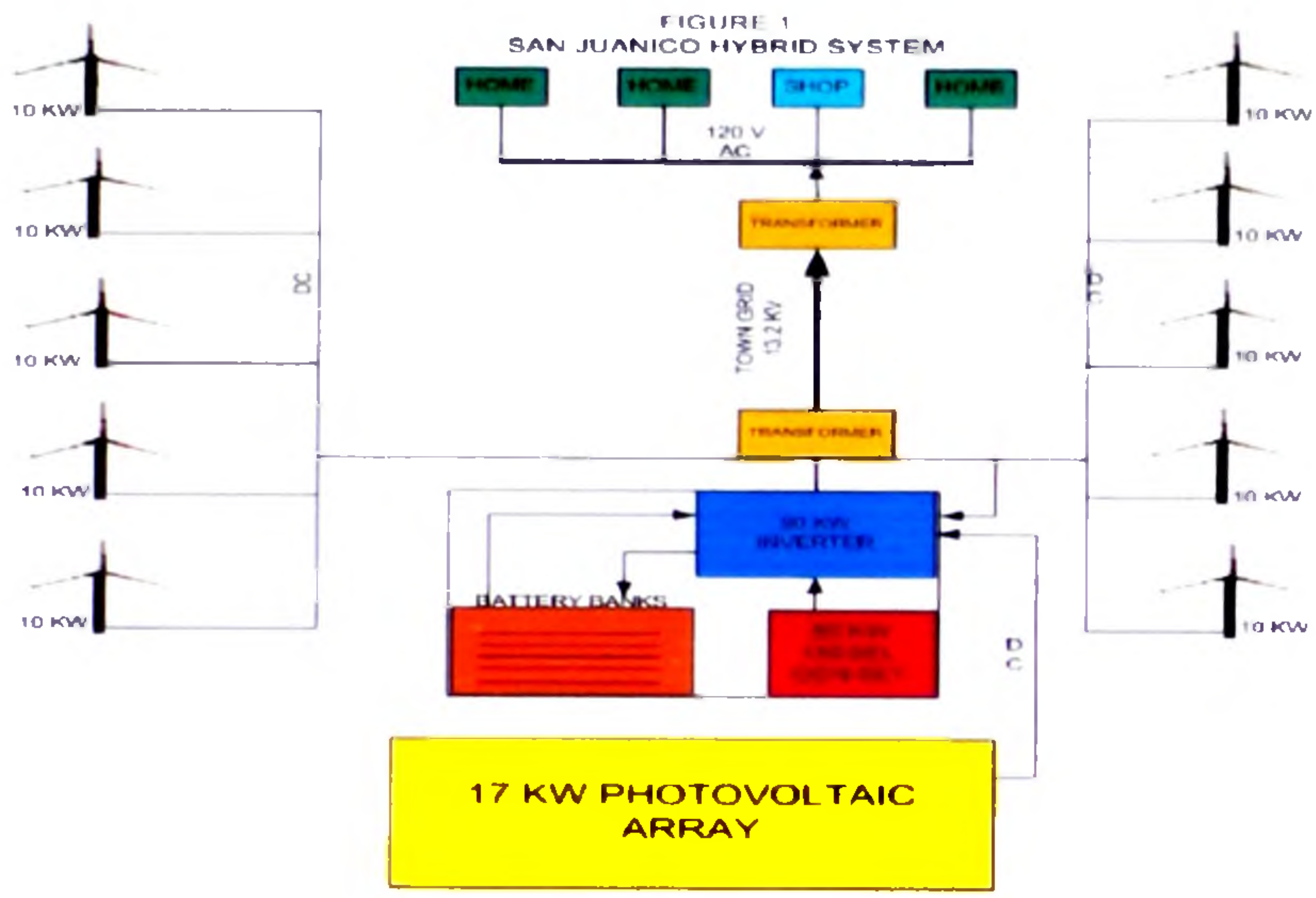
All these equipments are integrated to operate automatically in the following manner: During hours where there is sufficient sunlight and/or wind, electric energy is delivered through the inverter. During this time the diesel generator is kept in reserve. During times when wind or sunlight conditions are low, electric energy is taken from the battery bank and delivered through the inverter as well. The diesel generator only comes into play when both renewable sources or the battery bank can no longer meet demand. As one can plainly see, the proper operation of the inverter is crucial to the plant. This inverter's principal function is to convert 240 Volts of DC power coming in from the wind generators, PV cells or the battery bank into 240 Volts of AC power. Also, the inverter is also the brain of the whole plant since it contains a computerized controller that starts up and stops the diesel generator while monitoring different parameters of equipment operation, most importantly, battery voltage. In order to deliver electricity to the town while maintaining minimum losses along an 800 meter distance between the plant and the town, a transformer in the plant raises the output voltage of AC power from 240 V to 13.2 kV. When it reaches town, another transformer reduces the voltage to 120 V, level at which power is delivered to the homes.

When the diesel plant is in operation, it delivers ac power at 240 Volts through the elevating transformer. This power is used simultaneously to feed demand and to recharge the battery bank. When the battery bank reaches its full charge, the inverter sends a signal to the diesel generator to stop, leaving delivery of power to the inverter. However, the operation of the diesel generator under the hybrid configuration was to be relegated only for back-up to guarantee uninterrupted service. Comparing the performance of different diesel generators, this operation schedule was taken into account to guarantee the optimum efficiency to lower fuel consumption.

After a study of a 24 hour uninterrupted service demand profile was conducted ([Mathai, 1997 #70], the capacity of the diesel generator was established. This is important because the choice of diesel generator directly affects operation and maintenance costs. The more a diesel generator operates outside of its optimum performance range, the more fuel and maintenance costs that will have to be funded. Typical performance for maximum efficiencies are in the 3 kWh/liter range; while performances for 25% of nominal charge can be in the 2 o 1 kWh/liter range. Taking this into consideration, the estimated diesel fuel consumption for the hybrid plant was 19,000 (nineteen thousand) liters per year under a 24 hour a day consumption pattern. This is in striking contrast to the 29,000 (twenty nine thousand) liters per year that the preceding diesel generator consumed for only three hours daily of power. In theory, this represents a 34% savings in diesel fuel consumption. If we were to compare both options (hybrid vs. diesel generator only) under a 24 hour day consumption profile, we would could report a 70% diesel fuel savings ([Mathai, 1997 #70]. The system was designed to deliver power 24 hours a day, 365 days a year, using its wind energy and the excellent insolation levels San Juanico enjoys. According to the CFE, the design of the plant was aimed at it being a self/sustaining installation; that is, the income received from the sale of the energy should be enough to finance its operation and maintenance. Finally, NREL plays a role in monitoring the system through on site Data Acquisition System. The system can record meteorological data as well as system and components data. This data is collected with a

Campbell 23x Data Logger, AM416 multiplexer, Com200 modem and Com100 cell phone [Bianchi, 1999 #23]. At the time of the author's visit, the trace inverter, data loggers and communications equipment were not in functioning order. A recent conversation with Mr. Carlos Sánchez of the CFE revealed that APS had donated a new battery bank, but that the trace inverter was still broken.

Figure 1. San Juanico Hybrid System



Existing Institutional Frameworks

Existing literature described the formation of the previously mentioned community power authority, the Patronato. This organism is a seven community member committee, democratically elected by simple majority. Its main functions are the monthly billing of electricity, the procurement of diesel fuel and spare parts, the operation and maintenance of the hybrid system and general upkeep of installations.

Information found in existing literature and received in conversations with CFE representatives and Patronato members indicates that CFE plays a technical supervision role. However, during the planning stages of the hybrid plant, CFE was in charge of the construction plans and execution, and the design of the energy price structure. This structure was one which considered the dangerous possibility of a rapid expansion in the load. In an attempt to exercise demand side management (DSM), the CFE designed the pricing structure so as to create incentives for curbing amounts of electricity used at home and in businesses. This structure only takes into account electricity used. The existing tariff structure is defined as follows in Table 3[, 1998 #58]:

Table 4. 2002 Electricity Prices for San Juanico Hybrid System

Consumption Ranges	**Tariff (Pesos)**
1 - 33 kWh	1.45
34 - 66 kWh	1.55
67 - 100 kWh	1.65
101 - 150 kWh	1.85
151 - 200 kWh	2.05
201 - 300 kWh	2.25
301 - and beyond	2.45

(Source: CFE)

Finally, the National Renewable Energy Laboratory (NREL) plays an evaluatory role by collecting data sent by the system's inverter modem. NREL collects data on site resources (wind, irradiation, temperature, etc) and system performance (generation by source, battery bank condition, etc).

Research Approach

Socio-Economic Effects

A survey akin to a consumer satisfaction survey measured household impressions of the system within the receiving community. The survey was geared and designed toward the measurement of the system's social contributions in terms of institutional and social factors. It detected if the system is socially acceptable, its range of usage characteristics, life improvements, effects on employment, leisure, access to education, entertainment, health, women's activities and the level of involvement of the community in the installation and maintenance of the system. It also measured the perceived reliability of the system by the community. The statistical analysis was conducted using the computer software package SPSS for Windows. The main objective was to evaluate the functioning and the effects, both positive and negative, the HEGS has had on the community. Another principal aim of the survey was to determine the image the HEGS has with this community. Ninety one electricity receiving homes were interviewed for the survey. These homes represent nearly the total amount of homes that receive electricity from the HEGS, so this constitutes a census of nearly all users. There are approximately one hundred and fifty (150) homes in San Juanico, so it was not difficult to survey only those receiving electricity from the HEGS. Homes that do not receive electricity from the HEGS provide themselves with it through privately-owned gasoline generators or, in the case of the poorer members, simply do not have electricity. Only members that lived full time were considered. The town is divided into blocks, so this survey was started the survey at the North-East corner of town and proceeded up and down the North-South oriented streets taking the survey door to door. Selection of the person to be interviewed within the homes was done at random, with the only consideration that they be eighteen (18) years (legal age in Mexico) or older. This method was employed given time limitations and could have introduced bias in respondents answers based on the percentages of respondents in different demographic categories. The survey could not be applied to the totality of homes receiving electricity from the HEGS since five (5) homes turned down the interview. The interview itself was conducted face to face and had an average duration of five (5) to seven (7) minutes. The maximum estimated error is plus/minus seven point seven percent (+/-7.7%) at a ninety percent (90%) confidence interval. Mr. Hector Soubervielle, actuary and poll specialist in Mexico City, reviewed final survey results and offered comment based on his professional expertise. His main comments are in relation to the household income question of the survey. His explanation is described in the results section.

Employment of Probit Model for Survey Results

Survey data was ordered and analyzed utilizing a probit binary choice model. This type of model is used to determine the probability that an individual with a given set of attributes will choose one or another alternative. It determines if variables are related, to predict the expected frequencies of a dependent variable, to understand the relative importance of different independent variables in predicting a dependent and to confirm models using a goodness of fit test. Probit regression is an alternative to log-linear approach for analyzing dependent variables in a normal distribution. The form of the model involves the dependent variable assuming a binary response which takes values of 1 and 0. Two dependent variables were considered for this model:

FAIRPRIC = Likelihood that an individual thinks he or she pays a fair price for the electricity provided by the hybrid energy system. Acceptance of fair pricing by poor rural communities is essential for system sustainability. If those receiving energy from these systems don't consider the price fair, system failure is guaranteed.

WTPPRICE = Likelihood that an individual would be willing to pay a higher price for electricity if the hybrid energy system were reliable. Willingness to pay is recognized as a fundamental aspect for the sustainability of any system. If people are not willing to pay, it sends a clear signal about any particular product's or system's ability to satisfy consumer's needs. Independent variables considered for this model were as follows:

SYSBEN = this variable is a combined score of total qualitative benefits that an individual experienced from all the positive aspects of the system. If this figure is high, a given individual may tend to recommend the system to others and pay a higher price for electricity. Hence, it is expected to have a positive association with the dependent variables. These benefits include:

LEISMORE = Percentage of respondents who thought they experience more leisure time since the installation of the hybrid electricity system.

ENTRMORE = Percentage of respondents who thought they experience more entertainment since the installation of the hybrid electricity system.

WRKLTIM = Percentage of respondents who thought they carried out more work in less time since the installation of the hybrid electricity system.

REVNMORE = Percentage of respondents who thought they experienced a higher income since the installation of the hybrid electricity system.

HELTMORE = Percentage of respondents who thought they experienced a better access to health services since the installation of the hybrid electricity system.

EDUNMORE = Percentage of respondents who thought women experienced better access to education since the installation of the hybrid electricity system.

WORKMORE = Percentage of respondents who thought women experienced better access to job opportunities since the installation of the hybrid electricity system.

COMMECOM = Percentage of respondents who thought the system improved the community's overall economy.

BUSSREV = Percentage of respondents who thought they experienced a higher revenue at business since the installation of the hybrid electricity system.

Each of the above benefit variables was given a score of "1" if the respondents agreed they had received the benefit and a score of "0" if they had not. Then, the SYSBEN was computed as the sum of all the individual benefit variables.

COSTLIV = Percentage of respondents who thought they experienced a lower cost of living since the installation of the hybrid electricity system. Given extremely limited economic resources in poor rural communities, decreasing the cost of living is often regarded as a development item of major importance. This variable is expected to be positively related to the dependent variables.

SYSINFO = Percentage of respondents that thought information on the hybrid system was always available to community members. Often, community projects lack the necessary transparency to gain social acceptance. This variable is expected to be positively related to the dependent variables.

FAILFIX = Percentage of respondents that thought authorities took immediate action to fix the hybrid system when it failed. Often, remote community projects are not supported and go for long periods of time unrepaired. This variable is expected to be positively related to the dependent variables.

LIFEEASY = Percentage of respondents that thought life was generally easier since the installation of the hybrid electricity system. Given that activities in poor remote rural communities are often manual and physically straining, any improvement in making activities easier is well regarded. This variable is expected to be positively related to the dependent variables.

FAMSIZE = Family size. This variable is expected to be directly related to the dependent variables.

EDUCAT = Level of education.

INCOME = Level of yearly income.

GENDER = Gender of respondents.

Electricity Price Comparison Analysis

In order to assess the economic environment in which the HEGS must operate and justify its costs, a CFE tariff (cost per kilowatt-hour) and avoided cost analysis for the interconnected grid of the CFE was conducted. This analysis aims to answer the following question: Are the prices paid by the hybrid energy system customers competitive with CFE rates? To do so, historical CFE tariff and avoided cost data was collected using internet access to information provided by the CFE.

The focus of the analysis was based on tariffs charged to "Industrial Users" . The tariff is identified as TARIFF HS. This choice of tariff was selected because it is the tariff that is less impacted by subsidies and other market distortions to which domestic tariffs are subject. Furthermore, the analysis only included industrial tariffs in the transmission area of the state of Baja California. This state lies directly north of the state in which the HEGS is located (Baja California Sur). This state was selected because it is the state with the highest costs of electricity in Mexico, in terms of tariffs and in terms of avoided cost. The main justification for this choice is that the comparison of the CFE's worst case operating scenario, in terms of costs, should provide a good measure of competitiveness for the HEGS, should the option of building transmission to San Juanico be considered in the future.

Historical tariff data for base, intermediate, peak and semi-peak periods was collected from the CFE webpage. The tariffs data was available for the period 1997 through 2004. The data for Avoided Cost was for the period July 2003 to July 2004. This data was then structured into data matrixes for each year by month and time of day. Monthly and yearly averages were taken for convenience of data handling and were plotted on graphs showing the behavior of tariff growth over time. Also, after taking the CFE tariff data (cost per kilowatt-hour of energy in each billing period: base, intermediate and peak) and obtaining monthly weighted average costs, data relevant to Billable Demand (fixed cost charged by the CFE to customers based on the amount of capacity reserved for each load in kilowatts of capacity) was taken for the same years. The Billable Demand component is factored into the final price of energy. This data was combined into a formula that is representative of the procedure that CFE employs to bill customers. The results allow us to compare the price of energy paid by the hybrid system customer with regards to the most expensive price of CFE's grid.

Institutional and Managerial Framework Observations of the Hybrid System

Information referring to the challenges existing institutional and managerial frameworks had to deal with was obtained and documented through informal surveys of San Juanico residents, informal conversations with CFE engineers, informal conversations with NREL staff, literature review and personal observations. Amongst these last ones, several telling aspects of the operation of the hybrid energy system provide obvious clues as to why the system has not been reliable. Informal interviews with local residents provided important information on the general context in which the hybrid system had to perform, and more specifically, several underlying reasons as to why it failed. They also provided information as to how the energy was used towards productive activities. One of these informal interviews with the head of the Patronato, yielded surprising information as to the allocation of responsibilities. Specifically, the person chosen to be in charge of the day to day operation of the system was the local "electrician". As explained to this author, this man was the only resident with any experience in repairing electrical apparatuses, this being the principal reason for which he was chosen for the task. However, further inquiries on this man revealed he had barely any formal technical background. To make matters worse, he was a dysfunctional alcoholic that being incapacitated in many occasions, would send his fourteen year old daughter to check on the plant (battery bank temperatures, inverter readings, diesel and oil for the genset, etc). This version of the facts was confirmed by several other residents. Under these operation conditions, it is no surprise that the system failed.

Other informal interviews with the three local shop-keepers revealed that this particular activity had greatly benefited from electricity availability. Namely, the ability to refrigerate goods allowed them to offer customers more goods than before. However, all three indicated their increase in profits had been directly related to an approximately three-fold increase in sales of cold beer. This is interesting in as much as the hybrid system really only allowed few residents to increase their profit at business (shop-keepers), while providing a well-appreciated service (cold-beer) that is generally not seen as a contributor to productivity. Many remote rural communities in Mexico suffer from a high incidence of alcoholism. The possibility that a hybrid energy system may indirectly exacerbate this issue is an unforeseen consequence of its installation. Informal interviews with local CFE engineers in charge of monitoring and providing technical oversight to the system yielded useful information. They mentioned their commitment to the plant, but found it very hard to manage given the managerial structure the system was operated under. The main difficulty they encountered was a chronic lack of budget to resolve operational issues. This lack of funds limited their ability to fix the system in a permanent manner and forced them to continuously provide short-term fixes that would ultimately prove insufficient. This characteristic is one of the most telling signs for failure and will be discussed further in the next chapter.

Finally, informal interviews with American part-time residents revealed another interesting aspect of how the hybrid system was deployed. The vast majority American part-time residents who owned property in San Juanico elected not to be connected to the system. This decision was based on several reasons. At meetings held between system developers, residents and non-residents before the installation of the system, many local residents felt American part-time residents should pay a higher price for energy. This discrimination was clearly not well-appreciated by the latter group and in essence, isolated them from the project as a whole. This discrimination provoked an enormous lost opportunity while exacerbating the "haves" and "have-nots" division in the town. Had an equal treatment been promoted since the beginning of the hybrid project, the opportunity of having English-speaking people with higher degrees of education and ability to travel back and forth often from the United States (where most components of the system came from) actively involved with the system would have given the system a better chance of succeeding. At the time of these informal interviews, most of these non-residents powered their homes with small gasoline gensets.

