BUILDING SUSTAINABLE HOUSING ON THE U.S.-MEXICO BORDER: INSIGHTS FROM TECATE, BAJA CALIFORNIA




U.S.-Mexico border

Any brief overview of the demograph... economic forces propelling ... in the U.S.-Mexico border re... around the city of Tecate reveal ...his is a region that is unde tremendous pressure of change. Th editor of *El Bordo, Retos de Frontera,* website where numerous scholarly ar ticles are presented by academics and investigators, (Ungerleider Kepler, undated), describes the rationale for thi effort as follows: "*Creemos que exist una gran necesidad, aquí en la frontera norte de nuestra nación, de estudios y trabajos serios de investigación que puedan esclarecer y/o cuestionar la compleja realidad socio-económica y política que estamos viviendo. Por tanto, lo que pretendemos es fomentar la discusión, el debate y el diálogo en torno a los problema que nos conciernen como académicos y fronterizos.*". (We believe that a majo necessity exists, here on the northern border of our nation, for studies and serious works of investigation that ar able to clarify and/or question th complete socio-economic and politica reality [in which] we are living. Certainly, what we propose is to fomen discussion, debate, and dialogue regarding the problems that concern us as academics and inhabitants of the border.

HEMALATA C. DANDEKAR

There are implications of thes changes for the quality of housing and the quality of life enjoyed by residents in the U.S.-Mexico border and a window of opportunity to set in place regulation, guidelines, incentive and assistance to protect what a city such as Tecate enjoys currently. Ther are additional forces related to culture

U.S.-Mexico border

BUILDING SUSTAINABLE HOUSING ON THE U.S.-MEXICO BORDER:

INSIGHTS FROM TECATE, BAJA CALIFORNIA

School of Planning
College of Design
Arizona State University
P.O.Box 872005, Tempe, AZ 85287-2005

Manuscript Editor: Vivienne Armentrout
Graphic Design: Robert Cao-Ba

BUILDING SUSTAINABLE HOUSING ON THE U.S.-MEXICO BORDER: INSIGHTS FROM TECATE, BAJA CALIFORNIA

Hemalata C. Dandekar

Table of Contents

FIGURES

Acknowledgements

The primary body of research which informs this monograph was supported by the Southwest Center for Environmental Research and Policy (SCERP). The SCERP Board of Directors and SCERP Managing Director Rick Van Schoik have demonstrated extreme patience given an attenuated time line in bringing this project to completion. Dr. Paul Ganster, long-standing SCERP Board Member, has provided critical counsel at key junctures of this effort. The author is appreciative of this opportunity to engage in a deeply interesting and changing region on the U.S.-Mexico border.

The SCERP project culminated in a technical report titled *Housing and Sustainable Communities in Rapidly Urbanizing Border Regions*. The report emphasizes an analysis of existing housing in informal communities and the technical options for building sustainable housing which can serve to mitigate the negative impacts of informal housing settlements on the environment. This monograph draws heavily from, and builds on, this report. It organizes the findings so that they are accessible to a lay and concerned audience. It also contextualizes the challenges and possibilities of building sustainable housing in the border region within trends and concerns regionally and nationally.

The research team consisted of three faculty researchers: Dr. Harvey Bryan, School of Architecture, Arizona State University; Dr. Kenneth D. Walsh, Department of Civil and Environmental Engineering, San Diego State University; and, the author, Dr. Hemalata C. Dandekar, School of Planning, Arizona State University. They were assisted by four graduate assistants: Ernesto Fonseca; Paloma Giottoninin Badilla; Claudio Munõz Whiting; from Arizona State University, and Aaron Portilla, San Diego State University. The four students brought insight and creativity to the field data collection and the analysis of the literature and government

documents. All four are native speakers of Spanish, an important facility in communicating with constituencies in the City of Tecate. Dr. Bryan and Mr. Fonseca had major responsibility for the research on materials addressed in Chapter Five. Dr. Walsh and Mr. Portilla had major responsibility for the research on construction process and inventory of existing housing in El Rincon and El Descanso addressed in Chapter Three. The author and Ms. Giottoninin Badilla had major responsibility for the research on cultural factors and housing overview addressed in Chapters One and Two. The author and Mr. Munõz Whiting had major responsibility for the research on energy efficient approaches to housing design addressed in Chapter Four. The author appreciates the insight and commitment the team brought to the project and is grateful for their efforts. Melina Dempsey, a graduate student in the School of Planning at ASU, had sole responsibility for field investigation of colonias in Yuma County, Arizona and Imperial County, California. The author is grateful for the rigor and organization she brought to the task.

In the City of Tecate, Fundación La Puerta and its former Executive Director Mario Salzmann provided generous support and encouragement to work in the city. Architect Eduardo González Aguirre, Director of Urban Administration, Tecate provided data, insight and historical context. Mr. Cosme Cazares Burgueno, Regidor, (Municipal Council, Tecate) encouraged us to work in El Rincon and provided introductions to residents and leaders of the El Rincon neighborhood. The community leaders in El Rincon were friendly and welcomed the research team during the data collection phase. The author appreciates their generosity and the opportunity to engage in the efforts to maintain the quality of life and fabric of a unique city on the U.S.-Mexico border.

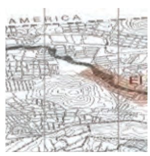
For this monograph, Robert Cao-Ba was responsible for graphic design and layout, and also assisted greatly in production of the printed document under a tight schedule. Vivienne Armentrout served as the manuscript editor and helped to ensure a consistency and smooth flow across the disparate sections of the monograph.

Hemalata C. Dandekar, Ph.D.
Professor and Director, School of Planning,
College of Design
Arizona State University, Tempe, Arizona

December 2006

Introduction





Increasing attention is being given within the United States of America to its border with Mexico. While such issues as national security in the post-9/11 era, securing the border against illegal immigration, and effects of the North American Free Trade Agreement (NAFTA) on bilateral trade have been dominant nationwide, in the Southwest region of the U.S. there is also recognition of the impact of the rapid growth of the informal communities which have emerged on the border. This phenomenon, which has social, spatial, and environmental aspects, is only partially understood. The quantity and quality of the housing in these communities is of particular concern. The report *Current Housing Situation in Mexico 2005*, which takes a macro, national, look at the housing sector in Mexico, particularly its finance, states that "Despite the huge efforts made in 2004 to make housing more accessible, there is still a significant sector of the population that remains unattended—specifically, families in rural or informal sectors." The report emphasizes the continued need for housing people with low incomes and states, "New housing technologies related to environmental sustainability and energy saving, such as water-saving systems, systems for recycling grey water and sewage water treatment, electrical and thermal energy savers, among others, must be incorporated." The report fails however, to mention approaches in building design and construction which also achieve significant long-term energy efficiencies and contribute to savings in water utilization and energy consumption. These approaches are referred to in the planning and architecture literature as "green" and sustainable. They have been embraced at city and state levels in the U.S. and incentive structures for their adoption are in place. The Pacific Northwest Pollution Prevention Resource Center (PPRC) is an excellent source of information on good examples and the City of Scottsdale Green Building Program is one case of a

Figure 1: El Rincon and El Descanso colonias in Tecate – by the U.S.-Mexico Border

Figure 2: Sustainable Park Designs for El Rincon and El Descanco, Tecate

voluntary regulatory and incentive structure that has proved effective for the specific city context. A few cities such as Boulder, Colorado have instituted mandatory green building requirements.

Green technologies are just one facet of building sustainable housing. Sustainability is context and site specific and is derived from an understanding of technical factors such as climate, soil and vegetation type, water and materials availability; social factors such as culture, history, community and class; economic factors such as productive capacity, skills and income; and organizational factors such as structures of governance regulation and the status and power of resident groups. Given a supportive context, sustainable housing can be attained through judicious choices in the design of the housing units themselves; in their orientation and configuration of layouts; in the materials of construction and their assembly and finish; and in the choice and location of landscaping and ground cover. Furthermore, choices leading to sustainability need to be made by institutions in both the private and the public sectors and by individuals and the community. In short, building sustainable housing requires multiple actors and multiple commitments.

This monograph details the results of research intended to introduce sustainable housing approaches into an informal community or *colonia* (see Chapter Two, p.15) settled on the railroad right of way in El Rincon, city of Tecate, Baja California, Mexico. The research was conducted by a team of faculty researchers and graduate students and supported by the Southwest Center for Environmental Research and Policy (SCERP). The research led to an understanding of the social, cultural, demographic, and economic factors affecting housing choice in this community, and the physical conditions and construction methods used in the current housing stock. It then considers a variety of factors that contribute to construction of sustainable housing, including design principles and materials selection. Finally, it describes two prototype sustainable houses that were built on the basis of these principles and outlines the characteristics for designing such housing in *colonia* communities such as in El Rincon.

The history of this inquiry illustrates the complexity of such an enterprise and the necessity of bringing all potential stakeholders and players together for success. The El Rincon *colonia* community presented itself as a site for investigation of housing needs through a serendipitous set of encounters. The Tecate River, part of the Tijuana River Watershed, runs through the city, defining its urban image and form. Its historical character of being a natural source of pristine water has been threatened. The river corridor was designated in the city plan as an area needing significant attention. River water was dammed upstream rendering the river dry as it entered the city. Grey water and discharges into the riverbed made for a polluted water flow downstream. In 2003, Fundación La Puerta sought advice from the Department of Landscape Architecture at California State Polytechnic University, Pomona. Faculty and graduate students developed a document titled "Tecate River Park: A Framework for an Urban River Environment in Tecate, Mexico." Building on this project, officials from the City of Tecate and the Director of Fundación La Puerta approached the School of Planning and Landscape Architecture (SPLA) at Arizona State University (ASU) for technical assistance in addressing the problem and opportunities of the Tecate Riverfront, a project for which no public resources or relevant skills were available within the city.

Six design solutions for two urban eco-parks along the river were developed in a SPLA Landscape Architecture Studio at ASU in Fall Semester of 2003. Two sites, El Rincon and El Descanso, were selected according to the Urban Development Plan of the City of Tecate. As a result, a monograph entitled Urban Eco-Parks in Tecate, Baja California, México was developed (Dandekar et.al., 2004) which was used as a decision-making tool by the City of Tecate and as a funding instrument by Fundación La Puerta and was awarded the ASLA Arizona Chapter Professional Design Award in Fall 2004 in the Communications Category (Figure 2).

In the process of executing the work, the research team was asked by the residents and community leaders in the El Rincon neighborhood to develop strategies for improvement of their housing and settlement. At the time, community residents were very hopeful that they would acquire the right to land on which their homes were located. In anticipation of acquiring land tenure they hoped to initiate the process of consolidating and upgrading their houses. There was a compelling possibility of evolving design solutions which would aid in developing informal housing in ways that made for long term sustainability. The El Rincon neighborhood was an attractive study site because it had a significant housing need and a mobilized active community with strong leadership which was committed to obtaining improved housing and settlement security. Residents lived in substandard housing on land fronting the Tecate River on the western outskirts of the city which was the railroad right-of-way. Lacking legal tenancy but having political support from representatives on the City Council of Tecate, the neighborhood appeared to be on the way to obtaining security of land tenancy. Residents were planning to make home improvements and upgrade following legalization of land tenure. They were interested in, and thus offered an opportunity for, implementing the findings of this research in prototype housing constructions which could be designed with stakeholder input.

Post-election changes in the composition of the Tecate City Council in 2005 resulted in changed agendas for the City and new leadership and mission for the Department of Urban Administration. The El Rincon community's aspiration to legalize their land tenancy and engage in housing consolidation was no longer supported by the Tecate City Council. Instead, the Council moved to level, regrade and redesign the river banks near the community, making access to that area more difficult. Construction of prototype housing units exemplifying sustainability attributes in El Rincon was no longer feasible.