IV. RESULTS

To establish the larger socio-demographic context in which the survey sample was collected, I have included information from the latest national census which was taken in the year 2000. This information will be useful to provide an official reference point when measuring socio-demographics in the study area. According to the XII Censo General de Población y Vivienda 2000 (CGPV) (National Census), San Juanico is found in the Municipality of Comondu, number one of Baja California Sur. Also according to the census, the reported total population of San Juanico was 357 people. The data from table 5 and figures 2, 3 and 4 was taken from the 2000 National Census (CGPV, 2000):

Table 5. General Information about San Juanico, BCS, Mexico

Total population	357
Total homes	87
Average household size	4.1
Number of homes with elec.	74 (85% of total)
Number of homes with TV	65 (75% of total)
Number of homes with fridge	46 (53% of total)

Table 5. General information about San Juanico, BCS, Mexico
Source: XII Censo General de Población y Vivienda 2000

Figure 2. Age distribution of San Juanico Population

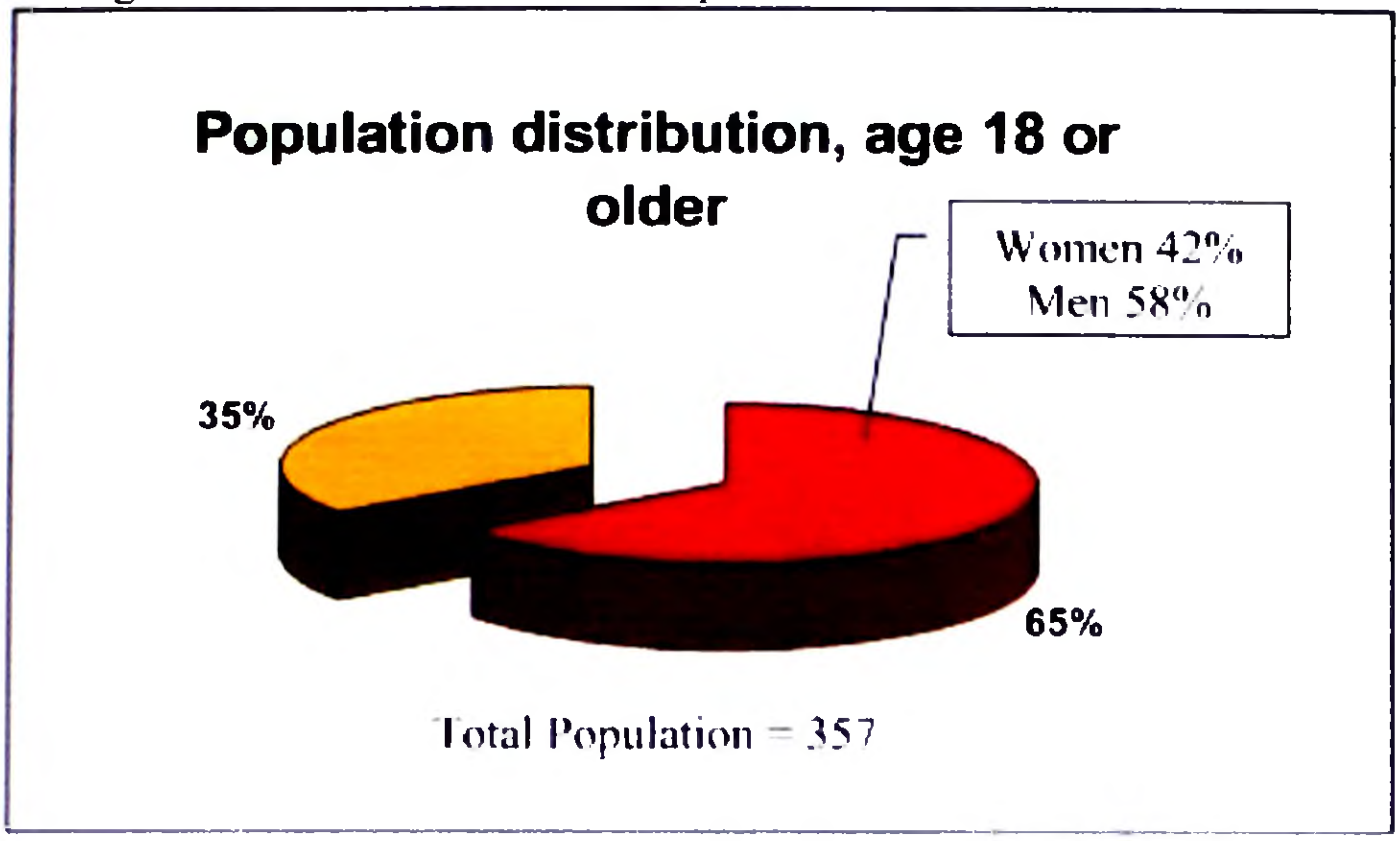


Figure 2. Age distribution of San Juanico Population

Figure 3. Gender Classification of San Juanico Population

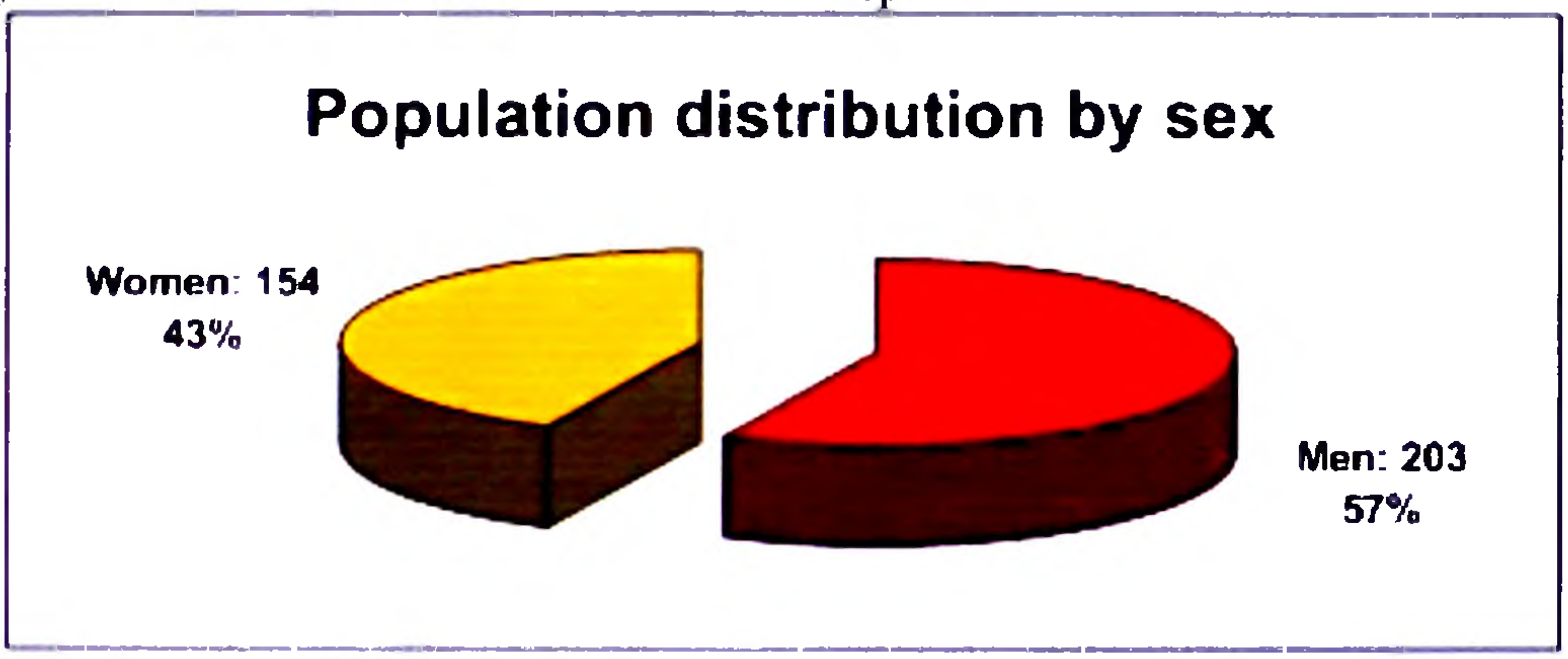


Figure 3. Gender Classification of San Juanico Population

Table 6 presents numbers of homes with different sizes. The average household size was 4.14 while the median size was 4. About 8.8% of the households had only one member. The most percent of houses (23.1%) had five people living in the house.

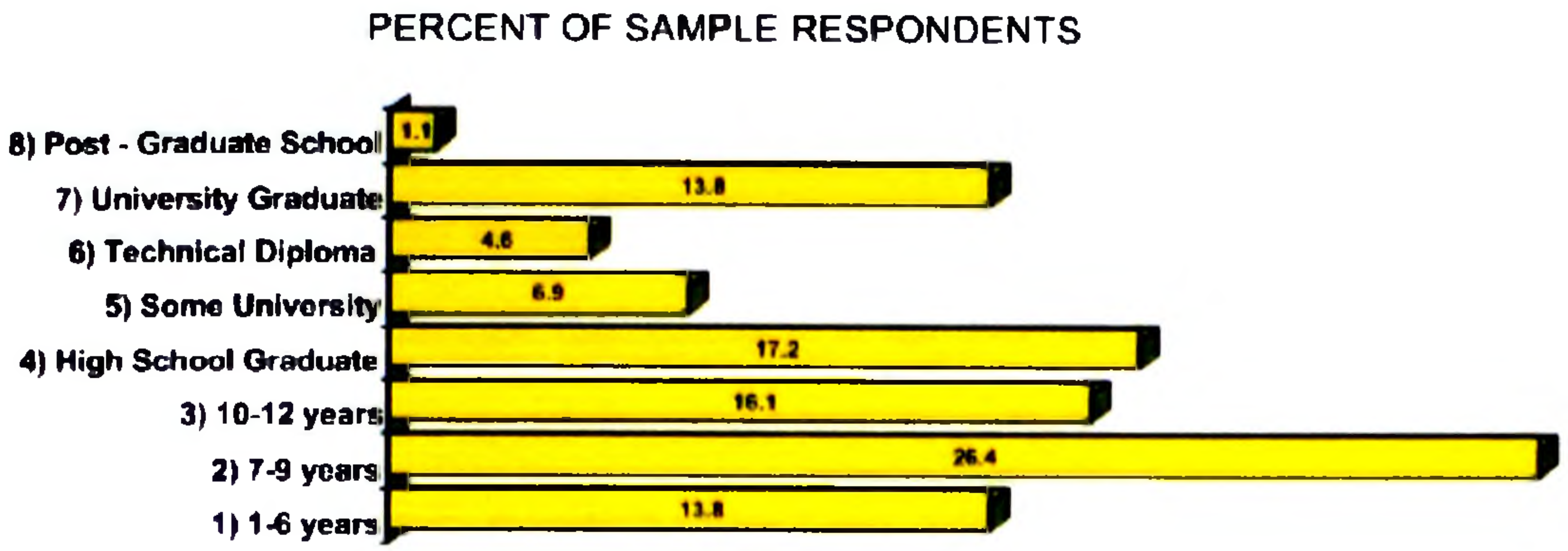
Table 6. Distribution of homes in San Juanico by household size

Table 6. Distribution of homes in San Juanico by household size

Number of people	Porcentage of homes
1	8.8
2	12.1
3	15.4
4	18.7
5	23.1
6	13.2
7	6.6
8	1.1
9	0
10	1.1
Average	4.14
Median	4

The next question asked was the level of education the respondents to the survey had completed over their life time. The levels of education were placed in the intervals of 1 - 6 years, 7 - 9 years, 10 - 12 years, high school graduate, some university education, technical diploma, university graduate or post-graduate education. The level of education each individual has attained helps determine the quality of answers given to some important questions. It is also a rough indicator of the quality of life respondents enjoy. Figure 4 displays the results of this question. The most respondents (26.4%) has completed 7-9 years of school. About 17.2 % of them had actually completed high school. About 25% of the sample respondents had college or technical education.

Figure 4. Level of education attained by sample respondents in San Juanico

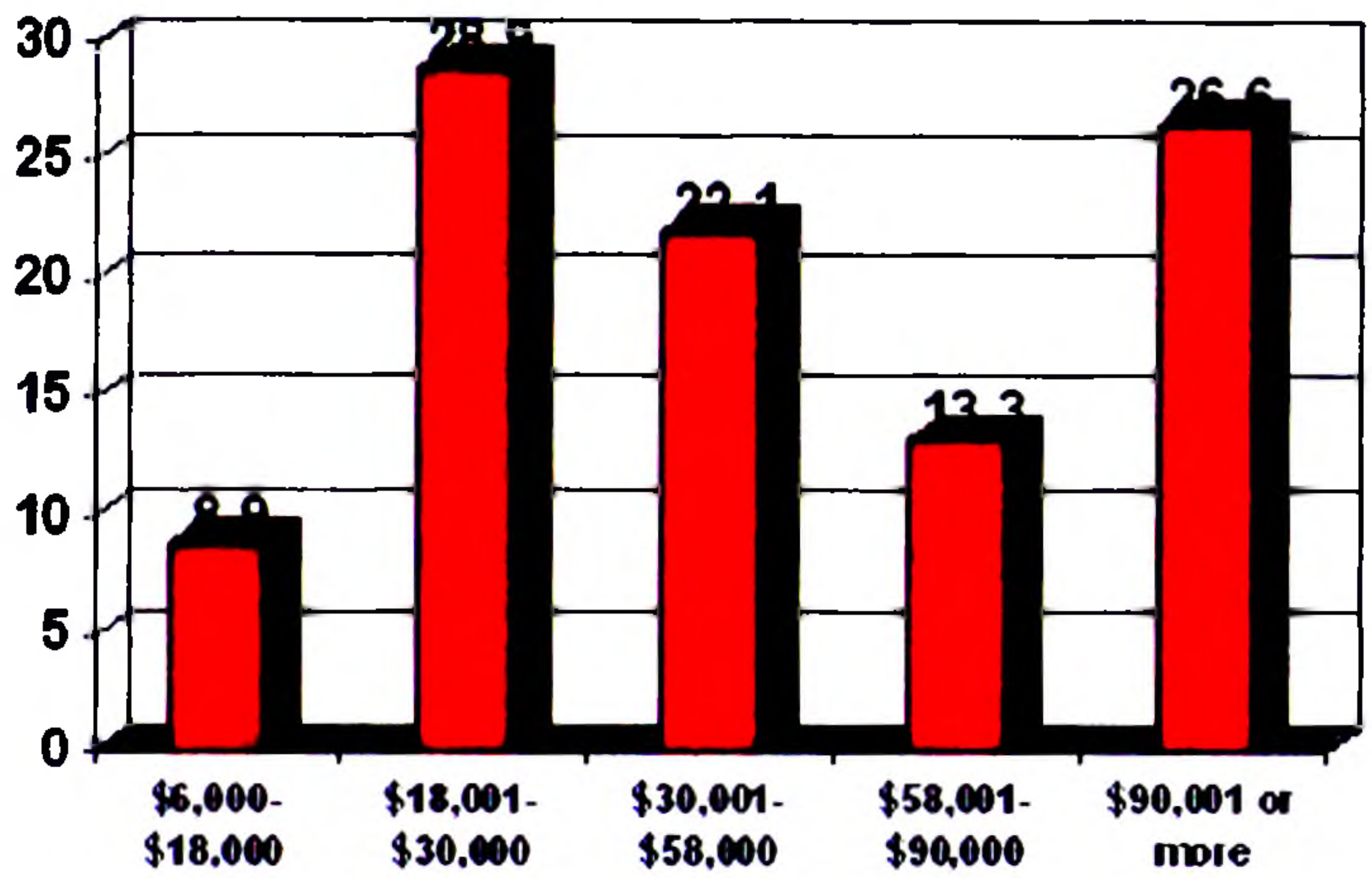


Base =91 interviewed
What is the highest level of education held by any member of your family?

FIGURE 4. Level of education attained by sample respondents in San Juanico

The next question relates to the level of income respondents enjoy. Mr. Hector Soubervielle made it clear the format of this question was inaccurate for surveys conducted in Mexico. According to Mr. Soubervielle, it is common for surveys conducted in the United States to include a similar question to the one found in this survey regarding income. Furthermore, it is very common for people in the United States not to be threatened by this question and to be absolutely aware of their income level. This is not the case in Mexico and other developing countries. The National Census estimates income levels using formulas where the results of several questions are computed to yield an approximate result. Questions used in these formulas are commonly the number of bathrooms a house has, the number of light-bulbs and other indicators that are analyzed in these formulas to get an accurate read on income. In essence, the following results could introduce a bias in analysis since in most cases, people are not expected to know their income level and some, are hesitant to share the correct answer of a direct income question with strangers. Figure 5 presents the distribution people by income level, in Mexican Pesos. Roughly 29% percent of respondents thought they belonged in the $18,001-$30,000 income bracket, while about 27% of respondents thought they belonged in the $90,000 or more income bracket. About 60% of sample respondents earned less than $58,000 in the year 2001, while nearly 40% of respondents thought the earned more than $58,000 during the same year.

Figure 5. Percent Distribution of the Sample by income level in San Juanico



Base =45 interviewed, 46 of those interviewed answered "Don-t know"
In which of these groups did your total family income, from all sources, fall last year, 2001, before taxes, that is?

Figure 5 Percent Distribution of the Sample by Income Level in San Juanico

This survey was conducted over a total of ninety one (91) homes with electricity and we know that eighty five percent (85%) of homes within the community have electricity (2000 National Census): estimated homes with electricity = 91/(0.85)=107. If we have a total estimate of 107 homes and an average of 4.1 habitants per home, then: estimated number of inhabitants: 107*4.1=443. If we have an estimated total of 443 inhabitants and we know that 65% of the population is of 18 years of age or older then: estimated number of inhabitants that are 18 years of age or older: 443*0.65=288. These results are remarkably close to those found in the 2000 national census. In conclusion, all statistical estimations will be based taking into account an estimated total of 107 homes, an estimated total of 443 inhabitants and an estimated total of 228 people that are 18 years of age or older within the Community of San Juanico. So, taking into account the natural distributions of the sample, the population distribution for people of 18 years of age or older by sex and level of education is the following:

Estimated pop. 18 years or older	**288**
Pop.18 or more men (58%)	167
Pop.18 or more women (42%)	121
Pop. 18 or more w/elec. (85%)	**245**
Pop. 18 or more w/elec. men	142
Pop. 18 or more w/elec. women	103
Pop. 18 or more w/elec. mid. school	105
Pop. 18 or more w/elec. some/Univ.	78
Pop. 18 or more w/elec. Univ. or more	62

Table 7. Distribution of Sample by gender and education

Estimated pop. 18 years or older	**288**
Pop.18 or more men(58%)	167
Pop.18 or more women(42%)	121
Pop. 18 or more w/elec. (85%)	**245**
Pop. 18 or more w/elec. men	142
Pop. 18 or more w/elec. women	103
Pop. 18 or more w/elec. mid. school	105
Pop. 18 or more w/elec. some/Univ.	78
Pop. 18 or more w/elec. Univ. or more	62

Table 7. Distribution of Sample by gender and education.

Another question included in the survey was aimed at determining the average number of several electrical apparatuses in each home. The results of this question can be interpreted as indicators of quality of life, as the effects of owning these electrical apparatuses influence people's lives, their time usage and level of physical effort in accomplishing different tasks in and around the home. Also, in the case of radios and televisions, people's lives are affected by entertainment and education. This is especially the case in remote rural communities in Mexico, where it is often the case their main source of formal education emanates from state-sponsored televised primary, middle and high-school level daily classes. Figure 6 shows the main findings of this analysis.