The findings of the research continue to have relevance for communities such as El Rincon where residents seek to better their quality of life by improving their housing and surroundings in ways to reduce ongoing energy costs. Finding ways to improve, upgrade and construct housing in *colonia*s so as to make it sustainable and energy efficient will serve not only to improve the quality of life of *colonia* residents but to reduce the negative environmental impact of human settlement growth in the region. The technical analysis completed on housing in El Rincon, and the design approach that was delineated was applied by graduate student assistant Ernesto Fonseca, working with the Stardust Center for Affordable Housing in the design and construction of two prototype housing units in

Guadalupe, Arizona and Nageezi, New Mexico, which are presented here; other prototypes constructed on these sustainability principles are also mentioned.

There is great potential on both sides of the U.S.-Mexico border to move prevailing housing construction practices toward more sustainable, low environmental impact modes. There is a range of shelter and settlement activity in the private and the public sectors. If government policy and regulatory practice could encourage adoption of the principles delineated here and in other cited work for building housing to enhance environmental sustainability, the reduction in energy costs would benefit not only homeowners but would also improve the quality of life for all residents in the U.S.-Mexico border region.

Through the case study investigation of the housing and infrastructure realities in El Rincon, this monograph develops information of interest to those individuals and communities designing and constructing sustainable, energy efficient, low environmental impact housing in the entire region. It seeks to facilitate the design and building of housing and human settlements that are energy efficient, design appropriate, economically feasible, minimize impacts on the environment and fulfill the desires and aspirations of the local community. It addresses the particular realities and concerns of housing construction for lower-income families. This is the segment of the population which is particularly addressed in the assessment of trends in housing construction and in the examples offered to illustrate sustainable construction approaches. An inventory of technical information related to community planning, housing design and construction is provided. It is hoped that this information is useful for lay stakeholders engaged in housing and community construction and development. The goal is to assist in the making of appropriate technical choices in layout, building envelope, materials, and utilities and infrastructure that will lead to construction of more sustainable housing and community settlements.

CHAPTER ONE

Cultural Factors Shaping Housing at the U.S.-Mexico Border



Any brief overview of the demographic and economic forces propelling growth in the U.S.-Mexico border region around the city of Tecate reveals that this is a region that is under tremendous pressure of change. The editor of *El Bordo, Retos de Frontera*, a website where numerous scholarly articles are presented by academics and investigators, (Ungerleider Kepler, undated), describes the rationale for this effort as follows: *"Creemos que existe una gran necesidad, aquí en la frontera norte de nuestra nación, de estudios y trabajos serios de investigación que puedan esclarecer y/o cuestionar la compleja realidad socio-económica y política que estamos viviendo. Por tanto, lo que pretendemos es fomentar la discusión, el debate y el diálogo en torno a los problemas que nos conciernen como académicos y fronterizos."* (We believe that a major necessity exists, here on the northern border of our nation, for studies and serious works of investigation that are able to clarify and/or question the complete socio-economic and political reality [in which] we are living. Certainly, what we propose is to foment discussion, debate, and dialogue regarding the problems that concern us as academics and inhabitants of the border).

There are implications of these changes for the quality of housing and the quality of life enjoyed by residents in the U.S.-Mexico border and a window of opportunity to set in place regulation, guidelines, incentives and assistance to protect what a city such as Tecate enjoys currently. There are additional forces related to culture, identity, a sense of belonging, and ownership as well as security which also have great implication for the kind of housing individuals, families and communities chose to live in and build. Some of these are explored here with a view to determining their importance and implications in building sustainable housing.

Figure 3: Community Stakeholders of El Rincon - Needing Sustainable Housing
Figure 4: El Rincon Children Walk to School on an unpaved road by the Tecate River
Figure 5: Women of El Rincon Discuss Community Housing and Infrastructure Needs

Identity

The cultural identity of the Mexicans continues to be discussed some 500 years after the Spanish conquest. The question is very much alive in the border region, where most of the population arrived as recently as the1950s. This is particular true of the population in the western states of Baja California, Sonora and Chihuahua. Local culture and traditions in this region consist largely of a mix of several cultures brought by the new immigrants to this region. The result is often in contradiction to the rest of Mexico's accepted, traditional culture. Nonetheless, as Maria Socorro Tabuenca, a writer from Ciudad Juárez, states, even when "Mexicans embody multiple identities—individual, regional, and national ones […] that does not make them less Mexican." (Ruiz 1998, p. 101). Specifically in the border area, the mix of cultures is a phenomenon which is intensified both by the proximity of this region to the United States and the great distance of the region from the country's 'historic cultural core'—Mexico City. In the border region, "Mexicans interact with another's way of life and, sooner or later, invariably adopt aspects of its values and aspirations" (Ruiz, 1998, p. 104) This factor is reinforced by the fact that most migrant newcomers bring with them the a desire to improve their lives and this is sometimes interpreted as needing to leave behind everything they are and believe in, and adopting and adhering to a foreign culture and lifestyle.

For most residents of the Mexican side of the U.S.-Mexico border region, particularly those who have spent a continuous period of time in the border region, their new communities provide them with new tight social interactions which are a source of economic and social support. "In many ways, border communities feel closer to their cross-border neighbors than to Washington or Mexico City, or even to their state capitals." (Hernández 1992). This sense of belonging, even when for some their time in the border region is temporary, has conferred a specific regional identity to these communities. It is one where people feel bound together as they face problems and share aspirations and achievements.

Northern Culture

For the Mexican population in general people in the western states of the country are perceived as "raw" and there is a prejudiced perception that they lack in cultural and intellectual capacity. This prejudice applies even more strongly to the U.S.-Mexico border cities, which central Mexicans are reputed to describe as a place with nothing to see and nothing to do.

"All you have in Ciudad Juárez, —a person from Central Mexico tells a native of that city— is El Paso. Chilangos, Mexicans from Mexico City, talk of the tijuanazo, the cultural shock that meets them upon arriving in Tijuana, a city so at variance with others in the republic" (Ruiz, 1998, p. 101). Given that Tijuana was some time ago known as the "sin city" of California, and is now crowded with a migrant population from a wide array of cultural backgrounds, some temporarily in the city trying to cross the border into the United States, others trying to find a job in the maquiladoras, it is no surprise that a unique culture has arisen in the city, one that is reflective of the U.S.-Mexico border region. It is a common perception of people who live in distant places in the Mexican republic, and even for some citizens of Baja California, the state in which Tijuana is located, that Tijuana is a different place, one they don't identify with.