Figure 6. Percentage of Sample homes with electrical apparatuses

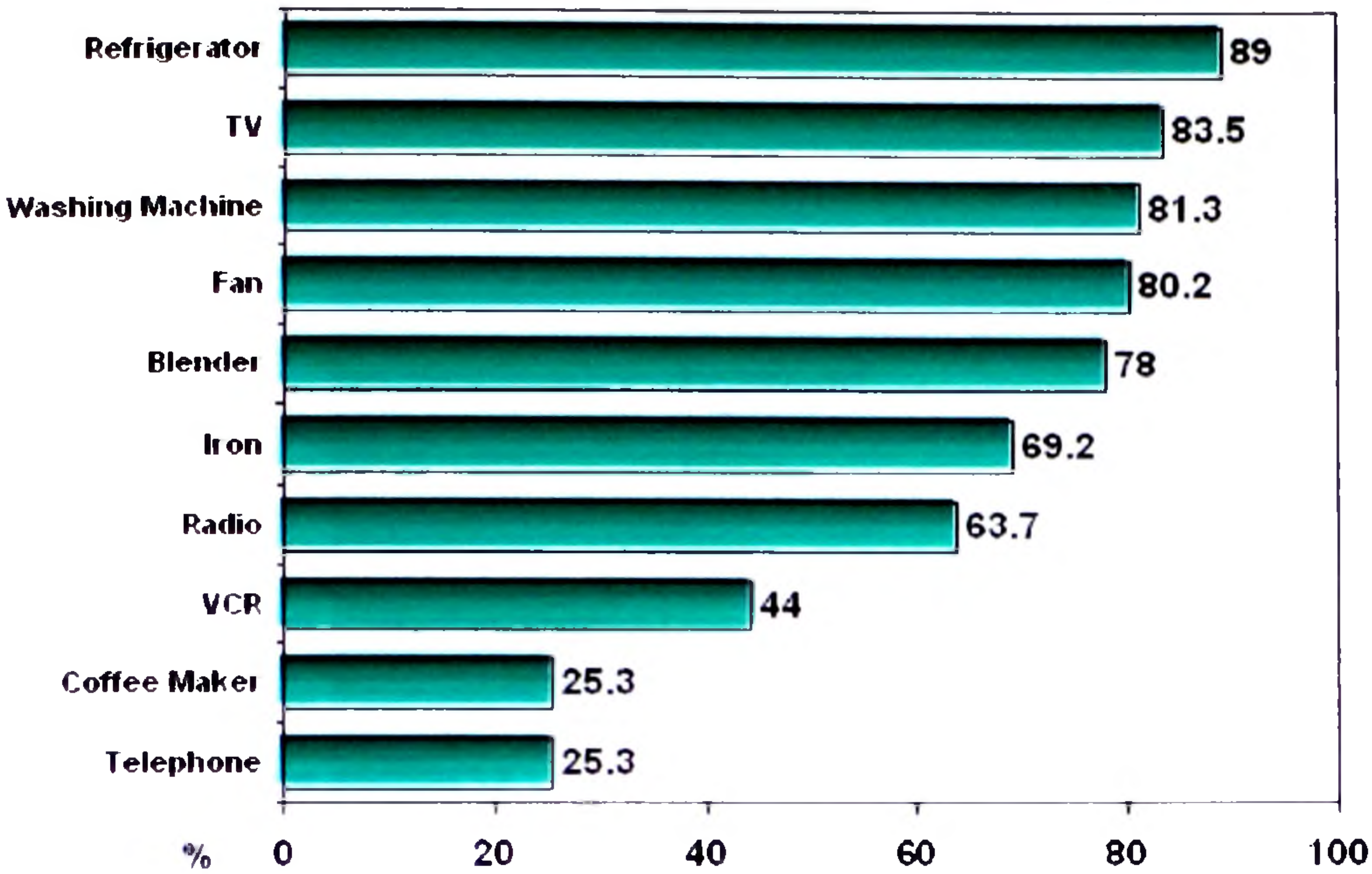


Figure 6. Percentage of Sample Homes with Electrical Apparatuses

Approximately 4 out of every 5 homes use a refrigerator, TV, washing machine, fan and blender while 2 out of every 3 own an iron and a radio. The most indispensable electrical apparatuses seem to be strongly present amongst San Juanico homes. Specially refrigerators, which indisputably increase quality of life by allowing for safe preservation of food, and fans, which help ameliorate the high temperatures people must endure living on the west side of the Baja California Peninsula.

Figure 7 shows the less significant results of the last question regarding electrical apparatuses found in San Juanico homes. It is important to signal out that most of these items, while considered essential in developed countries, are regarded as luxuries in developing countries like Mexico and specially so in rural settings. Therefore, these items were used less frequently in the sample household.

Figure 7. Percentage of Sample homes with electrical apparatuses

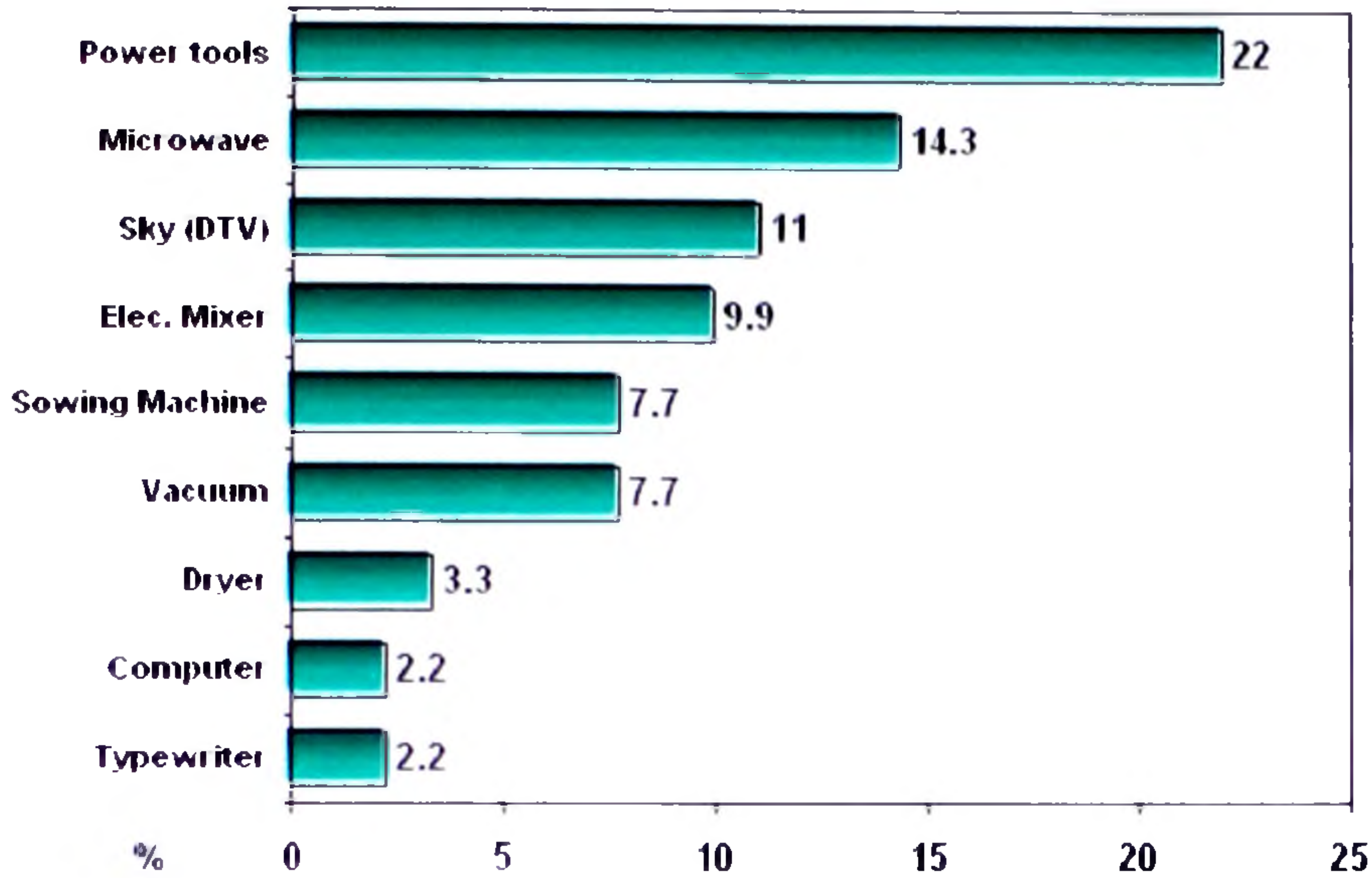


Figure 7. Percentage of Sample Homes with Electrical Appartuses

Effects of the Renewable - Hybrid System on the Community Lifestyle

The next set of questions has more qualitative value regarding a social evaluation of the HEGS in San Juanico. These questions were designed and geared toward understanding the actual impacts the HEGS has had in the community members' lives. Survey respondents were asked specific questions regarding the impact of the HEGS on their usage of time, their family time, their access to entertainment and education, amongst others, and were given the answer options of agree, disagree and uncertain. This set of questions has proven to be a central piece in the development of credible reasoning to support the first hypothesis of this study: the renewable-hybrid system has positively affected the life of the community by increasing its productive capabilities and quality of life. These questions allow us to gauge how it has positively affected life and productive capabilities. Figure 8 summarizes the results:

Figure 8. Sample agree responses about impact of hybrid system on community lifestyle

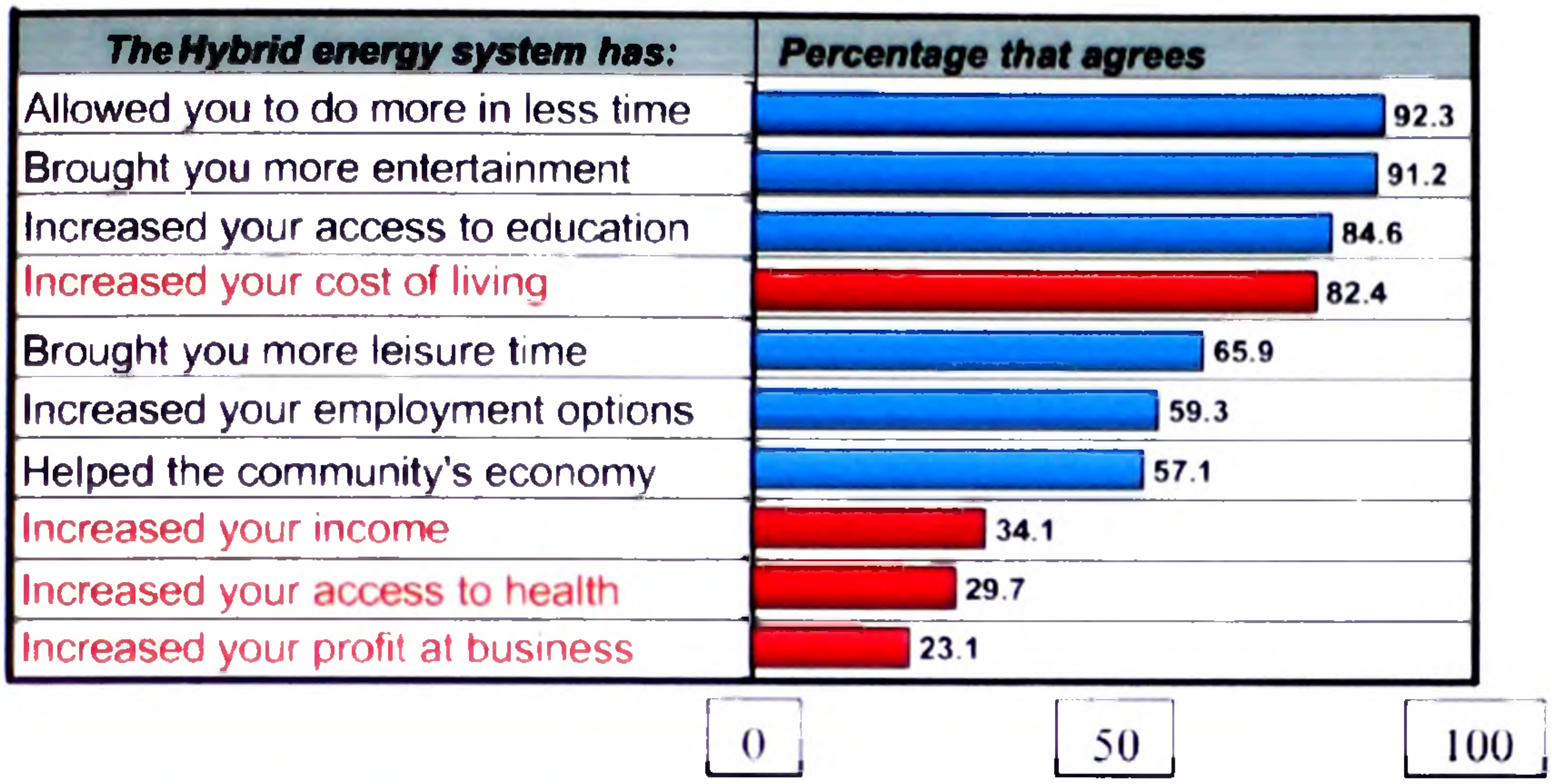


Figure 8. Sample Agree Responses about impact of Hybrid System on Community Lifestyle

The blue percentage bars represent agree responses while red percentage bars represent disagree responses. According to the respondent sample, at least 4 out of every 5 were in agreement with the statement: "the hybrid energy system has allowed you to do more work in less time", especially women. The same can be said of the statements: "the hybrid energy system has "brought you more entertainment" (91.2%) and "increased your access to education" (84.6%). Approximately 3 out of every 5 respondents thought that the hybrid energy system has "brought you more leisure time" (65%), "increased your employment options" (59.3%) and "helped the community's economy" (57.1%). By looking at the "disagree" responses, we can conclude that even if the hybrid energy system has provided some advantages, such as leisure, access to education and better time efficiency in conducting several activities, it was also perceived as responsible for "increasing the cost of life" (82.4%). Another important observation is that the hybrid energy system "has increased your income" (34.1%), and it was perceived amongst very few that the hybrid energy system has "increased your profit at business" (23.1%). In conclusion , the hybrid energy system has provided savings in time utilized performing everyday chores, brought more entertainment and increased access to education, but all of this came with a cost that was not reflected in the community's income or in an increase of profit in businesses. This last observation is best explained by the fact that electrification was geared towards households rather than to serve specific productive activities the community's members are involved in.

To further understand the value of the above responses, an analysis of the actual respondents was undertaken, by gender and level of education. This was performed in order to better understand who exactly perceived the advantages and disadvantages the hybrid energy system was providing. Significant differences were searched and, where possible, measured and registered. However, because of the small sample size, few significant differences were observed between genders and even less so by level of education. The results of this analysis can be found in table 8.

Table 8. Percentage agree responses by gender and level of education in sample

Table 8. Percentage Agree responses by gener and level of education in sample

The HEGS has...	Tot	Gender		Level of education...		
Percentage that is in Agreement		Men a)	Women b)	7-9 c)	Some univ d)	Univ. or more e)
Base	***91***	***50***	***41***	***39***	***29***	***23***
Allowed you to do more work in less time	92.3	88.0	97.6a	97.1	89.7	87.0
Brought you more entertainment	91.2	90.0	92.7	94.3	82.8	95.7
Increased your access to education	84.6	86.0	82.9	80.0	93.1	78.3
Increased your cost of life	82.4	80.0	85.4	91.4e	82.8	69.6
Brought you more leisure time	65.9	62.0	70.7	62.9	65.5	65.2
Increased your employment options	59.3	52.0	68.3	62.9	48.3	65.2
Helped the community's economy	57.1	52.0	63.4	54.3	55.2	60.9
Increased your income	34.1	36.0	31.7	34.3	27.6	39.1
Increased your access to health services	29.7	30.0	29.3	17.1	41.4d	34.8
Increased your profit at business	23.1	26.0	19.5	25.7	20.7	17.4

1. Values in the Total column are for the entire sample.
2. The letters a/b/c/d next to the percentages indicate significant differences with the columns assigned to each letter, based on the t statistic with a confidence level of 90%.

The system seemed to have allowed significantly more women than men to do more work in less time. Since women do more house chores than men in the Mexican culture, a system supplying power for household needs touches the life of women more than that of men. The system also seemed to have increased the cost of living more for people with lower levels of education than that of people with higher levels of education. This is best explained by the high possibility that people in rural communities with higher education have higher incomes. Given this assumption, electricity bills comprise a smaller percentage of overall yearly expenses for this group than that with lower education levels, who will be directly impacted by any price fluctuation in this expenditure. The next set of questions set out to observe the intensity of repercussions the HEGS has had amongst community members in several areas of everyday life. A set of measured responses were given as answers. Examples of the possible answers include: "much more", "bit more", "the same", "a bit less" and "much less". Possible answers range from the most to the least in each subject area. According to those surveyed (Figure 9), a little more than 60% answered they spend a bit less or spend much less time doing household work. The reductive effect on time spent doing household work was perceived to be moderate. Finally, there does exist one third of those who answered who do not perceive any difference in time spent doing household work whatsoever.

Figure 9. Sample responses by provided answer to household work time usage

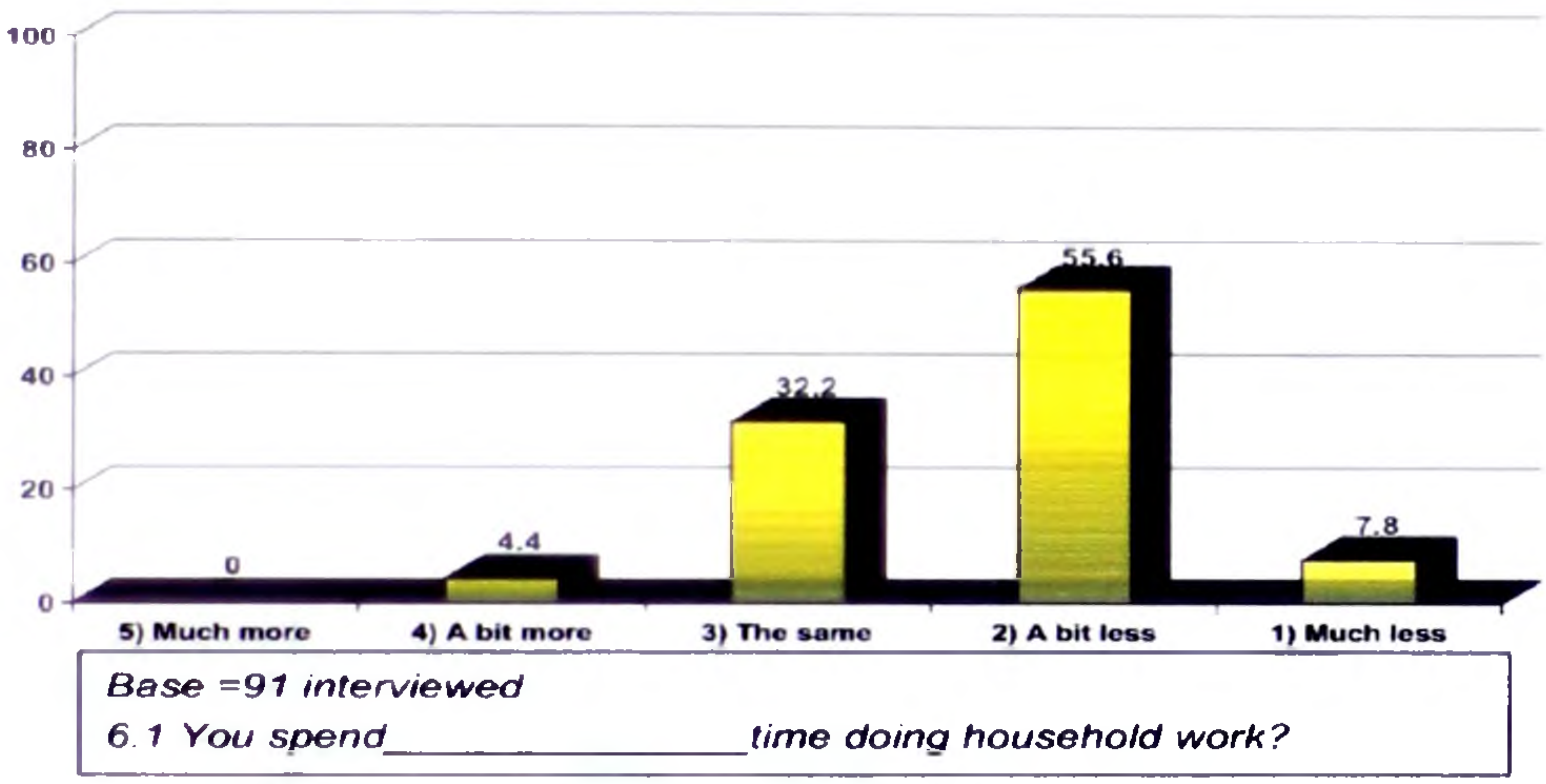


Figure 9. Sample responses by provided answer to household work time usage

A t-student distribution was used to find significant differences in responses to the question above. The letters a/b/c/d/e located next to the percentages indicate significant differences with the columns assigned to each letter, with a confidence interval of 90%. Table 9 summarizes these findings.

Table 9. Percent of people spending much more or a bit more time doing household work

Table 9. Percent of people spending much more or a bit more time doing houshold work					
Total	**Gender**		**Level of Education**		
	Men a)	Women b)	7 - 9 c)	Some Univ. d)	Univ. or more e)
91	***50***	***41***	***39***	***29***	***23***
4.4%	6.1	2.4	5.7e	6.9e	0.0

The next question relates to the amount of time families spend together after the installation of the hybrid electricity system. This question is aimed at determining if family interaction patterns in everyday life have changed with the electrification of the town. In essence, do people spend more quality time with their families because their homes are illuminated at night or not. The question was asked as follows: "You spend______time with your family?" Figure 10 describes findings to this question.

Figure 10. Sample responses by provided answer to time spent with family

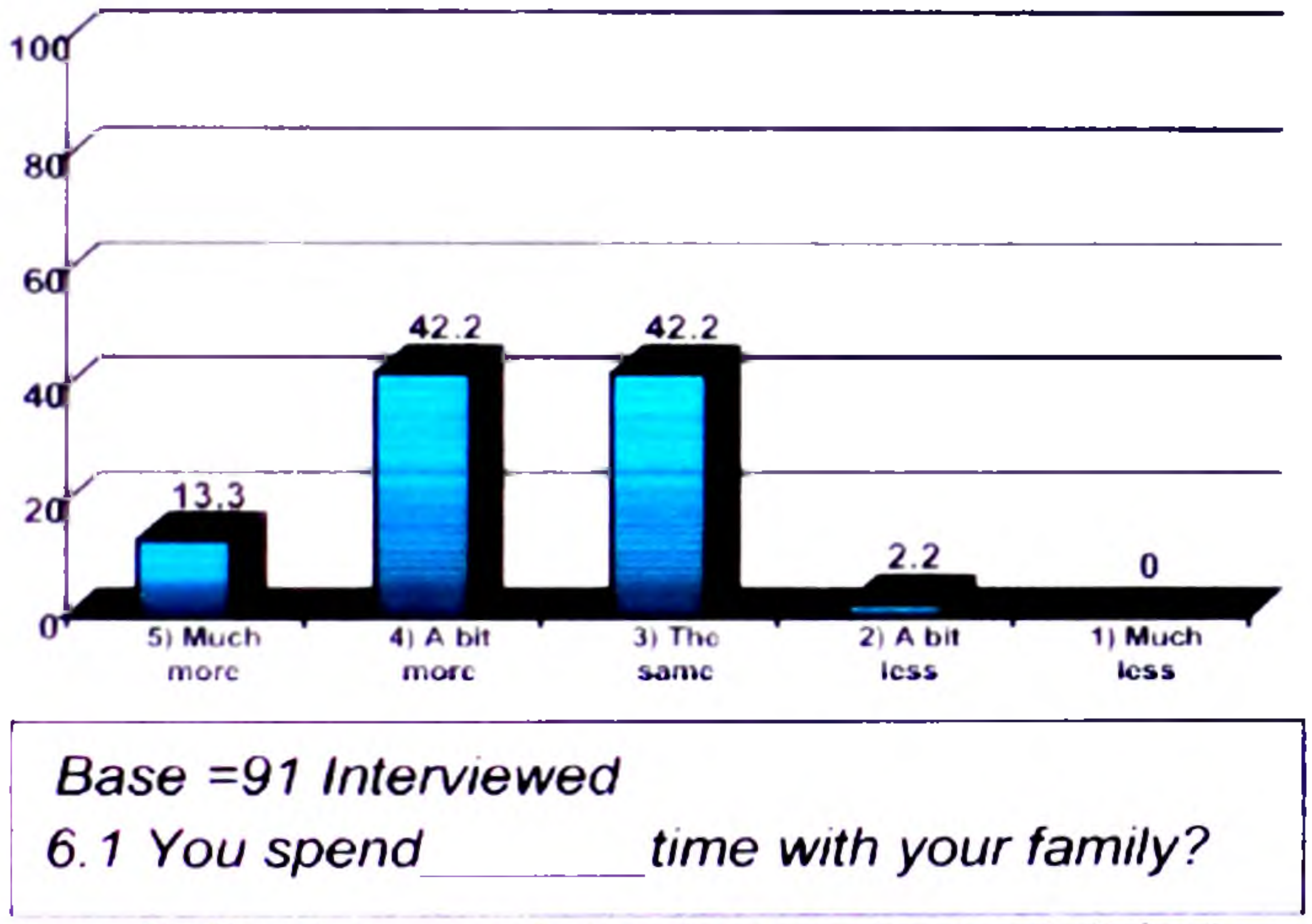


Figure 10. Sample responses by provided answer time spent with family

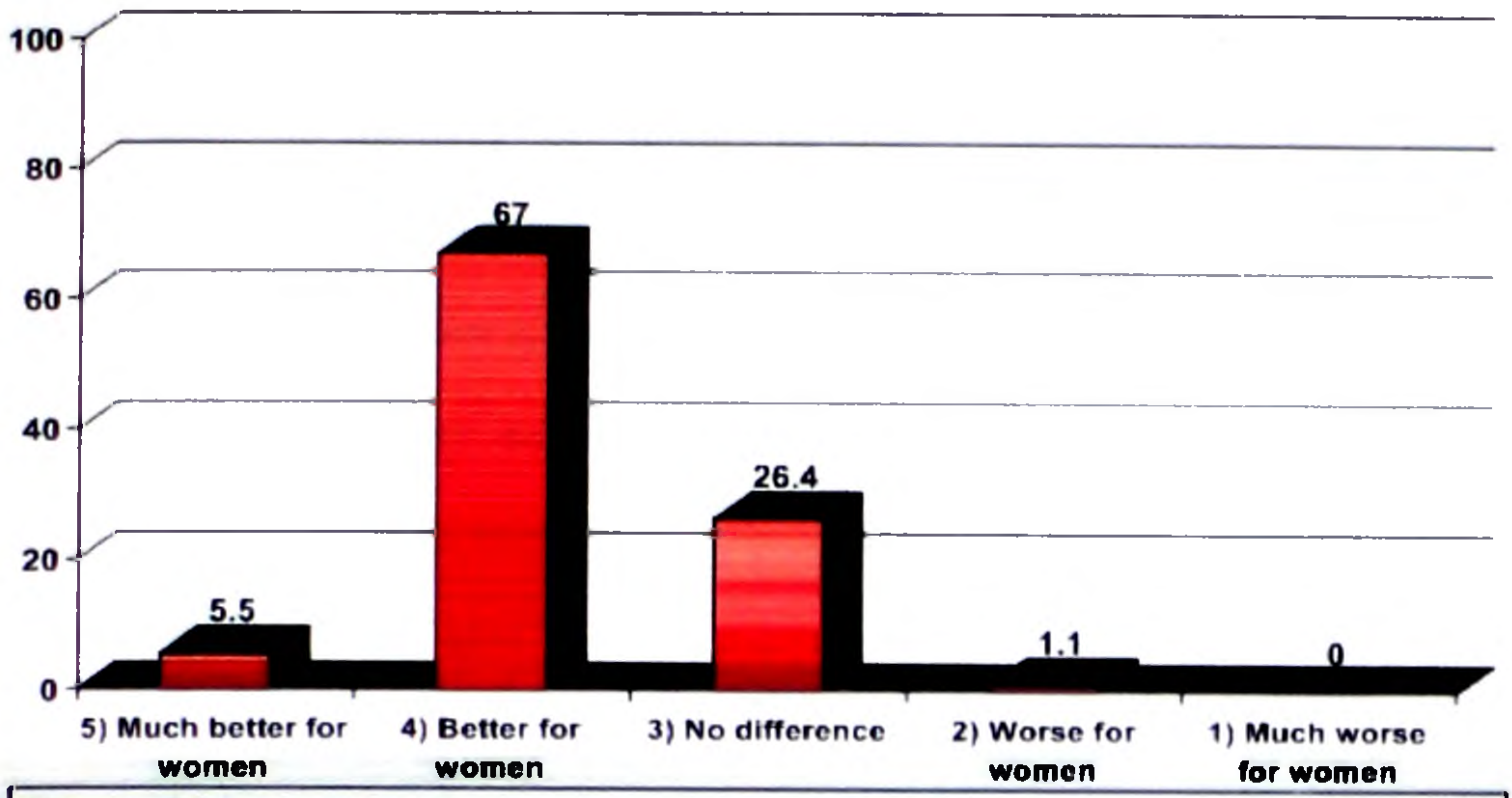
According to those surveyed, the hybrid energy system provoked an increase in time spent with their family. Approximately 56% thought they spend a bit more or much more time with their family after the installation of the HEGS, this case was significantly so amongst women. Table 10 shows the t-student distribution applied to these answers with a 90% confidence interval. The letters a/b/c/d/e found next to the percentages indicate significant differences with the columns assigned with each letter.

Table 10. Percentage of people spending much more or a bit more time with family

Table 10. Percentage of people spending much more or a bit more time with family					
Total	**Gender**		**Level of education**		
	Men a)	Women b)	7 - 9 c)	Some Univ. d)	Univ. or more e)
91	*50*	*41*	*39*	*29*	*23*
55.5%	46.9	65.8a	62.9	44.8	50.0

The next question was geared to determine the effects of the hybrid energy system on the quality of life within the community. This question relates to the opportunities and difficulties women encounter in attaining education. As mentioned before, in remote rural Mexico basic education is propagated through state-sponsored televised programming. However, rural school must first have electricity to make use of this service. In the past, San Juanico only enjoyed few hours a day of electricity and the education program at the local school often struggled to stay on its feet. The question was asked as follows: "Would you say that opportunities for education are, in general, better or worse, for women than before the energy system was installed?" The answers are presented in Figure 11.

Figure 11. The effect of rural electrification on women's education



Base =91 Interviewed
6.3 Would you say that opportunities for education are, in general, better or worse, for women than before the energy system was installed?.

Figure 11. The effect of rural electrification on women's education

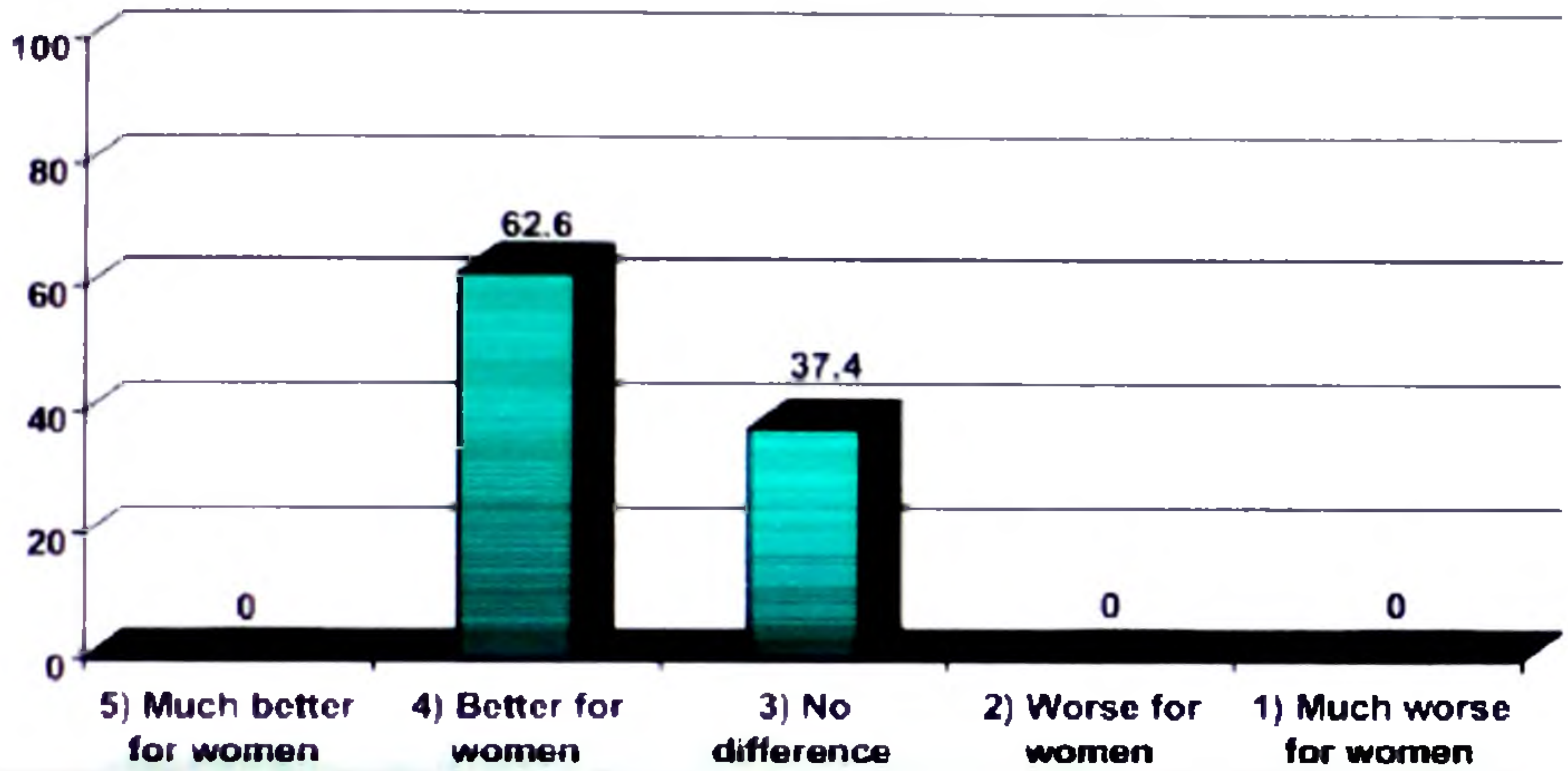
More than two thirds of those who answered think that opportunities for women's education were better or much better for women since the installation of the HEGS. This is especially true amongst women with low levels of education. We can observe this in Table 11 using a t-student distribution with a confidence interval of 90%:

Table 11. Significant differences in answers to impact on women's education

Table 11. Significant differences in answers to impact on women's education by genders and levels of education					
Total	Gender		Level of education		
	Men a)	Women b)	7 -9 c)	Some univ. d)	Univ. or more e)
91	**50**	**41**	**39**	**29**	**23**
72.5%	62.0	85.4a	82.9d	62.1	65.2

The next question relates to the impact the hybrid energy system has had on opportunities for women to find employment within the community. The specific question was: "do you think opportunities for employment for women are_______than before the HEGS? If women can spend less time doing daily chores around the house because of the HEGS, there is an implicit opportunity to invest saved time in business activities to raise family or individual income. With electricity, women could invest in electricity-driven tools to improve their productivity at work. The results of this question are depicted in Figure 12.

Figure 12. The effect of rural electrification on women's job opportunities



Base =91 Interviewed
6.4 How about job opportunities for women, do you think they are, in general, better or worse than before the energy system was installed?

Figure 12. The effect of rural electrification on women's job opportunities

According to those surveyed, nearly two out of three people thought that opportunities for employment for women have increased after the installation of the hybrid energy system. If we interpret this question and the one before it as a closed question, improvements in both education and employment opportunities for women have improved since the installation of the hybrid energy system. Table 12 illustrates significant differences regarding people's perceptions about job opportunities for women.

Table 12. Percentage of people who perceive much better or better job opportunities for women

Table 12. Percentage of people who perceive much better or better job opportunities for women					
Total	**Gender**		**Level of education**		
	Men a)	Women b)	7 - 9 c)	Some/univ. d)	Univ. or more e)
91	***50***	***41***	***39***	***29***	***23***
62.6%	56.0	70.7	68.6	51.7	60.9

Community's Perception of the Hybrid Electricity Generation System

Table 13. Community's sample agree-disagree answers on questions on the system

Table 13. Community's sample agree-disagree answers on questions regarding the hybrid energy system

Statements	% uncertain	%agree vs % disagree	
In general, life is easier since the installation of the hybrid energy	3.3	81.3	15.4
When the system fails, authorities take action to fix it immediately	3.3	64.8	31.9
Information about the system is always available to the people of	0	35.2	64.8
You pay a fair amount of money for electricity	5.5	31.9	62.6
The system is reliable and works most of the time	0	1.1	98.9

0% 50% 100%

Base =91 interviewed

The above set of questions relate to specific opinions on the HEGS. They are closed-ended questions where the possible answers are agree or disagree or uncertain. As can be seen in Table 13, the system was not reliable and doesn't work most of the time, however, they did think that life in general, was easier since the installation of the energy system (4 out of every 5 answered so). Only approximately one third of those who answered the survey agreed that information on the system was always available to the people of the community and that they paid a fair amount of money for electricity. Furthermore, 2 out of every 3 were of the opinion that when the system fails, authorities took action to fix it immediately. Table 14 describes sample responses by gender and level of education.

Table 14. Sample percentage agree responses by gender and level of education

The energy system has...	Tot	Gender		Level of education...		
Percentage in Agreement		men a)	women b)	7 - 9 c)	Some Univ. d)	Univ. or more e)
Base	***91***	***50***	***41***	***39***	***29***	***23***
In general, life is easier since the installation of the hybrid energy system	81.3	70.0	95.1a	71.4	89.7c	91.3c
When the system fails, authorities take action to fix it immediately	64.8	62.0	68.3	71.4e	72.4e	47.8
Information about the system is always available to the people of the community	35.2	42.0	26.8	34.3	48.3	21.7
You pay a fair amount of money for electricity	31.9	36.0	26.8	28.6	20.7	52.2cd
The system is reliable and works most of the time	1.1	2.0	0.0	2.9	0.0	0.0

Base = 91 interviewed

Negative opinions were also recorded, specifically for the "system is reliable and works most of the time" statement. Only one respondent answered this question with an "agree" response. A polar opposite response was received for the question "Do you perceive any negative environmental effects from the hybrid system?". The pie chart below summarized these findings. Results for this question are of little value since such a unanimous response was captured. In strict terms, this means that everybody was aware of the possible negative environmental effects the hybrid system can have and that the system performed so well that it never gave people anything to be concerned about. A more probable reason for such a unanimous response is that the vast majority of the people were not aware of the possible negative environmental effects that the plant carries in its daily operation (fuel and lubricant spillage, diesel emissions, chemical spillage from the batteries, inadequate battery disposal, inadequate use of paint and other maintenance substances). Figure 13 shows these results.