"...the way of life on the border compared to lifestyles in other parts of the republic is a world apart. True, proponents of this view admit that the most learned did not migrate north; rather, it was the restless and audacious, eager to strike out on their own. As one local writer explains, border society amalgamates cultural roots carried by migrants from all over the republic. The northern way of life evolved on the margins of the cultural imperialism of "Tenochtitlán," mother of Mexico City snobbism, imitating neither the Yankee model nor others. The configuration of northern society rests on the integration of and receptivity to Mexican regional variations, modified by daily contact with a neighboring country." (Ruiz, 1998, p. 102).

It is useful to analyze this perception considering that Tijuana is growing continuously in the direction of the city of Tecate. This is not only a physical reality but also, possibly, a social and cultural reality. If culture is defined as the sum of activities and behaviors which characterize a group or organization, then border culture does exist, but it is indeed at variance with the general culture of Mexico further to the south. It might be described as an "in-between" culture of recent formation. People from the border regions are seen as "Americanized" Mexicans. They are blamed for carrying on a foreign way of thinking, an American way of living, which tends to be more individualized and less focused on social issues, and which goes opposite to the ideals of the rest of the country. "Precisely because of that, for a majority of Mexicans the defense of the national culture starts at the border" (Ruiz, 1998, p. 101).

In contrast, the perception of the locals, who are long-standing residents of the border region, is that "southerners, the recently arrived, are the most prone to fall in love with American consumerism" (Ruiz, 1998, p. 102). The population in the border communities which have been settled for a longer time are characterized as modern, hard working and willing to take greater risks than other Mexicans. "They are more ambitious and believe that hard work and frugality pay off" (Ruiz, 1998, p. 102). Mexicans have an attraction for the northern border of the country. Years ago it was because of, and for, tourism. Now it is because of the potential for work and an increased income, especially through work in the maquiladoras.

Maquiladoras and the Transitional Dwelling

In Mexico the manufacturing industry for export production, also known as maquiladoras or la maquila, has been perceived to be highly profitable. It has been seen as conferring great economic growth and benefit for the communities where it locates. International companies have selected border towns to establish their industries due to the advantages of location near the border with the U.S. which significantly reduces transportation, communication and installation costs, and for other incentives provided for industries by the Mexican government. But even when maquiladoras bring many advantages, especially in regions where no other option for economic development seem to be available, their economic success is sustained as a result of salary scales that hardly surpass the legal minimum wage. This is revealed in economic indicators for border cities like Tijuana which reveal relatively high poverty levels and precariousness or insecurity which do not correspond to and are at odds with the higher level of economic activity and industrial development in the region (Canales, 1999). While Tijuana has one of the most active and dynamic economies in the country, this is not reflected in the quality of life enjoyed by the majority of its population.

According to Ruiz Vargas and Aceves Calderón, "even though (Tijuana) was characterized as a zone of opportunities and the required access point towards the American dream", nowadays it "presents poverty indices lower than those of other large cities in the country, inequity and social decline have began to transform its urban physiognomy, especially in the last two decades". In spite of this, Tijuana is still an attractive magnet for Mexicans of the south who migrate to Tijuana and other similar border cities, looking to improve their lives, at least economically. This attraction has had an impact not just on the city but on the surrounding region too.

This impact and effect is noticeable in Tecate where we perceive a greater marginality than expected relative to the size of the town. Though the presence of "misery belts" as they have been described in the literature is a recurrent phenomenon in proximity to the large cities in Mexico, it is not so observable in smaller towns, where a more sustainable development is obtained almost organically due to the relatively slower, more natural scale of growth. Similar "misery belts" surround other maquila-towns along the border, such as Mexicali, Nogales, Ciudad Juárez, etc; to the point that it has been suggested that maquila industries require this type of development in order to sustain themselves. In their essay, Pobreza y Desigualdad Social en Tijuana, Ruiz Vargas and Aceves Calderón state four factors which, from their perspective, contribute to generating situations of poverty and inequity in this region:

1. Income levels and their relationship with labor, inflationary levels and cost of living.
2. Income distribution which demonstrates an inequity in the concentration of wealth.
3. Quality and form (construction) of dwellings and infrastructure problems.
4. The presence of human settlements in risk zones and natural hazards due to an unplanned and exclusionary urban growth, which usually coincides with low-income populations.

These factors, especially the third and fourth, are present in most border cities and are ones that planners and architects are increasingly attentive to in the Southwest region of the U.S. (Teddy Cruz, 2006, Gidwitz, 2006, Necessity Housing, 2006). Some border cities do not have a comprehensive plan for development, and, when they do, the implementation is not supported, or falls behind the impact and consequences of accelerated demographic growth. A decisive factor is also the perception of the inhabitants as well as of the authorities that these settlements are only temporary habitation. Settlements along the border are supposed to be transitory and are treated as such, even when the length of stay in them becomes extended as a consequence of particular circumstances. This is one of the reasons why such settlements are poorly constructed, their level of maintenance is low, and minimum living conditions are hardly attained.

The literature indicates that the migrants think of their "real" home as the one that was left behind and think of the dwellings in the border city merely as transitional lodging—its sole function being to satisfy the basic need of protection from the environment. Often the maquiladoras provide basic services such as showers to keep their workers content and healthy. This has the effect of developing worker dependency on the work place for meeting basic services. It ties the worker to the place of employment and acts as a deterrent to workers making improvements to their dwellings.

In terms of architectural identity, migrants are portrayed in the literature as longing for the home left behind, dreaming of going back, sure that real life is waiting back home. Even though that usually does not happen, this sensibility can be perceived to be reflected in their mode of housing construction. Over the period that migrants establish a new life in the border, changes in their housing, observed through time, might be construed to reflect their changing sensibility to place. Starting with housing constructed of cardboard which might be improved with the addition of wooden pallets and then a few bricks, the house will consist of one multiuse room. A sheet metal or galvanized iron roof may be added. No glazed windows will yet be in place. Rather, the openings in the walls for a door and window will be covered by pieces of cloth or cardboard. With time, and if legality of tenure and land occupancy is obtained, the construction will evolve to more permanent, better quality materials. Connections to electrical services will be established. Usually water and sewer are the last services to which access is obtained, preceding the construction of paved access alleys and roads.

According to researcher Eloy Méndez (Méndez, 2003) an urbanist from Colegio de Sonora in Hermosillo, the neighborhoods in these newly formed cities consist of dwellings which are constructed in ways that eliminate people's sense of belonging to place. This disassociation is expressed in the generic morphology and use of the spaces in these neighborhoods which erase any cultural identity and create an urban fabric which is incapable of affirming itself as a place, and a dwelling dispossessed of the facility to make sense. Méndez asserts that this brief and transient occupation promotes the denial of place. In his paper, whose title in translation is "Physical and social space in the Mexico-USA border region", Méndez states that the social nature of the migrant living in the border cities promotes the establishment of fragile spaces, rapidly changing signs, polyvalent symbolic identifications, and volatile morphologies. These scenarios are based in local communication codes based on conventions subtracted from their original places. The self-constructed neighborhoods materialize and make tangible the occupant's possibilities (of activities, aspirations, representations, of being); they are erected as the result of the repetition of a series of activities in the same site, which will continue to be repeated indefinitely. In these terms, the dwelling becomes an anonymous recipient lacking of any significance. Coincidentally, in the interviews that Méndez carried out, he finds that the border residents perceive the regional architecture as temporary, transient, improvised, out of time and place, and without identity.

Méndez later argues that the identity of the house in the border settlements expresses the consciousness of the ephemeral passing. Always present in the memory or the migrant is the closeness to the other country (U.S.) and the place of origin. Even when there is a desire to give a Mexican identity to their dwellings, imported materials and building procedures are clearly incorporated in these structures. This is especially true in Tijuana where the acquisition of pieces of and sometimes even complete dwellings, usually from San Diego, is frequently observed. What has been termed a "filtering" process from north of the U.S.-Mexico border to south of materials, construction types, recycled materials and modules of housing manufactured and otherwise is apparent. Cruz (2006) states "Two completely different urbanisms expressing two different attitudes toward the city have grown up in reaction to the phenomenon of the border. If San Diego is emblematic of the segregation and control epitomized by the master-planned communities that define its sprawl, Tijuana's urbanism, evolved as a collection of informal, nomadic settlements or barrios that encroach on San Diego's periphery." He notes the Tijuana speculator who travels to San Diego to buy up little bungalows that have been slated for demolition to make space for new condominium projects. The houses are loaded onto trailers and travel to Tijuana. He says, "For days, one can see houses, just like cars and pedestrians, waiting in line to cross the border."

CHAPTER TWO

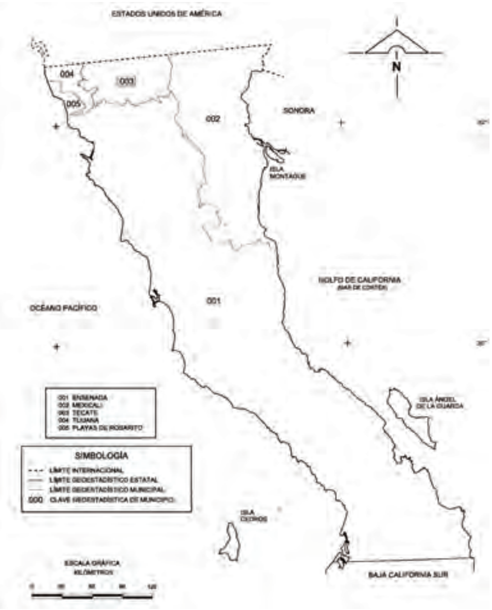
Overview of Housing in Tecate, Baja California

The City of Tecate, Baja California faces challenges because of its location just beyond the edge of the expanding Tijuana metropolitan region. While the local government has sought to retain the quality of life and ambience of a small Mexican border town, it is threatened by an increase in the population of the region and a proliferation of *colonias*, informal communities housing low-income migrants who have often been drawn by the maquiladora economy. In order for the community to meet this challenge and also to provide adequate living conditions for both old and new residents, it is important to understand the state of the housing supply as it exists.

GEOGRAPHIC SETTING

The City of Tecate, Baja California is located on the western edge of the U.S.-Mexico border in the northern Mexican state of Baja California (Figure 6). It is just east of the coastal city of Tijuana. The city has a smaller counterpart, Tecate, California, across the border in the United States.

As in every Mexican state, Baja California is divided into municipalities which are the equivalent to counties in the U.S. Each municipality has a main city, which is called the "head of the municipality". These municipalities include rural and urban areas, and are the basic sub-state administrative unit in Mexico. The municipality of Tecate is the third largest in geographic area (Figure 7) and the fourth largest in population counts of the five municipalities in the State of Baja California (North). Its main city is the City of Tecate.



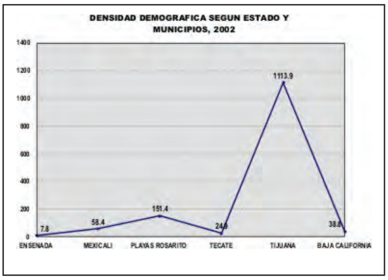


Figure 6: Location of Tecate
Figure 7: Municipalities in the State of Baja California
Figure 8: Urban Density in Municipalities of Baja California

Economic Characteristics

Baja California is a state known for its maquila-oriented economy and also for the fact that the population density in its rural areas is low, especially towards the southern end of the state. In the northern part of the state a majority of the population concentrates in cities along the border, particularly in the large cities of Tijuana and Mexicali. The phenomenon of growth of border cities is long-standing (Peach and Williams 2003) but has been particularly significant in the past decade, since the implementation of the North American Free Trade Agreement (NAFTA) between Canada, the United States and Mexico in 1994 (Peach and Williams 2000). The strategic location of the border cities such as Tecate has facilitated the introduction of maquiladora (manufacturing) industries, which have promoted economic development and increased the attractiveness of the city for immigrants in search for jobs and a better quality of life.