Figure 13. Sample percentage yes-no answers to perceived negative environmental effects caused by hybrid system

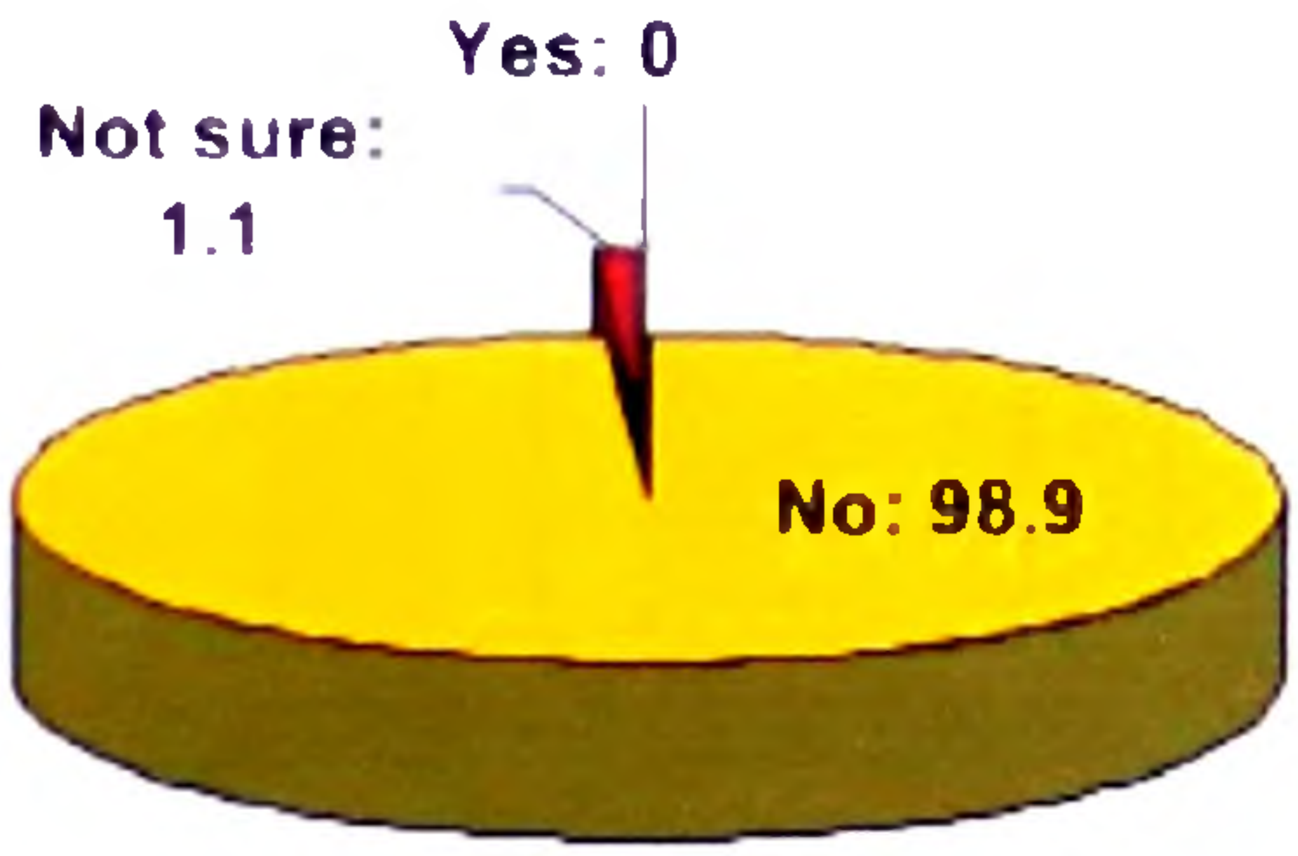


Figure 13. Sample percentage yes-no answers to perceived negative environmental effects by hybrid system

A more valuable response is found for the question "would you recommend a similar system to other villages in Mexico?" Only a little over half of those surveyed said they would recommend a similar system to other villages.

Figure 14. Sample percentage yes-no response to recommending similar hybrid systems to other rural communities in Mexico.

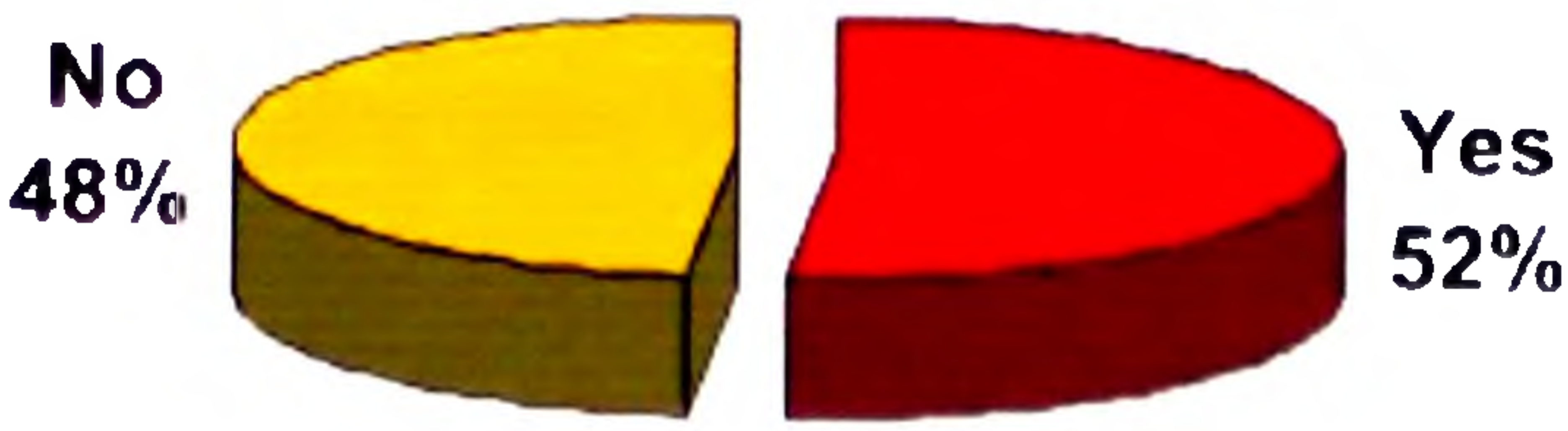


Figure 14. Sample percentage yes-no response to recommending similar hybrid systems to other rural communities in Mexico

Figure 15. Sample yes response to recommending a similar hybrid system to other rural communities in Mexico by gender and level of education.

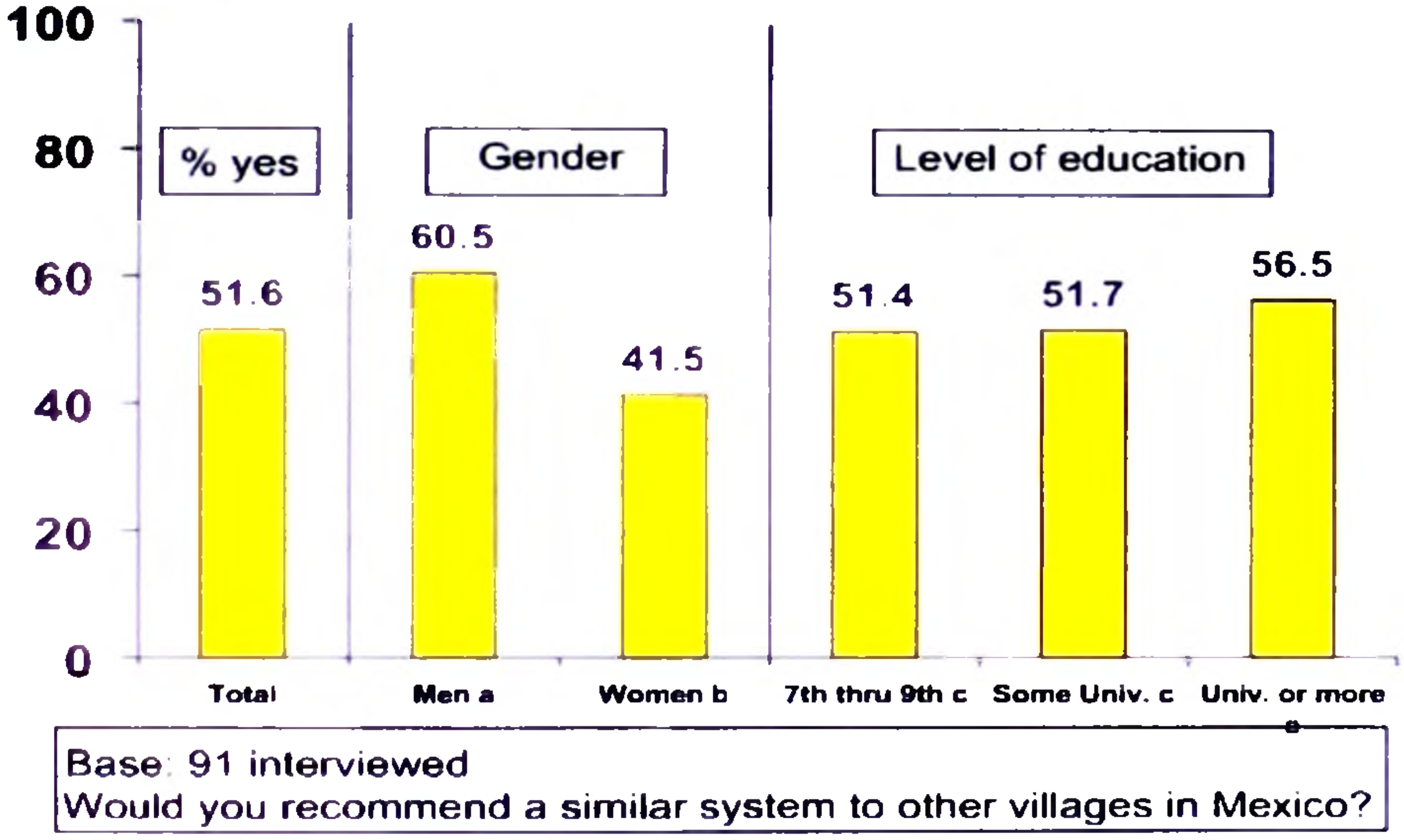


Figure 15. Sample yes response to recommending a similar hybrid system to other rurual communities in Mexico by gender and level of education

Of the sample respondents, men are more likely to recommend a similar hybrid energy system to other remote rural communities than women (Figure 15). However, given that most men in San Juanico are day-fishermen, they are less impacted by system malfunction, whereas women in this case are not as likely as men to recommend the system. This case is best explained by the fact that electrification for San Juanico was aimed at households, where women spend most of their time. In short, women are more adversely affected than men by system failure.

The next question was aimed to gauge, albeit in a qualitative way, the success of the hybrid system insofar as its benefits and advantages are perceived by the community. The ultimate proof of any product's or service's success in any given market is the willingness of consumers to pay a higher for said product or service. The question that was posed to survey respondents was "Would you be willing to pay a higher energy cost if the hybrid system becomes a fully renewable system in the future?" This question was aimed at qualitatively answering a) if people would be willing to pay more for electricity as a service and b) if people would be willing to pay more for having the source of that electricity converted to a fully renewable source.

Figure 16. Sample percentage yes-no answers to willingness to pay a higher price of electricity if the energy source was completely renewable.

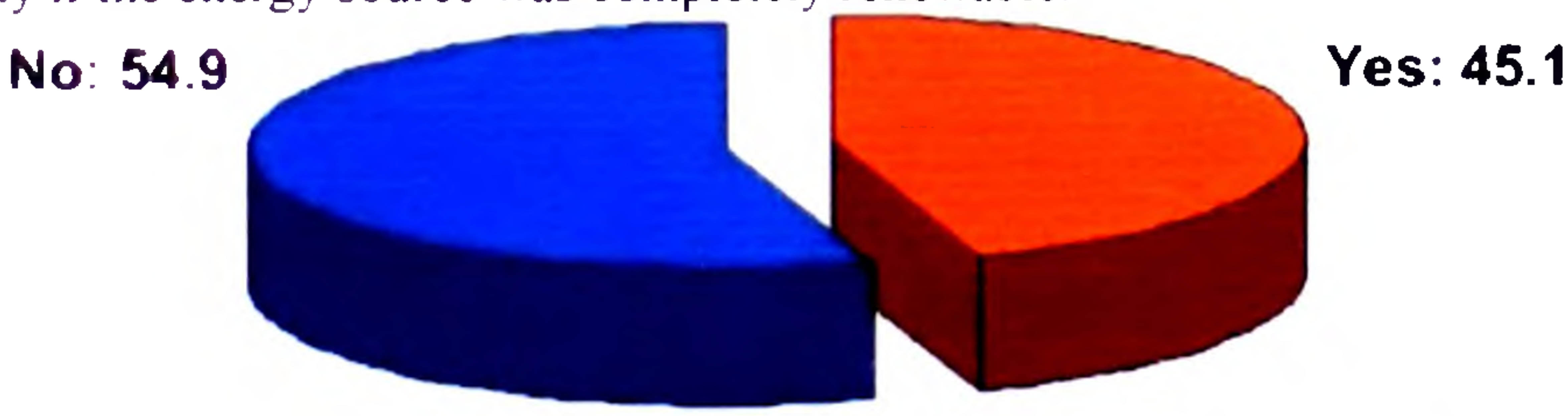


Figure 16. Sample percentage yes-no answers to willingness to pay a higher price of electricity if energy source was completely renewable

Forty five percent (45%) of those surveyed would be willing to pay a higher energy cost if the hybrid system becomes a fully renewable system in the future. This disposition to pay a higher price for renewable sourced energy increases to 60% when the level of education is greater. Figure 17 describes this case.

Figure 17. Sample percentage of yes answers to willingness to pay a higher electricity price if energy source were fully renewable by gender and level of education.

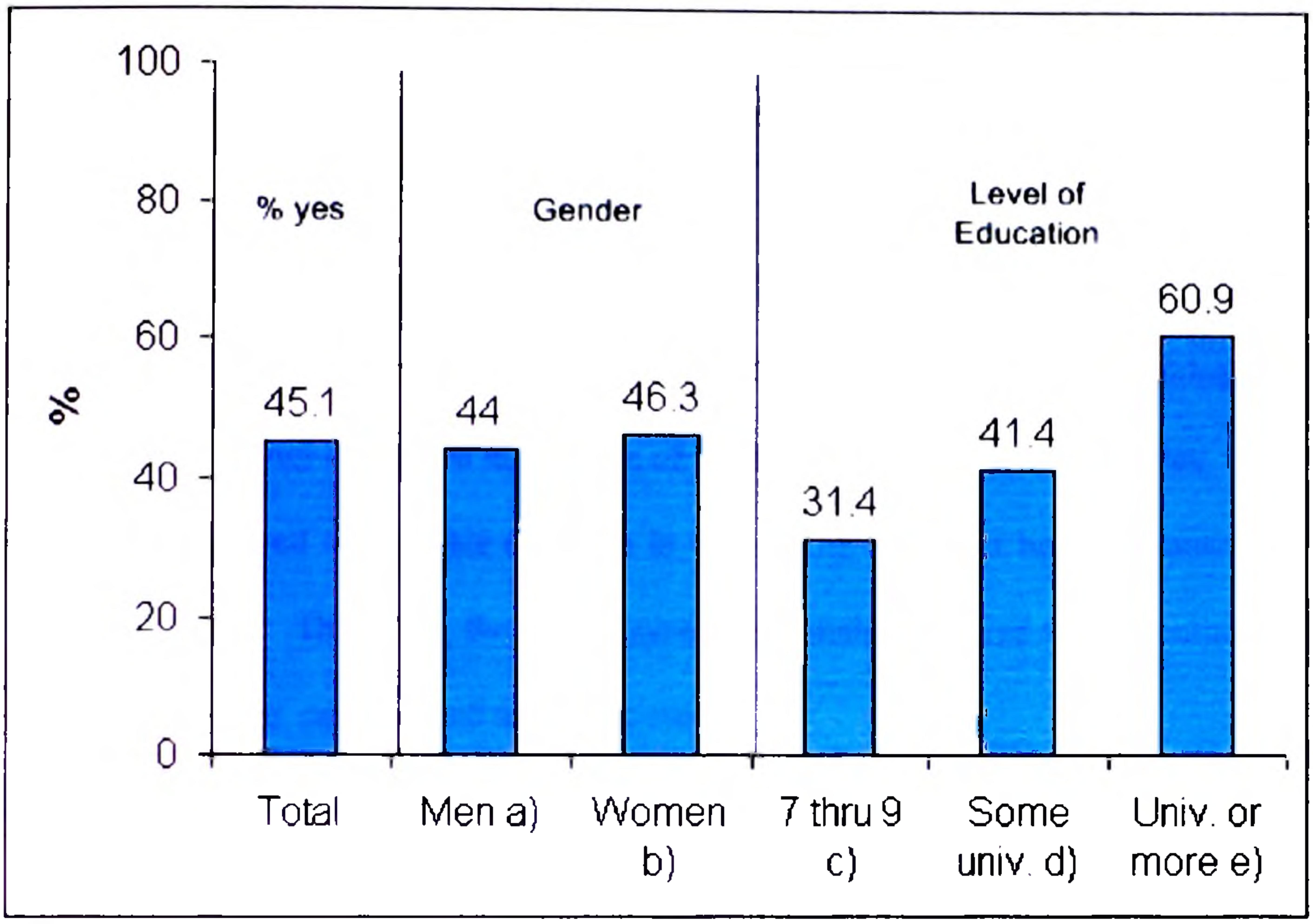


Figure 17. Sample percentage of yes answers to willingness to pay a higher electricity price if energy source were fully renewable by gender and level of education

The results of the "willingness to pay" question are interesting. They reflect the common conclusion that more educated people are often economically better off and consequently more willing to pay higher prices for what they consume. The answer is also in accordance to the percentage of people that thought they paid a fair amount of money for their electricity, namely people with higher education. One reason why people might be willing to pay a higher price for a renewables-based system is that at the time this survey was taken all the electricity came from the diesel component of the system and none from the renewables' components. However, people who were surveyed seem to prefer a renewables-based system that other options. One major reason for this might be that the system is already installed and only needs to be fixed. The general conclusions for the survey results are the following:

1. Sample households perceive a savings in time and an increase in entertainment because of the system, but they also perceive the cost, and do not find a benefit in their pockets or for their business because of the system. This conclusion makes sense since the primary economic activity of San Juanico is the fishing industry and electricity has not been used to enhance or modernized their current practices.
2. People perceived a moderate decrease in time doing chores at home because of the hybrid system. Therefore, the hybrid system has mainly catered to residential needs such as lighting, cooking and air conditioning.
3. People perceived a significant increase of time spent with their family since the installation of the Hybrid Energy system.
4. People also perceived improvements in opportunities for education and jobs for women since the installation of the electricity system.
5. The system was not reliable and does not work most of the time. However, the overwhelming proportion of households think the system has made life easier. Information about the system was scarce amongst community members and two thirds of the community members surveyed thought they paid an unfair price for

electricity. Only two thirds of those surveyed felt authorities took immediate action to fix the plant when it failed. In essence, one third of those interviewed were still unsatisfied.

6. No negative environmental effects caused by the system are perceived amongst those surveyed.
7. Only half of those surveyed would recommend similar energy systems for other rural communities in Mexico.
8. Forty five percent of households would be willing to pay a higher cost for the energy if the system was based entirely on renewable sources. This percentage is high if we considered the fact that the majority of people had felt they were already paying too much for electricity.

Probit Model Results

FAIRPRIC: All things being equal, the Probit estimation for this dependent variable showed that significant independent variables that influence the probability that a respondent will think he or she pays a fair price for the energy produced by the hybrid energy system were the overall benefits of the system (SYSBEN), the speed and efficacy with which authorities fix the system when it fails (FAILFIX) and the respondent's level of education (EDUCAT). Variables which didn't show significance were the impact on cost of living (COSTLIV), the availability of system information for community members (SYSINFO), the possibility that the system has made life easier for the community (LIFEEASY), the household size (FAMSIZE), income level (INCOME) and the respondent's gender (GENDER). Table 15 shows the maximum likelihood estimates and Probit results for this model. As indicated in table 15, people who perceive more overall system benefits will consider they pay a fair price for energy from the system (SYSBEN, t-ratio=1.9879). Also, people who perceive authorities are expeditious in fixing the system when it fails (FAILFIX, t-ratio=2.3757) and people with lower levels of education (EDUCAT, t-ratio=-2.07829) will also consider the price for energy from the hybrid system to be fair.

Table 15. Probit Model Maximum Likelihood Estimates and results for FAIRPRIC

Weighting Variable	ONE
Number of Observations	90
Iterations Completed	5
Log Likelihood Function	-46.49685
Restricted Log Likelihood	-56.56799
Chi-Squared	20.14227
Degrees of Freedom	9
Significance Level	.1705440E-01

Binomial Probit Model Results for FAIRPRIC.

IND. VAR.	COEFF.	STD. ERR.	T-RATIO	P-VALUE
ONE	-1.21139	0.980263	-1.23578	0.216539
SYSBEN	0.189469	0.095311	1.9879	0.046823
COSTLIV	-0.45119	0.404556	-1.11526	0.264738
SYSINFO	-0.01231	0.17634	-0.0698047	0.944349
FAILFIX	0.417581	.0177881	2.3757	0.018896
LIFEEASY	0.002027	0.42667	0.00475162	0.996209
FAMSIZE	-0.08972	0.097562	-0.919605	0.357779
EDUCAT	-0.16282	0.078345	-2.07829	0.037683
INCOME	0.022615	0.018376	1.2307	0.218436
GENDER	-0.56272	0.352809	-1.59496	0.110722

WTPPRICE: All things being equal, the Probit estimation for this dependent variable showed significant independent variables included the overall system benefits (SYSBEN), the available information of the hybrid system for community members (SYSBEN), household size (FAMSIZE) and income level (INCOME). Non-significant independent variables included the impact of the system on the cost of living (COSTLIV), the speed and efficacy with which authorities fix the system when it fails (FAILFIX), the possibility that the system has made life generally easier (LIFEEASY), the level of education (EDUCAT) and gender (GENDER). Table 16 shows this Probit model's maximum likelihood estimates and results. As can be seen in table 16 people who perceive higher overall benefits from the hybrid system (SYSBEN, t-ratio= 2.98426), who receive more information on the system (SYSINFO, t-ratio=-1.94177) and have a higher income (INCOME, t-ratio=2.52009) will be willing to pay a higher price for energy from the hybrid system; while people with larger family sizes will be disinclined to paying a higher price of energy.

Table 16. Binomial Probit Model Maximum Estimates and Results for WTPPRICE

Weighting Variable	ONE
Number of Observations	90
Iterations Completed	5
Log Likelihood Function	-46.30658
Restricted Log Likelihood	-61.82654
Chi-Squared	31.03993
Degrees of Freedom	9
Significance Level	.2913987E-03

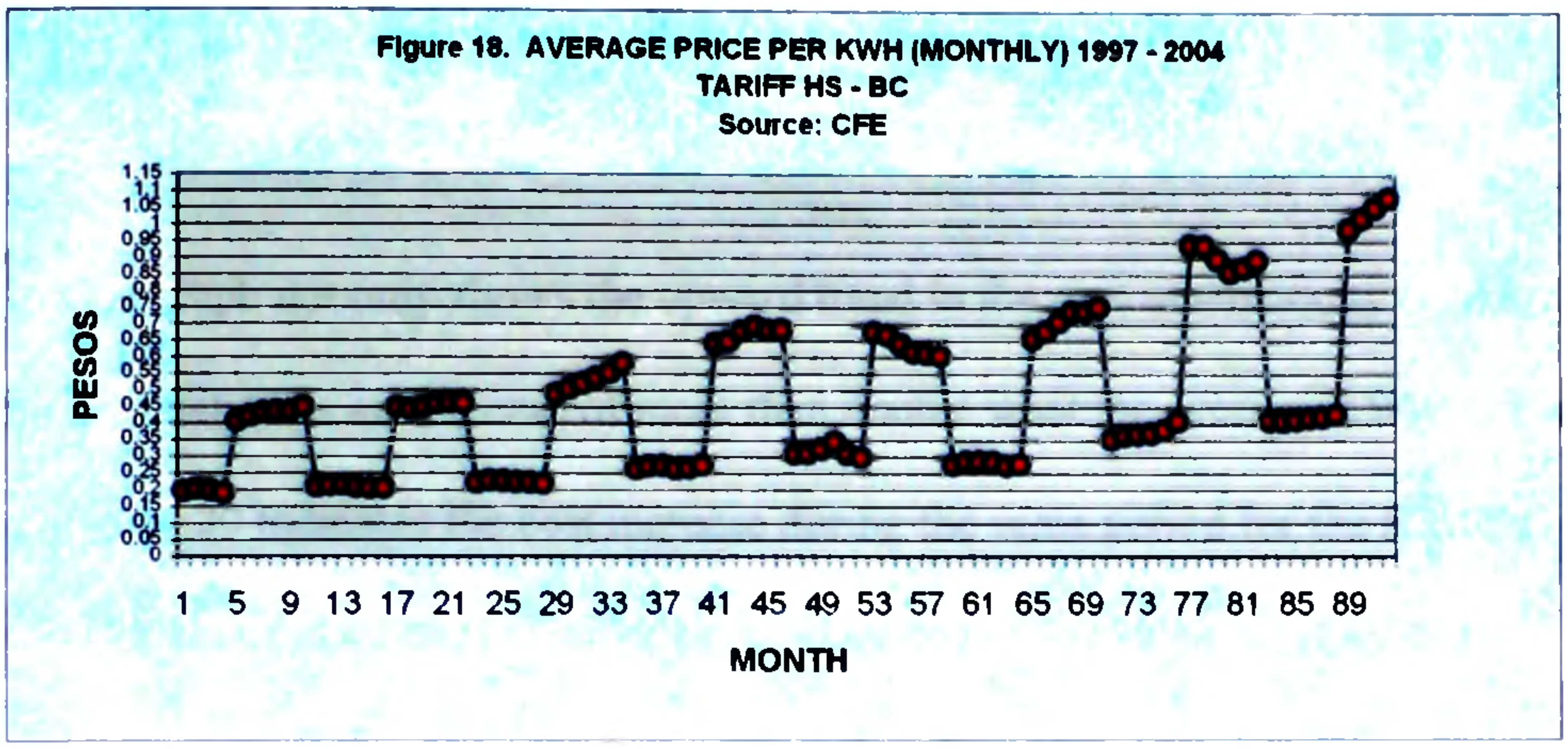
Binomial Probit Model Results for WTPPRICE

IND. VAR.	COEFF.	STD. ERR.	T-RATIO	P-VALUE
ONE	-.029165	0.979466	-0.297763	0.765884
SYSBEN	0.291556	0.097698	2.98426	0.002843
COSTLIV	-0.61901	0.47358	-1.30708	0.191186
SYSINFO	-0.35421	0.182417	-1.94177	0.052165
FAILFIX	0.121356	0.178832	0.678602	0.49739
LIFEEASY	0.654784	0.438575	1.47246	0.140896
FAMSIZE	-0.35936	0.108603	-3.3089	0.000937
EDUCAT	-0.05529	0.072324	-0.76442	0.44461
INCOME	0.045098	0.017896	2.52009	0.011732
GENDER	-0.07747	0.340453	-0.227549	0.819997

CFE vs. Hybrid System Electricity Price Comparison

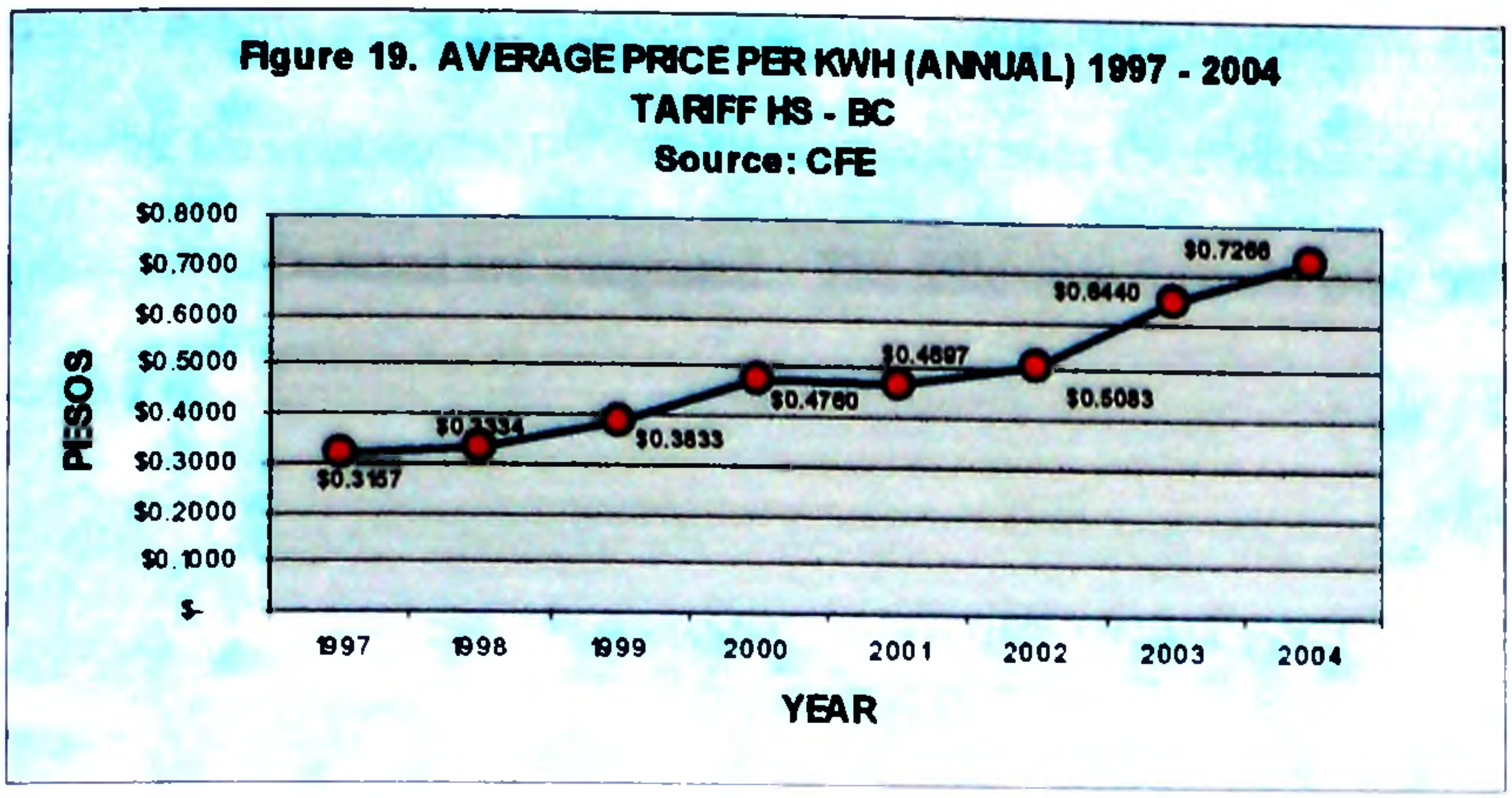
Results for CFE's tariff data analysis are presented in figures18 thru 21. Figure 18 below describes CFE weighted average monthly energy (kWh) price for CFE industrial tariff HS for the period 1997-2004.

Figure 18. Average price per kWh (monthly) 1997-2004



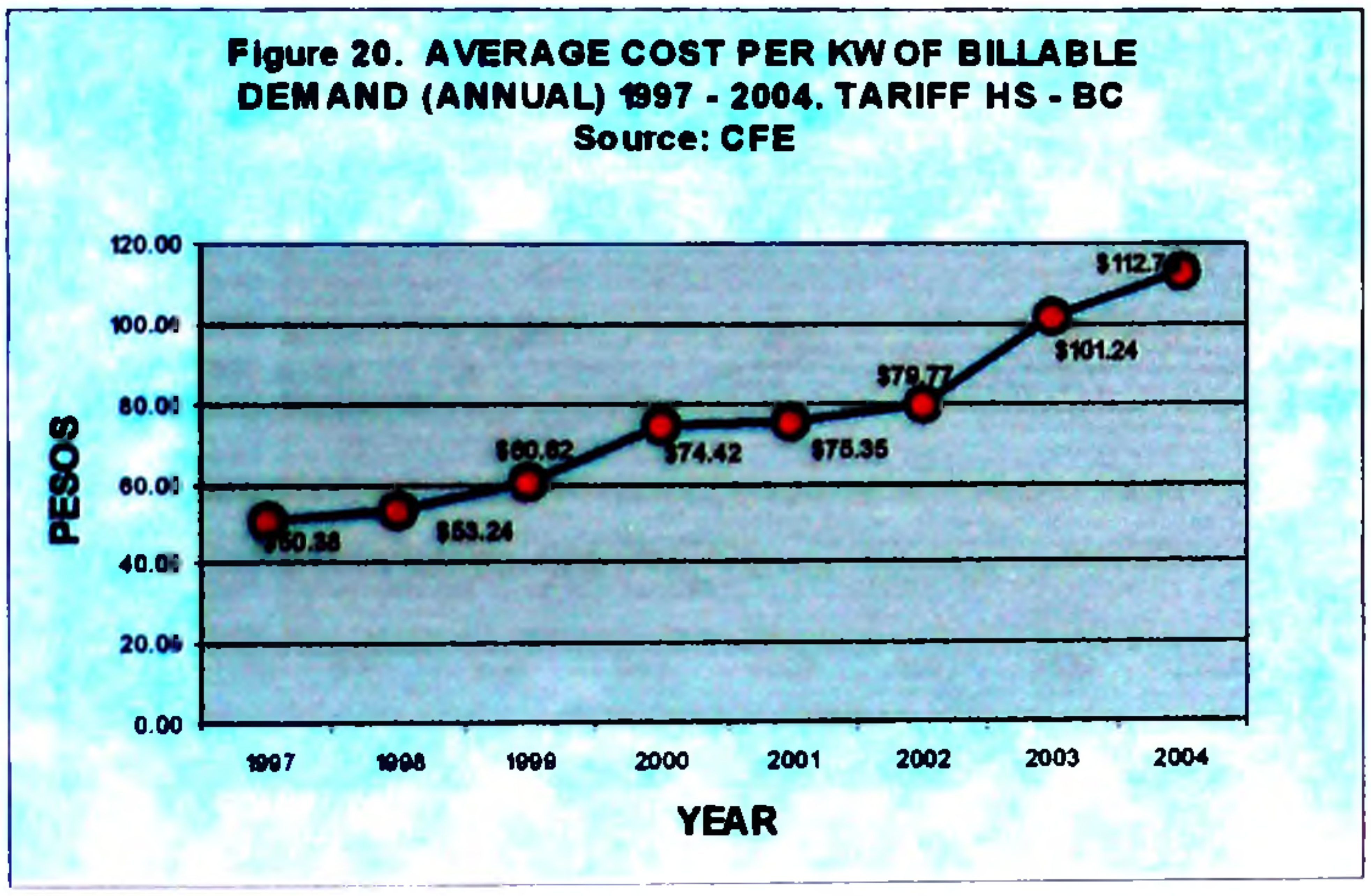
This graph indicates that tariffs fluctuate between two seasons per year: summer and winter. This structure is set by the CFE to compensate for the increase in demand during the summer months. The graph clearly indicates the difference between the summer and winter tariffs. However, it also allows the viewer to see the upward trend. Below is a graph showing the average yearly price for electricity:

Figure 19. Average price per kWh (annual) 1997-2004



This graph not only shows the upward trend in the cost of electricity on the Tariff HS, but also indicates an increase of more than double what the average KWh cost was in 1997. Figure 20 indicates the cost increase during the same period for the Billable Demand (fixed cost for reserved capacity in Kilowatts) component of CFE billing.

Figure 20. Average cost per kW of billable demand (annual) 1197-2004



The preceding graphs behave in the same manner. This is not surprising since they all belong to the same price structure and historical behavior. Below is a graph showing the behavior of the cost of electricity once the components of established tariff and Billable Demand are integrated. The following formula was used to integrate these factors:

$$PI = CKWH + [(CPDF)(CC)(12)]*1.1 / 8760$$

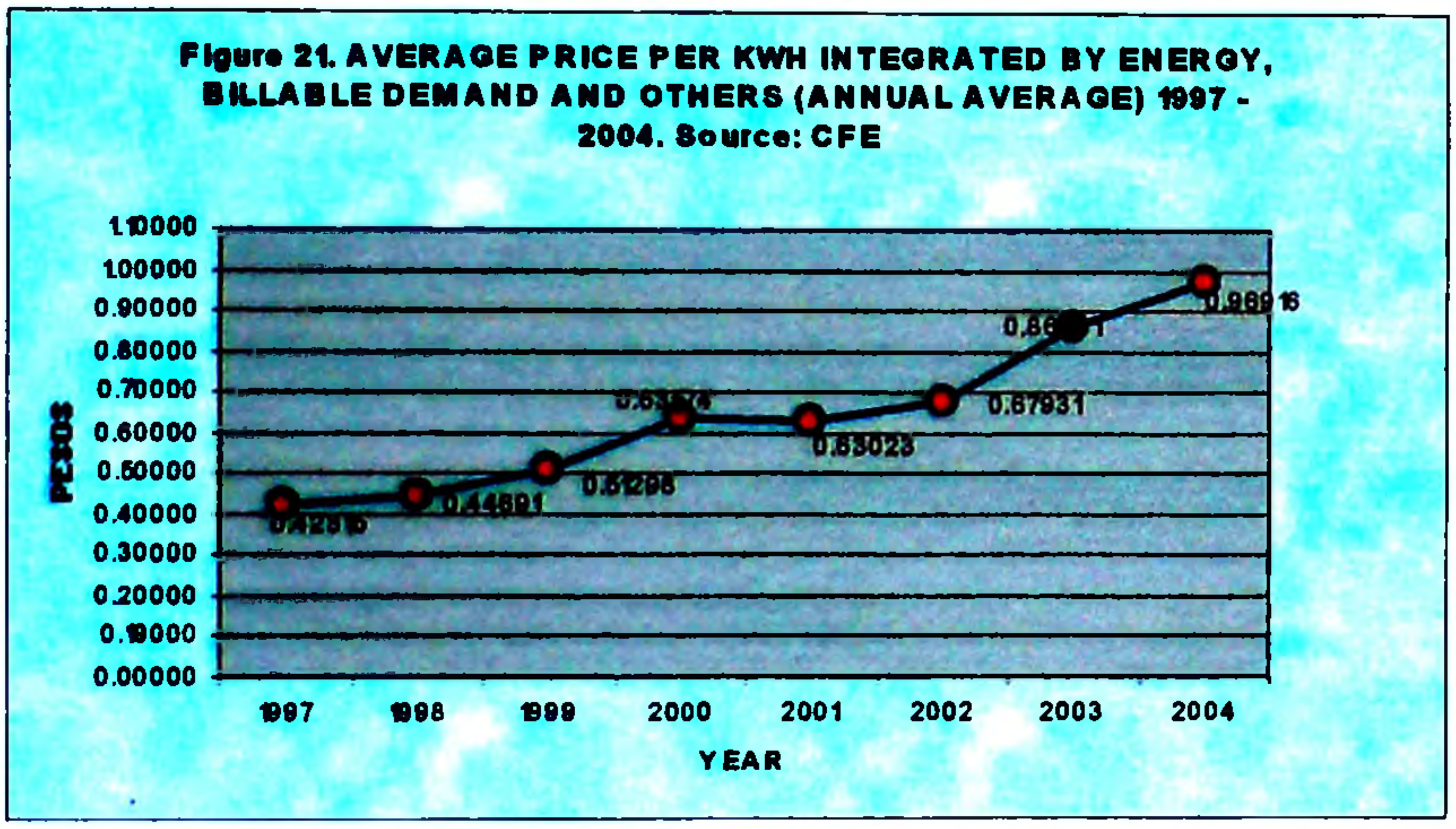
(Source: CFE)

Where:

PI = Integrated Price
CKWH = Yearly average cost of energy in KWh
CPDF = Yearly average cost of Billable Demand.
CC = Contractual Demand
12 = number of months in a year
8760 = number of hours in a year

Assumption: the multiplier "1.1" refers to an estimated cost of additional billable services by the CFE.