Cuamea Velázquez and Gerber (in Ganster et al. 2002) provide a detailed overview of economic activity in Tecate. They point out that the long-term economic boom in northern Mexico has been led by the maquiladora sector and associated companies. Employment in the maquiladora sector in Baja California has not been limited to the two most urban municipalities of Tijuana or Mexicali. Although Tecate is the most rural of the municipalities in Baja California it has a more concentrated manufacturing economy than both the nation and the state. In 1998 Tecate's manufacturing sector accounted for 61 percent of total employment and the bulk of this (95.4%) was accounted for by the maquiladora sector (Cuamea Velázquez and Gerber, in Ganster et al. 2002).

Population

Tijuana and Mexicali have experienced exponential population growth. This in-migration in search of jobs has brought with it a need for housing and presented challenges in instituting rational systems of urban planning and provision of housing and infrastructure. To some extent the City of Tecate, Baja California has escaped proliferation of low-income marginal housing,

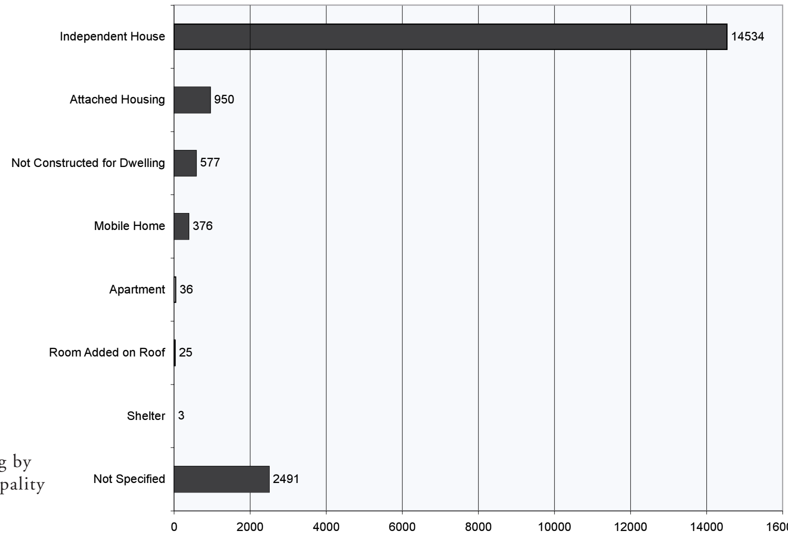


Figure 9: Private Dwelling by Type in Municipality of Tecate

Source: Municipality of Tecate, Department of Urban Administration

inadequately provided with infrastructure, because the interaction between the two countries across the border at Tecate has been significantly lower than in Tijuana and Mexicali. Access to Tecate, California (U.S.A.) is by two-lane roads, and the town is much smaller than Tecate, Baja California, Mexico. Nonetheless, the elected political leadership of the City of Tecate is well aware that the city is currently in the line of Tijuana's growth towards it to from the west. It has begun to experience the effects and problems of uncontrolled growth and urbanization.

In 2000 the Municipality of Tecate had a population of 77,795 inhabitants (CONAPO 2000), which represented only the 3.1% of the population of the State of Baja California. The characteristics of the population are similar to the rest of the state with one exceptions—a much larger share of the population in Tecate Municipality (32.7%) lives in rural areas as compared to that of Ensenada (18.4%) and the largest Municipalities of Tijuana (0.9%) and Mexicali (13.4%). Tecate, located between the cities of Tijuana and Mexicali, is under pressure from their growth, especially on its western edge where the border with Tijuana is close and the urban population is rapidly expanding.

Growth Rate and Urban Density

In the 1990s, the state of Baja California and the municipality of Tecate grew faster than the country as a whole. From 1995–2000, the Tecate Region had an annual growth rate of 4.4%, which is well above the 1.4% population growth rate for Mexico and the 3.3% for the Baja California region (INEGI 2000). In the second half of the 1990s, Tecate's growth rate exceeded that of the state's by 1.1% and the nation by three percentage points (Cuamea Veláquez and Gerber in Ganster, 2002). Despite this growth one of the factors that helps Tecate maintain its 'small town' character is its low population density. Even when 67.3% of the population of the Tecate municipality lives in the city of Tecate, the municipality has a relatively low density of 24.98 people per sq. kilometer (64.69 people per sq. mile). Compared to the state's average density of 35 people per sq. kilometer (Figure 8), and the neighboring municipality of Tijuana's density of 1113.9 persons per sq. kilometer, Tecate's low density offers a great opportunity for the City of Tecate to develop in a sustainable way so as to maintain a high quality of life. However, this comparative advantage is threatened. The presence and expansion of the maquiladora industries have attracted a worker population to the city and increased the need and demand for housing. The city of Tijuana is rapidly expanding towards Tecate as its working population seeks habitable land for housing construction.

Figure 10: Occupancy Levels and Housing Type Municipality of Tecate

Number of occupants	Total	Independent House	Apartment	Attached Housing	Mobile Home
1	1355	1102	52	60	69
2	2450	2074	122	94	56
3	3158	2645	183	126	76
4	3788	3187	241	138	91
5	2984	2579	183	73	54
6	1627	1424	89	50	12
7	807	717	40	16	7
8	398	343	23	11	7
9 and more	513	463	17	9	4
Total	**17080**	**14534**	**950**	**577**	**376**

Figure 11: Households in the Municipality of Tecate by Family Type 2000

	Household Type	Total Households of Type	Households with Men as Head	Households with Women as Head
Family Households		15725 (91%)	12881	2844
	Nuclear	11566	9919	1647
	Extended	3737	2645	1092
	Integrated	305	222	83
	Unspecified	117	95	22
Non-family Households		1547 (9%)	1082	465
	Individual	1403	973	430
	Shared	144	109	35
	Unspecified	16	13	3
Total		**17288**	**13976 (81%)**	**3312 (19%)**

Figure 12: Provision of Water, Sewer and Electricity to Regularized Private Housing Units in Tecate

	Inhabited Private Houses	With Piped Water	With Sewer	With Electricity
State	559402	499982	458047	543561
Municipality	17080	13744	14518	16173
City of Tecate	11780	11332	11306	11689
Percentage Houses within City Served		96.2	96.0	99.2

Source Figures 10, 11 & 12:Municipality of Tecate, Department of Urban Administration

Housing Characteristics in Tecate

In 2004 there were 19,020 dwellings in the City of Tecate (CONAPO 2004). The City Department of Urban Administration estimated that at that time this represented a deficit of around 4,000 dwelling units (personal interview with Architect Eduardo German Gonzalez Aguirre, Urban Administration Director, November 1, 2004).