Figure 21. Average price per kWh integrated by energy, billable demand and others



The trend in the cost of energy in the State of Baja California has been on the rise, more than doubling in the last seven years. The average price per KWh during the first seven months of 2004 was $0.9691 Pesos. If this number is converted to dollars at $11.32 ($0.11 USD/kWh) the result is .0856 USD/kWh. This number only comes close to the lowest consumption price range for the San Juanico energy plant (1-33 kWh/month, $0.14 USD/kWh). As it was, the hybrid system can hardly compete in terms of price and reliability.

V. DISCUSSION

This study set out to establish the impact of a hybrid electricity generation system on the community of San Juanico. Two objectives were established:

1. Evaluate the economic and social contributions of the renewable-hybrid energy system to the community of San Juanico
2. Provide policy insight on the applicability and sustainability of renewable-hybrid systems for rural electrification.

The evaluation of the first objective was carried out through the performance of a specifically designed survey, which has been discussed and its results summarized in the appropriate section of this paper. The second objective will be addressed in the last section of this paper. Two questions were framed to accomplish these goals:

How has the implementation of the renewable-hybrid system positively/negatively affected the productive capabilities and quality of life of the community?

In the case of this first question, the survey established the areas in which the HEGS has had significant positive/negative impacts on daily life and development opportunities for the community of San Juanico. The second question:

What have been the main problems with the system, its implementation and the institutional structures that control it?

This question was answered mainly through existing published and anecdotal information obtained through direct contact with San Juanico villagers, CFE personnel and electronic communication with NREL personnel.

To answer these questions, two main hypotheses were formulated:

(1) The renewable-hybrid system has positively affected the life of the community by increasing its productive capabilities and quality of life. (2) The system was designed and implemented under sustainable development guidelines.

In the case of the first hypothesis, we can establish that the renewable-hybrid system has indeed positively affected the life of the community by increasing its quality of life. However, it remains unclear how this system has increased villager's productive capabilities since most applications for the electricity generated seem to fall either improvement of domestic chores or leisure time spent with family. The link between increased access to electricity and economic productivity of the community as a whole is at this time hard to establish. San Juanico's main productive activity is fishing. Given that electrification project did not include a semi-industrial refrigeration load for the town's fishing cooperative, increased access to refrigeration occurred mainly at the household level, with no direct impact on increased ability for said coop to serve larger markets.

Based on the study findings we rejected the second hypothesis. The failure of the system to operate continuously in a satisfactory manner, the lack of a strong institutional structure to operate and manage the system, and the associated disappointment by its customers supported the view that the renewable hybrid system was not a sustainable system. This view is supported by explanations given by Patronato members and CFE representatives. Below are the main issues identified with system sustainability based on conversations with the mentioned authorities and information found in existing literature.

1) Although the main sources of financing for the San Juanico pilot power project were APS and Niagara Mohawk, they have not played a significant role in the institutional frameworks that are in charge of operating and maintaining the system. Inversely, the CFE and the Patronato, the two smallest sources of financial resources, have played the central role of regulator and administrators.

2) According to conversations with CFE representatives, the project was implemented under the same structure that the CFE traditionally uses for decentralized projects. Typically, CFE will prepare plans and budgets for electrification and then work closely with State and local authorities to establish priorities and schedule specific projects. CFE then oversees the projects, and owns the completed generation and distribution facilities. However, it normally transfers operations and maintenance responsibilities to a local cooperative, or Patronato, under a formal contract. This reduces CFE's liabilities and allows the operators to charge tariffs that are closer to actual costs of operation, which are much higher than the rates charged to customers connected to the

national grid system. In essence, the CFE avoids financing subsidies that might be required to operate these systems. This allocation of responsibilities creates a real mismatch between communities' capabilities and the technical requirements a project demands. This view is supported in existing reviewed literature. It is well known that the success of any decentralized project should rely in part on local participation and integration [Marquand, 1998 #39]. However, this participation must be limited to tasks that are realistically matched to communities' technical capabilities. In essence, one cannot place space-age technology in a community that still hasn't even experienced the industrial revolution and expect it to run properly without emphasizing proper and thorough training of local participants, and institutions that would provide permanent on-going technical assistance and training. For instance, it makes more sense to integrate the community in the building of the plant than it does in the maintenance of it, at least in the initial phases of the project. In time, and after thorough and complete training, jobs in maintenance and operation can be created.

3) Although no explicit reference is made to its responsibilities in the statute that creates it, its responsibilities mainly focus on the operation and maintenance of the energy system [, 1998 #58]. Upon visitation of the site and conversations with the president of the Patronato, it quickly became clear that said organism was ill-equipped to operate and maintain the power system. Moreover, the implied responsibility of participating as a member of the Patronato is viewed as undesirable by many community members because of problems associated with the technical, billing, fuel purchasing and transport aspects of keeping electricity in supply for the town. The Patronato, authority

responsible for the operation and maintenance of the hybrid system, was not constituted as a fiscal entity or enterprise under any of the existing legal options available in Mexico (IPP, self-generator, BLT project). This limits not only its accountability, because it is incapable of issuing receipts to the system's customers, but also its ability to respond to day to day administrative functions which require a clear legal standing. This characteristic also impedes its ability to receive governmental financial support or donations because it cannot request invoices to prove disbursements. The only taxes associated with the operation and maintenance of the system are borne in the purchase of the diesel fuel. For all practical purposes, the Patronato is an organization floating in a legal limbo where in name it is in charge of operating and maintaining the system, but in reality lacks the formal legal and financial tools and frameworks to do so.

4) Although the CFE has routinely deployed its technical expertise, it's clearly not enough to guarantee 24 hour uninterrupted electricity for the town. This is in large part because technical expertise is just not helpful when there is a lack of spare parts and fuel or the money to purchase them.

5) Finally, the most compelling evidence for the lack of system sustainability is the overwhelming disagreement (98.9%) by community members to the statement posed to them in the survey: "The system is reliable and works most of the time".

Recommendations

This section intends to propose some recommendations to improve the deployment of hybrid systems based on the conclusions of this study. People surveyed perceived a savings in time and an increase in entertainment because the hybrid system was integrated into the community for household lighting. They also perceived an increase in cost of living (from light bills) and did not find a benefit to their income because of electrification. Hybrid system developers should keep in mind that different energy uses carry different costs and benefits. For instance, if developers are aiming to increase community income, electrification should first focus on improving a community productive activity. In the case of San Juanico this could have been done for a small fish processing and refrigeration plant. Differently, if developers are aiming to increase women's quality of life, household electrification goes a long way as we saw in this study. Of course, if sufficient resources exist, both should be considered.

The San Juanico hybrid system was not reliable at the time of this study, information about the system was scarce about the system and two thirds of those surveyed thought they paid an unfair price for electricity and that authorities took immediate action to fix the hybrid system when it failed. In order to avoid these problems in the future, hybrid energy system developers need to take into account the long term technical, economic and social factors of the system's integration to the community. Hybrid system reliability stems from use of best practices in design, construction, operation and maintenance, high quality components, reliable suppliers, reliable warranties, trained personnel, good planning and a clear set of responsibilities from all parties involved. If the system is to be run by community members, special emphasis should be placed in thorough training in all operations and maintenance aspects of the system. The cost and time involved in assuring competency should be carefully considered. Furthermore, a solid and transparent institutional framework should be designed with clear protocols for different situations. This will ensure that improvisation by personnel with limited training is kept to a minimum. This is crucial when complex and expensive components are part of the system. Communication with consumers is equally important. Whatever the institutional framework is designed to accomplish, it should periodically inform those directly affected on different aspects of pricing, the system and responsible parties during every phase of the hybrid project. This will reduce community resentments and confusion while empowering community members to find solutions based on knowledge provided by hybrid systems developers and operators.

Further Recommendations

This section includes personal recommendations based on three years of developing renewable energy projects in Mexico. The knowledge implicit in these recommendations comes, firsthand or secondhand, from within the organization I work for and personal first-hand experience. In contrast to conventional generation, systems that incorporate renewable technology must be located where the energy source (solar insolation, wind, etc.) is viable. To establish viability, developers must first carry out resource assessment studies on site. These studies must be carried out in strict scientific protocols to assure the quality of the data on which each system will be designed. In the case of wind, the process usually starts with anecdotal information followed by the installation of anemometry towers to monitor wind characteristics over a period of 3 to 5 years. Instruments installed on these towers should comply with industry standards and be carefully monitored on a routine basis to establish proper functioning. Also a routine data collection program should be established. This program has to identify who is responsible for data collection, how often the data is collected, the format of a proper log book for the due recording of all actions performed on met towers, the protocol for data sending to the analysis center, and finally, how much the responsible person is to be paid. This same type of program for solar insolation data collection has to be established as well.

In parallel with energy resource data collection and analysis, a study should be conducted to establish the community's level of ability to pay for electricity consumption. Ability to pay should be measured by mean income, current cost of living and the productive activities that make up the economic life of the community before the installation of the hybrid system. These studies should also take into account the increased productivity in some economic activities as a result of the installation. However, if the electricity system is to be installed independently, that is to say, without being part of a larger plan to increase production in a specific community activity, assumptions on increased economic activity and income because of the installation of the hybrid system should remain conservative. Ability to pay is better determined by what already exists than on estimations on future income.

Once the initial stage of resource and ability to pay data collection and analysis has been finished using the most current analysis techniques, developers must make technology choices based on the data collected in the field. This entails looking for the most appropriate power curves in wind generators, life span of equipment, service and warranties and proven experience. Since these projects have such a large influence in the lifestyle of isolated rural communities, and the investment needs to be protected, warranties and binding service contracts be put in place prior to the purchasing of the equipment. More than often it has been the case that hybrid projects end up with no recourse to attain parts, service or warranties when technology companies either disappear or decide that servicing in remote places is too expensive.

Since only those communities that are in or close to sites with good renewable sources are viable candidates, the hybrid energy system option should only be applied to these. Although one would think the statement above to be obvious, it is very surprising to see the amount of technology that has been installed in the most improper places. This improves the chances of these types of systems to remain a viable option since the implementation of the wrong technology in the wrong site always casts a negative impression on the application of these technologies as a whole.

The development of hybrid energy systems for poor isolated rural communities must be designed with simple and clear institutional frameworks that identify technical and economic responsibilities. The more complicated the institutional frameworks in these isolated places, the less of a chance these systems will have to remain sustainable in the long run. From the beginning, a limit on consumption should be initially set, in a fair manner to those involved. For example, a limit could be set for domestic consumption, and the same be done for productive activities (carpentry shops, welding shops) and another for small commerce (corner shops with larger refrigeration needs). From the beginning, people in the community must be informed on the limits of the system capacity, the cost of installing it and keeping it alive to their service. If developers do not integrate the community into the development knowledge on what will keep the project alive, there is likely to be over usage of energy, disregard for the system operation and maintenance and finally, system non-viability and breakdown. Observations similar to the one above stem from a combination of a "tragedy of the commons" situation and a complete ignorance on system functionality and requirements. However, if developers take the appropriate steps in the education of the community regarding the system, it will have a better chance to do well, since there will be a larger number of people who will start feeling as if these systems truly belong to them and the community.

Pricing of electricity should be established so that debt payments (if any), operation and maintenance are assured in the cash flow of the project. This has to include the ability of the system to purchase and store the most common spare parts in quantities necessary to assure high system reliability. The pricing structure should be designed in the simplest possible way to avoid any misgivings amongst community users. Electricity tariffs should be established in an equitable manner, reflecting the need to limit consumption to within the capacity parameters of the system.

In the case of Mexico, since the law only allows CFE to conduct the operation of electrical systems for public service, it should be precisely the CFE that operates and manages these systems. There are several reasons for this proposal. First, the CFE is the State's instrument for public electrification. This means that CFE's mission is to electrify communities. Being the most technically competent entity in Mexico, the CFE is the best positioned to expand its services to poor remote communities. Besides this goal being completely in line with CFE's mission there are many opportunities to learn from these systems and ultimately profit from their deployment. Essentially, these communities are in the need of being electrified. The CFE can choose either of two options: send a transmission line to the community, with the associated losses involved, or develop specifically designed energy systems for these communities. As the country develops, there will be a time when these communities are interconnected to the grid. However, line losses and costs associated to this reality will be significantly lowered if the sites being interconnected are generating rather than just receiving. Also, should CFE decide to pursue the distributed generation option, it would gain significantly from purchasing larger amounts of components, lowering the capital cost of projects.

Even if the notion of introducing cleaner energy systems into poor remote communities falls within the scope of sustainable development, the implementation itself needs to be sustainable. It does not suffice to use benign technologies if those technologies can't survive in real-world scenarios. Although renewable energy technology has had only a limited impact on Mexico's energy portfolio, it represents an enormous area of opportunity [Energía, 2003 #82]. One side of the solution is creating formal markets for solar technologies where learning curves and standardization can start reducing costs. On another front, the creation of specialized financing sources for both private and governmental initiatives in renewable energies needs to be set up based on the savings created by avoided emissions. There is now a market for several types of fossil-fuel emissions so there is a price that can be put to these avoided emissions. Necessary to the full implementation of these technologies is the creation of legislation supporting private and institutional initiative in the field. Finally, the development of renewable energy projects in Mexico will ultimately depend on the credibility these systems might achieve with the population, which in turn depends on the efficacy of the institutions that regulate, design and drive their market. Integration, participation and education are crucial to the success of this expansion. As Mexico seeks its own development, there is a place for hybrid renewable energy generation systems, if these systems can be properly designed, operated and maintained to propel specific economic productivity and societal goals.

LIST OF REFERENCES

(1927). Constitución Política de Los Estados Unidos Mexicanos.

(1992). Ley del Servicio Público de Energía Eléctrica.

(1995). Ley de la Comisión Reguladora de Energía.

(1998). Acta Constitutiva Del Comité Pro-Electrificación: 1-4.

Agredano, J. D., J. M. V. Huacuz, et al. (2000). HYBRID SYSTEMS: THE MEXICAN EXPERIENCE, Instituto de Investigaciones Eléctricas. 2002.

APS (1999). Hybrid Power Plant Opens in Baja California, Stewart, Sally. 2002.

APS (2002). Wind Power, APS. 2002.

ASE (2001). San Juanico, Baja California, Mexico.

ASE (2001). PV hybrid power station for San Juanico, Mexico. 2002.

Baring - Gould, I. (1998). Hybrid2 The Hybrid System Simulation Model, Users Manual. Golden, Colorado.

Barnett, B. and D. D. (1998). Market Guidebook of Renewable Energy Applications in Mexico. Albuquerque.

Basalla, G. (1979). Energy and Civilization. Science, Technology and the Human Prospect. C. Starr and P. C. Ritterbush. New York, Pergamon Press.

Bauer, M. and J. Quintanilla (2000). "Conflicting energy, environment, economy policies in Mexico." Energy Policy 28(5): 321-326.

Bergey, M. (2002). Bergey Windpower Case Study: San Juanico, Baja California Sur, Mexico.

Berry, T. and M. Jaccard (2001). "The renewable portfolio standard: design considerations and an implementation survey." Energy Policy 29(4): 263-277.

Bianchi, J. (1999). Hybrid Power System for San Juanico, Mexico, NREL. 2002.

Branscomb, L., R. Florida, et al. (1997). Investing in Innovation, The Steering Committe of the Project on Technology Policy Assessment.

Byrne, J. and D. Rich, Eds. (1988). Planning for Changing Energy Conditions. Energy Policy Studies. New Brunswick, Transaction Inc.

Chakrabarti, S. and S. Chakrabarti (2002). "Rural electrification programme with solar energy in remote region - a case study in an island." Energy Policy 30: 33-42.

Comision Federal de Electricidad (1999). Caracteristicas Tecnicas Proyecto Sistema Hibrido de Generacion Eolico-Solar-Diesel, en San Juanico, B.C.S., CFE: 4-7.

Comision Federal de Electricidad (2001). Planta Electrica Hibrida - Ponencia, San Juanico - Baja California Sur, Mexico. 2002.

Comision Federal de Electricidad (2001). Planta Electrica Hibrida - Documento, San Juanico - Baja California Sur, Mexico.

Comision Federal de Electricidad (2001). Planta Electrica Hibrida - Poster, San Juanico - Baja California Sur, Mexico.

Common, M. (1995). Some New Economics. Limits to Economics. Cambridge, Cambridge University Press.

Corbus, D. (1999). NREL Wind Technical Assistance to Mexico Renewable Energy Program, NREL. 2002.

Davis, D. H. (1993). Energy Politics. New York, St. Martin's Press.

Electricidad, C. F. d. Main Webpage.

Energía, C. N. d. A. d. (2002). Energía Eólica. Mexico City, CONAE.

Energía, S. d. (2003). Renewable Energies in Mexico. Mexico City.

Energía, S. d. (2004). Prospectiva del Sector Eléctrico 2004 - 2013. Mexico, Secretaría de Energía.

Espey, S. (2001). "Renewables portfolio standard: a means for trade with electricity from renewable energy sources?" Energy Policy 29(7): 557-566.

Flavin, C. and N. Lenssen (1994). Power Surge. New York, W.W. Norton & Company.

Foster, R., R. C. Orozco, et al. (1999). Lessons Learned from the Xcalak village hybrid system: a seven year retrospective. Jerusalem, 1999 Solar World Conference, International Solar Energy Society.

Francisco Torres Roldan, E. G. M. (2006). Renewable Energies for Sustainable Development in Mexico. J. C. M. Sandoval. Mexico City, Secretaría de Energía, Deutsche Gesselshaft für Technische Zusammenarbeit (GTZ) GmbH: 79.

Frantzis, L. and R. Katofsky (2002). Renewable Energy Renaissance; An Arthur D. Little Perspective.

Fuchs, D. A. and M. J. Arentsen (2002). "Green electricity in the market place: the policy challenge." Energy Policy 30(6): 525-538.

Gilbert, R. J. and E. P. Kahn (1996). International Comparisons of Electricity Regulation. Cambridge, Cambridge University Press.

Goldemberg, J. (1998). "Leapfrog energy technology." Energy Policy 26(10): 729-741.

Guzman Huerta (2001). Sistema Híbrido en San Juanico, Municipio de Comondú, Estado de Baja California Sur, México.

Guzman Sanchez, I. E. L. and I. J. Huerta Lara (2001). Planta Eléctrica Híbrida Eólica-Solar-Diesel San Juanico, Baja California Sur, México, CFE. 2002.

Hackett, S. C. (1998). Introduction to the Sustainability Perspective. Environmental and Natural Resources Economics - Theory, Policy, and the Sustainable Society. Armonk, New York, M.E. Sharpe: 207-212.

Hackett, S. C. (1998). Sustainable Economic Development. Environmental and Natural Resources Economics - Theory, Policy, and the Sustainable Society. Armonk, New York, M.E. Sharpe: 249-267.

Hanley, C. J., M. P. Ross, et al. (2000). Developing Sustainable Renewable Energy Markets in Mexico: Results and Future Challenges. Mexico DF, ISES FORUM 2000 Mexico City.

Harris, J. M., T. A. Wise, et al., Eds. (2001). A Survey of Sustainable Development - Social and Economic Dimensions. Frontier Issues in Economic Thought. London, Island Press.

Ibenholt, K. "Explaining learning curves for wind power." Energy Policy.

Instituto Nacional de Estadística, G. e. I. (2005). Censo de Población y Vivienda.

Islas, J. and U. Jerónimo (2001). "The financing of the Mexican electrical sector." Energy Policy 29(12): 965-973.

Jacobsson, S. and A. Johnson (2000). "The diffusion of renewable energy technology: and analytical framework and key issues for research." Energy Policy 28: 625-640.

Johnston, P. (1998). APS/CFE RENEWABLE ENERGY PROJECT, National Renewable Energy Laboratory.

Johnston, P., C. Napikoski, et al. (1998). Renewable Energy Pilot Project: San Juanico, Baja California Sur. Feasibility Study and Project Implementation Plan. Phoenix, AZ.

Lopez Ríos, S. (1999). Planta Eléctrica Híbrida San Juanico, B.C.S., México, Las Energías Renovables en el Desarrollo de las Comunidades Rurales. Morelia, Michoacan, Comisión Federal de Electricidad.

Lovins, A. (2002). Small is Profitable, The Hidden Economic Benefits of Making Electrical Resources the Right Size. Snowmass, Colorado, Rocky Mountain Institute.

Lovins, A. B. (1977). Energy Strategy: The Road Not Taken? Soft Energy Paths: Towards a Durable Peace, Harper & Row: 25-60.

Manwell, J., M. Guile, et al. (2001). Hybrid2, The Hybrid System Simulation Model. Golden, Colorado, National Renewable Energy Laboratory and University of Massachussetts.

Manwell, J., A. Rogers, et al. (1998). Hybrid2 - A Hybrid System Simulation Model, Theory Manual.

Marquand, C. J., J. C. McVeigh, et al. (1998). "Dissemination of renewable energy technologies in developing countries - lessons for the future." Journal of Ambient Energy 19(1): 3-32.

Mathai, C. V. a. M. B. (1997). Arizona Public Service-Comision Federal de Electricidad Renewable Energy Mini-Grid Project, Pre-Feasibility Study.

McKinsey & Company (2001). The Bay Area- A Knowledge Economy Needs Power. A Report on California's Energy Crisis and its Impact on the Bay Area Economy. San Francisco, Bay Area Economic Forum.

Morthorst, P. E. (2000). "The development of a green certificate market." Energy Policy 28(15): 1085-1094.

Munasinghe, M. and W. Shearer Key Concepts and Terminology of Sustainable Development. Washington, D.C., The World Bank: 19-27.

Patterson, W. (1999). Transforming Electricity. London, Earthscan Publications.

Philibert, C. (2000). "How could emissions trading benefit developing countries." Energy Policy 28(13): 947-956.

Reed, D. (1996). Sustainable Development. Structural Adjustment, the Environment, and Sustainable Development. London, Earthscan: 25-40.

Rozakis, S., P. G. Soldatos, et al. (1997). "Evaluation of an integrated renewable energy system for electricity generation in rural areas." Energy Policy 25: 337-347.

Sandia National Laboratories (1998). Program encourages use of renewable energies in Mexico, Chris Burroughs.

Sandia National Laboratories (1999). Renewable Energy Program in Mexico. 2002.

Sandia National Laboratories (2002). Hybrid Power Systems - Issues and Answers.

Schimmelpfennig, D. (1995). "The option value of renewable energy." Energy Economics 17(4): 311-317.

Secretaría de Energía (1999). Propuesta de Cambio Estructural de la Industria Eléctrica en México. México DF.

Secretaría de Energía (1999). Propuesta de Cambio Estructural de la Industria Eléctrica en México, Resumen Ejecutivo. México DF.

Secretaría de Energía (2000). Sector Electrico - Prospectiva 2000-2009. Mexico City, Secretaria de Energia.

Secretaría de Energía (2002). Propuesta de Reforma de la Industria Eléctrica en Méxicob. 2002.

Secretaría de Energía (2002). Oportunidades de Inversión en el Sector Eléctrico de México. 2002.

Starke, E., Ed. (2002). State of the World 2002 (an annual report on progress toward a sustainble society). State of the World (an annual report on progress toward a sustainable society). New York, Norton and Company.

Suding, P. H. (1996). "Opening up and transition, success and problems; Financing and reforms of the electric power sector in Latin America and the Caribbean." Energy Policy 24(5): 437-445.

Sustainable Development Department (SD), F. a. A. O. o. t. U. N. F. (1996). Technology assessment and transfer for sustainable agriculture and rural development in the Asia-Pacific Region. 2002.

The InfoShop (1999). Mexico-Renewable Energy for Agriculture. Mexico DF, World Bank.

UNCTAD (1999). Solar, Wind Hybrid Power Plant to Spark Development in Baja California, Stewart, Sally. 2002.
Vanestanos, K., P. Angelopoulou, et al. (2002). "Renewable energy sources project appraisal under uncertainty: the case of wind energy expploitation within a changing energy market environment." Energy Policy 30: 293-307.

Wiser, R. H. (1997). "Renewable energy finance and project ownership." Energy Policy 25(1): 15-27.

Zervos, A. (2006). The Need for Renewable Energy Policy. International Grid-Connected Renewable Energy Policy Forum, Mexico City, Global Wind Energy Council.

APPENDICES

Appendix 1. San Juanico Survey (English Version)

Hello, my name is Pablo Gottfried and I am a student at Florida International University. I am carrying out the following survey on impressions of the San Juanico community members about the improvements the hybrid energy system has brought since being installed. All information here will be kept confidential and annonimity is guaranteed. Thank you very much for taking your time to answer these questions.

1. Are you a resident of San Juanico?

   Yes ______ No ______

2. Please indicate your gender

   Male ______ Female ______

3. Do you have electricity in your home?

   Yes ______ No ______

4. Please circle appliances you use at home since the installation of the hybrid system:

   Television Radio Iron Washing-Machine Dryer

   Refrigerator VCR Computer

5. The hybrid energy system has:

	Agree	**Disagree**	**Uncertain**
Brought you more leisure time	1	2	3
Brought you more entertainment	1	2	3
Allowed you to do more work in less time	1	2	3
Increased your income	1	2	3
Increased your access to health services	1	2	3
Increased your access to education	1	2	3
Increased your employment options	1	2	3

Increased your cost of living	1	2	3
Helped the community's economy	1	2	3
Increased your profit at business	1	2	3

Others ___________________

6. The following questions are asked about your time usage after the installation of the hybrid energy system

- You __________time doing household work?

  1. SPEND MUCH MORE
  2. SPEND A BIT MORE
  3. SPEND THE SAME
  4. SPEND A BIT LESS
  5. SPEND MUCH LESS
  6. NA

- You ___________time with your family?

  1. SPEND MUCH MORE
  2. SPEND A BIT MORE
  3. SPEND SAME
  4. SPEND A BIT LESS
  5. SPEND MUCH LESS
  6. NA

- Would you say that opportunities for education are, in general, better or worse, for women than before the energy system was installed?

  1. MUCH BETTER FOR WOMEN
  2. BETTER FOR WOMEN
  3. NO DIFFERENCE
  4. WORSE FOR WOMEN
  5. MUCH WORSE FOR WOMEN

- How about job opportunities for women, do you think they are, in general, better or worse than before the energy system was installed?

  1. MUCH BETTER FOR WOMEN
  2. BETTER FOR WOMEN
  3. NO DIFFERENCE
  4. WORSE FOR WOMEN
  5. MUCH WORSE FOR WOMEN

- The system is reliable and works most of the time

1. AGREE
2. UNCERTAIN
3. DISAGREE

- Information about the system is always available to the people of the community

1. AGREE
2. UNCERTAIN
3. DISAGREE

- When the system fails, authorities take action to fix it immediately

1. AGREE
2. UNCERTAIN
3. DISAGREE

- You pay a fair amount of money for electricity

1. AGREE
2. UNCERTAIN
3. DISAGREE

- In general, life is easier since the installation of the hybrid energy system

1. AGREE
2. UNCERTAIN
3. DISAGREE

- Do you perceive any negative environmental effects from the hybrid system?

    1. NO
    2. YES
    3. NOT SURE

If YES, explain the nature of the effects____
____
____
____
____

- Would you recommend a similar system to other villages in Mexico?

  1. YES
  2. NO

- Would you be willing to pay a higher energy cost if the hybrid system becomes fully renewable system in the future?

  YES
  NO

Demographic Information

The following questions are asked for your personal information. You may not answer these if you do not feel comfortable. This is strictly for research purpose and will not be identified with your name or address.

- How many members does your immediate family include? __________

- What is the highest level of education held by any member of your family?

0	1-6 YEARS
1	7-9 YEARS
2	10-12 YEARS
3	H.S. GRAD
4	SOME COLLEGE
5	ASSO. DEGREE
6	BACH. DEGREE
7	GRAD OR PROF.
8	DK
9	NA

In which of these groups did your total **family** income, from all sources, fall last year, 2001, before taxes, that is?

$601-$1000	$4601-$5000	$8601-$9000
$1001-$1400	$5001-$5400	$9001-$9400
$1401-$1800	$5401-$5800	$9401-$9800
$1801-$2200	$5801-$6200	$9801-$10200
$2201-$2600	$6201-$6600	$10201 +
$2601-$3000	$6601-$7000	
$3001-$3400	$7001-$7400	
$3401-$3800	$7401-$7800	
$3801-$4200	$7801-$8200	
$4201-$4600	$8201-$8600	THANK YOU!

Appendix 2. CFE data on Baja California Tariffs and Billable Demands

1997	Charge per kilowatt of billable demand	Charge per Kilowatt hour in peak	Charge per kilowatt hour in intermediate	Charge per kilowatt hour in base	Charge per kilowatt hour in semi-peak
January	$ 49.98400	$ 0.95229	$ 0.22199	$ 0.18845	$ 0.41303
February	$ 52.14300	$ 0.99343	$ 0.23158	$ 0.19659	$ 0.43087
March	$ 50.40100	$ 0.96025	$ 0.22385	$ 0.19002	$ 0.41648
April	$ 48.57100	$ 0.92539	$ 0.21572	$ 0.18312	$ 0.40138
May	$ 46.50700	$ 0.88606	$ 0.20655	$ 0.17534	$ 0.38430
June	$ 48.30200	$ 0.92026	$ 0.21452	$ 0.18211	$ 0.39913
July	$ 49.44700	$ 0.94207	$ 0.21960	$ 0.18643	$ 0.40859
August	$ 49.86700	$ 0.95008	$ 0.22147	$ 0.18801	$ 0.41206
September	$ 49.89700	$ 0.95065	$ 0.22160	$ 0.18812	$ 0.41231
October	$ 51.46900	$ 0.98060	$ 0.22858	$ 0.19405	$ 0.42530
November	$ 53.29600	$ 1.01541	$ 0.23669	$ 0.20094	$ 0.44040
December	$ 54.61800	$ 1.04059	$ 0.24256	$ 0.20592	$ 0.45132
Average	$ 50.37517	$ 0.95976	$ 0.22373	$ 0.18993	$ 0.41626
1998					
January	$ 54.97300	$ 1.04735	$ 0.24414	$ 0.20726	$ 0.45425
February	$ 52.91200	$ 1.00807	$ 0.23498	$ 0.19949	$ 0.43722
March	$ 52.42500	$ 0.99880	$ 0.23282	$ 0.19765	$ 0.43320
April	$ 52.52500	$ 1.00070	$ 0.23326	$ 0.19803	$ 0.43402
May	$ 51.32700	$ 0.97788	$ 0.22794	$ 0.19351	$ 0.42412
June	$ 50.57800	$ 0.96360	$ 0.22461	$ 0.19068	$ 0.41793
July	$ 51.49900	$ 0.98114	$ 0.22870	$ 0.19415	$ 0.42554
August	$ 52.66800	$ 1.00341	$ 0.23389	$ 0.19856	$ 0.43520
September	$ 53.03700	$ 1.01043	$ 0.23553	$ 0.19995	$ 0.43825

October	$ 52.58100	$ 1.00174	$ 0.23350	$ 0.19823	$ 0.43446
November	$ 56.34100	$ 1.07336	$ 0.25020	$ 0.21240	$ 0.46555
December	$ 57.95800	$ 1.10417	$ 0.25738	$ 0.21850	$ 0.47891
Average	$ 53.23533	$ 1.01422	$ 0.23641	$ 0.20070	$ 0.43989
1999					
January	$ 57.80700	$ 1.10130	$ 0.25671	$ 0.21793	$ 0.47766
February	$ 56.75500	$ 1.08126	$ 0.25204	$ 0.21396	$ 0.46897
March	$ 56.51700	$ 1.07672	$ 0.25098	$ 0.21306	$ 0.46700
April	$ 55.81600	$ 1.06337	$ 0.24787	$ 0.21042	$ 0.46121
May	$ 55.83300	$ 1.06369	$ 0.24794	$ 0.21048	$ 0.46135
June	$ 57.75900	$ 1.10039	$ 0.25649	$ 0.21774	$ 0.47727
July	$ 59.54400	$ 1.13439	$ 0.26442	$ 0.22447	$ 0.49202
August	$ 61.33000	$ 1.16842	$ 0.27235	$ 0.23120	$ 0.50678
September	$ 63.27400	$ 1.20546	$ 0.28098	$ 0.23853	$ 0.52284
October	$ 66.40000	$ 1.26501	$ 0.29486	$ 0.25031	$ 0.54867
November	$ 67.06400	$ 1.27766	$ 0.29781	$ 0.25281	$ 0.55416
December	$ 69.38400	$ 1.32187	$ 0.30811	$ 0.26156	$ 0.57333
Average	$ 60.62358	$ 1.15496	$ 0.26921	$ 0.22854	$ 0.50094
2000					
January	$ 69.59200	$ 1.32584	$ 0.30903	$ 0.26234	$ 0.57505
February	$ 66.98900	$ 1.27625	$ 0.29747	$ 0.25253	$ 0.55354
March	$ 67.92700	$ 1.29412	$ 0.30163	$ 0.25607	$ 0.56129
April	$ 70.14100	$ 1.33631	$ 0.31146	$ 0.26442	$ 0.57959
May	$ 73.33200	$ 1.39711	$ 0.32563	$ 0.27645	$ 0.60596
June	$ 74.26300	$ 1.41485	$ 0.32977	$ 0.27996	$ 0.61366
July	$ 77.62700	$ 1.47894	$ 0.34471	$ 0.29264	$ 0.64146

August	$ 79.32700	$ 1.51133	$ 0.35226	$ 0.29905	$ 0.65551
September	$ 77.89100	$ 1.48397	$ 0.34588	$ 0.29364	$ 0.64365
October	$ 78.16400	$ 1.48916	$ 0.34709	$ 0.29467	$ 0.64590
November	$ 78.85000	$ 1.50230	$ 0.35010	$ 0.29730	$ 0.65160
December	$ 78.94000	$ 1.50400	$ 0.35050	$ 0.29760	$ 0.65230
Average	$ 74.42025	$ 1.41785	$ 0.33046	$ 0.28056	$ 0.61496
2001					
January	$ 82.46000	$ 1.57110	$ 0.36610	$ 0.31090	$ 0.68140
February	$ 87.62000	$ 1.66950	$ 0.38900	$ 0.33040	$ 0.72410
March	$ 78.88000	$ 1.50290	$ 0.35020	$ 0.29740	$ 0.65180
April	$ 76.14000	$ 1.45070	$ 0.33800	$ 0.28710	$ 0.62920
May	$ 77.24000	$ 1.47170	$ 0.34290	$ 0.29130	$ 0.63830
June	$ 76.39000	$ 1.45550	$ 0.33910	$ 0.28810	$ 0.63130
July	$ 73.16000	$ 1.39390	$ 0.32480	$ 0.27590	$ 0.60460
August	$ 70.25000	$ 1.33840	$ 0.31190	$ 0.26490	$ 0.58050
September	$ 69.77000	$ 1.32920	$ 0.30970	$ 0.26310	$ 0.57650
October	$ 69.15000	$ 1.31740	$ 0.30690	$ 0.26080	$ 0.57140
November	$ 70.33000	$ 1.33990	$ 0.31210	$ 0.26530	$ 0.58120
December	$ 72.78000	$ 1.38650	$ 0.32300	$ 0.27450	$ 0.60140
Average	$ 75.34750	$ 1.43556	$ 0.33448	$ 0.28414	$ 0.62264
2002					
January	$ 72.74000	$ 1.38560	$ 0.32280	$ 0.27440	$ 0.60100
February	$ 72.37000	$ 1.37850	$ 0.32120	$ 0.27300	$ 0.59790
March	$ 69.66000	$ 1.32690	$ 0.30920	$ 0.26280	$ 0.57550
April	$ 70.67000	$ 1.34610	$ 0.31370	$ 0.26660	$ 0.58380
May	$ 75.10000	$ 1.43050	$ 0.33340	$ 0.28330	$ 0.62040

June	$ 77.62000	$ 1.47880	$ 0.34460	$ 0.29280	$ 0.64120
July	$ 81.00000	$ 1.54310	$ 0.35960	$ 0.30560	$ 0.66920
August	$ 84.56000	$ 1.61100	$ 0.37540	$ 0.31900	$ 0.69880
September	$ 84.51000	$ 1.61000	$ 0.37520	$ 0.31880	$ 0.69820
October	$ 86.06000	$ 1.63960	$ 0.38210	$ 0.32470	$ 0.71100
November	$ 89.91000	$ 1.71290	$ 0.39920	$ 0.33920	$ 0.74280
December	$ 93.03000	$ 1.77230	$ 0.41310	$ 0.35100	$ 0.76860
Average	$ 79.76917	$ 1.51959	$ 0.35413	$ 0.30093	$ 0.65902
2003					
January	$ 93.82000	$ 1.78740	$ 0.41660	$ 0.35400	$ 0.77510
February	$ 94.36000	$ 1.79780	$ 0.41900	$ 0.35610	$ 0.77960
March	$ 96.96000	$ 1.84740	$ 0.43060	$ 0.36590	$ 0.80110
April	$ 103.92000	$ 1.98000	$ 0.46150	$ 0.39220	$ 0.85860
May	$ 107.58000	$ 2.04970	$ 0.47770	$ 0.40600	$ 0.88880
June	$ 107.25000	$ 2.04330	$ 0.47620	$ 0.40470	$ 0.88600
July	$ 102.70000	$ 1.95670	$ 0.45600	$ 0.38750	$ 0.84840
August	$ 98.16000	$ 1.87020	$ 0.43580	$ 0.37040	$ 0.81090
September	$ 99.60000	$ 1.89770	$ 0.44220	$ 0.37580	$ 0.82280
October	$ 102.18000	$ 1.94690	$ 0.45370	$ 0.38550	$ 0.84410
November	$ 104.32000	$ 1.98760	$ 0.46320	$ 0.39360	$ 0.86170
December	$ 103.97000	$ 1.98080	$ 0.46160	$ 0.39230	$ 0.85880
Average	$ 101.23500	$ 1.92879	$ 0.44951	$ 0.38200	$ 0.83633
2004					
January	$ 104.90000	$ 1.99840	$ 0.46570	$ 0.39580	$ 0.86640
February	$ 106.39000	$ 2.02680	$ 0.47230	$ 0.40140	$ 0.87870
March	$ 107.17000	$ 2.04160	$ 0.47570	$ 0.40430	$ 0.88510

April	$ 109.02000	$ 2.07690	$ 0.48390	$ 0.41130	$ 0.90040
May	$ 113.16000	$ 2.15580	$ 0.50230	$ 0.42690	$ 0.93480
June	$ 116.89000	$ 2.22690	$ 0.51890	$ 0.44100	$ 0.96540
July	$ 120.56000	$ 2.29680	$ 0.53520	$ 0.45480	$ 0.99570
August	$ 123.78000	$ 2.35810	$ 0.54950	$ 0.46690	$ 1.02230
September					
October					
November					
December					
Average	$ 112.73375	$ 2.14766	$ 0.50044	$ 0.42530	$ 0.93108