Housing Type

As illustrated in Figure 9, the dominant category of housing in the City of Tecate is private housing (99.85%), collective housing accounts for a negligible 0.15% of the total number of units. The majority (76.5%) of dwelling units are detached or independent houses. The second most common housing type is an apartment located in a building (5%), followed by attached housing (3%) also called "vecindad" and mobile homes (2%). The clearly indicated preference for individual housing units is also reflective of the fact that the density in this municipality is low. Interventions and suggestions for improvements towards sustainability must take note of this preference.

Occupant (Household Size) and Housing Type

As shown in Figure 10, the average occupancy per dwelling is 4.1 persons in the Municipality of Tecate. Units in apartment buildings consist predominantly of 2 to 5 inhabitants and attached housing units of 2 to 4 inhabitants. More than 18% of the units of mobile homes are occupied by single persons. Some explanation of this is the fact that there is a migrant population and it is relatively easer to obtain this type of dwelling unit given its "temporary" nature and price.

HOUSEHOLD COMPOSITION

As shown in Figure 11, an overwhelming majority (91%) of households in Tecate consist of family units with nuclear families (74%) predominating and another 24% living in extended family units. Also, a majority of households in Tecate (81%) have a male head of households. Thus the families in this area are fairly typical of the rest of the country. There are however, some 19% of households which are headed by women. This is a significant indicator because of the various reasons that women in these households have particular needs of their housing and community. In these households, in informal *colonia* settlement such as El Rincon, women often have to assume the responsibility for earning income, rearing children, and, sustaining the relationships within the community that are key to enjoying a safe and secure life. Their ability to do so is powerfully shaped by their housing (Dandekar, 1993).

Urban Public Services

Alegría and Castro Ruiz (in Ganster et al. 2002) provide a detailed description of the urban public services available in Tecate. They point out that potable water and sewage systems are managed by the State Public Services Commission of Tecate (Comisión Estatal de Servicios Públicos de Tecate – CESPTE), which is a decentralized state agency. Tecate also has a storm water drainage system which covers approximately 15% of the urban area. This service is under the responsibility of the municipal government (INPRODEUR). They point out the difficulties faced by the municipality in billing and regulating clandestine users of the services. The provision of electricity is Mexico's most complete service at the urban level and the fact of clandestine users remains an issue. As Figure 12 indicates, over 90% of regularized private housing units in Tecate are served with water, sewer, and electricity.

Colonia Housing

While the term *colonia* has its origins in the Spanish word for "neighborhood," in the U.S. it has come to refer to a residential development characterized by substandard living conditions such as a lack of access to potable water, sanitary sewer systems, paved roads, and standard mortgage financing. Definitional issues of what exactly constitutes a *colonia* pose a challenge (Mukhija and Monkkonen, 2007, Huntoon and Becker, 2001). While communities with high poverty rates and substandard living conditions exist throughout the U.S. and Mexico, *colonia* advocates contend that the *colonia* phenomenon is really a unique problem tied to the intertwined border economy between the two sovereign nations of Mexico and the United States. They posit that *colonias* in the U.S.-Mexico border region have become strategic locations where populations with low incomes have sought to fulfill their aspiration for access to housing and for home ownership through self-help. *Colonias* are often unincorporated communities located along the U.S.-Mexico border. Although numerous *colonias* developed in the 1950s, they remained relatively unnoticed until the 1980s. A 1983 Border Environmental Agreement between Mexico and the United States defined the "border region" as a zone within 100 kilometers, or 62 miles, on either side of the political boundary. The Environmental Protection Agency (EPA) began to address environmental issues of common concern through this agreement on cooperation between the two nations. Most of the families in *colonias* have limited resources with which to finance the construction of standard housing. This fact, coupled with an inability of government to enforce land use and zoning regulations, subdivision laws, and, building codes have resulted in the proliferation of informally constructed housing developments (Dandekar and Dabir, 2001).

Because of deficits in housing and infrastructure, residents of *colonias* tend to produce a disproportionate amount of environmental pollution. Practices such as the burning of garbage, and the burning of hazardous materials (such as tires) for heating and cooking tend to produce air pollution. The absence of sewers combined with substandard latrine construction causes waste to pollute the local area and eventually drain into local aquifers. Water shortage and contamination, air pollution, raw sewage, lack of solid waste disposal systems, and lack of appropriate infrastructure for small scale, income-generating activities with resulting environmental pollution, are some of the major environmental problems that characterize *colonias*. These conditions lead to public health concerns. Residents of *colonias marginales* or *colonias precarias* (the term which is often used for settlements in Mexico which are low income and have poor quality housing) are consequently at increased risk from environmental hazards associated with air pollution, inadequate plumbing, poor access to clean water, and makeshift sewage disposal systems (Sadalla et al., 1998.)

Because so many of these public health problems are associated with housing conditions in the *colonias*, improving these environments will help to improve environmental conditions and quality of life in the U.S.-Mexico border areas.

CHAPTER THREE

Characteristics of Housing Construction in Tecate colonias



The quality of housing construction in border *colonias* and the impact of this on the environment and on the health, safety, and quality of life of their inhabitants stems directly from the methods of construction of these dwellings, the materials used, and their design. These were investigated for two Tecate communities, El Rincon and El Descanso, which included *colonia* settlements. Conditions in these were compared to those in other *colonias* located in the border region and for the border region overall.

The characteristics of housing construction observed firsthand in El Rincon and El Descanco is similar to those of the general settlement and habitats in *colonias* of the U.S.-Mexico border. A relatively detailed review of selected *colonias* in and around Nogales, Sonora, based on surveys conducted in the selected *colonias*, provides a snapshot of construction and design practices in that region (Sadalla et al., 1998). Comparisons confirm that the findings in El Rincon and El Descanco are similar to observations further east in and around Nogales. Of the houses in the Nogales study area, 57% of the dwellings were composed primarily of wood, 32% of brick block or cement, and 3.3% of cartons/paper, while the rest were comprised of amalgamations of materials, including found materials.

Building on such findings the El Rincon and El Descanco *colonias* studies probed the means, methods and quality of housing construction especially regarding the range of materials and construction methods used; the sources of materials; the contractual methods and mode of construction and the capacity to create quality shelter; the diversity and capability of the contractor and subcontractor communities; and the prevalence of own-account or self-help housing. This information on the existing physical and social infrastructure, the economics of housing

Figure 13-19: Pictures of Housing in El Rincon

CAMERA 10		Place	Time	Comment
1			2:10 PM	Anabel Valdez. She does not like from her house that it does not have floor or light
2			2:10 PM	Anabel Valdez. She does not like from her house that water leaks through the roof and walls
3			2:15 PM	Maria Felicitas Moreno. She does not like from her house that it leaks
4			2:18 PM	Maria Felicitas Moreno. She does not like that water runs through her land when it rains

Figure 20: Pictures of Housing in El Descanso

Figure 21: Residents of El Rincon Photograph and Comment on their settlement

delivery, and the comfort levels and sustainability or lack of housing in the region provides a basis for assessing how a reconfiguration of the residential supply chain can more directly incorporate sustainable design and construction into colonia housing stock.

The presence of a large fraction of wood housing is surprising given the prevalence of concrete and masonry in formal housing in the region. The sources of these materials ranged from purchased to found materials, with a significant fraction of materials consisting of items found within a short distance of the colonia. The Nogales data indicated that approximately 60% of the floors in the study area were made of concrete (Sadalla et al., 1998).

Neighborhood infrastructure was quite variable. Very few of the residents sampled reported that they lived on paved streets. Only 7.9% of the areas self-reported the presence of pavement. The majority of the residents in this area arranged to have electricity in their homes. Overall, 80.8% of the sample reported some type of electrical connection, often informal or unregistered. The majority of dwellings in the surveyed *colonias* did not have a sewer connection. Thirty-one percent of the residents reported a sewer connection, while 69% reported no sewer connection. Residents who are not connected to a sewer system reported the use of latrines for the disposal of human waste. Based on observations of the area, latrines reportedly varied considerably in terms of quality of construction. However, a very large fraction were reportedly constructed in dense, rocky soil with poor drainage characteristics. Survey data indicated that houses with a sewer connection typically have piped in water; the fraction of houses reporting a water connection was identical to that reporting a sewer connection. Sadalla et al. (1998) point out that the conditions in the *colonias* they studied led to behaviors that were damaging to health and environment for the colonia residents and the surrounding communities. This concept was amplified by Davidhizar and Bechtel (1999).

Lumber is used elsewhere in the border region for the low income market. Lumber companies in Matamoros, Mexico had put into practice a decent and affordable housing for low income market by selling simply-constructed houses (Transborder Shelter Network 1998a). Their typical product measures 12 ft by 20 ft and includes 4 to 5 windows, and two wooden doors. The structures are pre-fabricated at the lumber company, then are transported by truck to the purchaser's lot and placed on top of their foundation. By laying a concrete foundation, the owner improves the stability of the house. No climate control methods are provided. This housing is considered a low-income or "starter" product, but is installed in formal settings and as such, must meet minimum sanitary requirements within the city of Matamoros.

The Fraccionamiento Voluntad provides a similar example located to the southwest of Mexicali (Transborder Shelter Network 1998b). At this location, new housing prototypes were constructed which were equipped with electrical and public lighting service. The housing units include 27 square meters, built with a multi-use room which can be divided with a wood or sheetrock wall. The typical lot covers an area of 160 square meters, which allows space for future expansion of the structure. A latrine is included in the housing to meet sanitary requirements. The structures were constructed with concrete block walls on a reinforced concrete foundation, and waterproof three-ply roof. Electrical service was provided in surface-mounted polyduct. The housing came without climate control equipment, but some ventilation was provided via anodized aluminum windows.

Some large tract developers have attempted to enter the low income market for *colonias* in the El Paso, Texas region (Transborder Shelter Network 1998c). These homes have been developed using prevalent U.S. technology of dimensional lumber combined with concrete masonry block, atop reinforced concrete floors and foundations. This market has been approached in some cases with specialized machinery and equipment to facilitate the efficient construction of homes and development of efficient supply chains. Some climate control methods have been implemented in the construction of houses, and housing is commonly constructed with fiberglass roll insulation. The El Paso example included the development of a master-planned community, with additional neighborhood amenities such as a community center. This level of housing appears to be quite unusual for the market (Davidhizar and Bechtel, 1999; Koerner, 2002)

Outside of the formal tracts as described above, there are also informal settlements in Texas (Cisneros, 2001). Houses often begin as tents or makeshift structures of wood, cardboard or other material. The houses are primarily built by residents little by little using found materials. As their finances allow, the owners add improvements, and rarely use professional builders. Many of today's colonia residents use septic tanks and cesspools; which are often at odds with the building and environmental regulations common in the area.

Housing Characteristics in El Rincon and El Descanso, Tecate

The Tecate region is primarily a hot arid climate. There are four microclimates in the region. The largest microclimate experiences average temperatures in the range of 12° C and l8° C. Owing to topographic features the temperature is somewhat variable, with some areas experiencing winter season temperatures averaging 4° C and some experiencing summer temperatures averaging up to 22° C. From a climate control perspective, cooling loads are dominant, although winter heating can be necessary for short periods, especially in the night-time hours. Average annual precipitation ranges from 150 to 300 millimeters. The winds are predominantly from the south and west.

The superficial soils in the region are mostly rocky. Fertility is quite variable, depending to a great extent on the availability of water. In the higher reaches of the landscape, litosols support pasturing and forest use. Land use is a mixture of industrial and hospitality, farming, and a mix of low-rise retail and residential sectors. The industrial use is concentrated predominantly in the urban zone of the city of Tecate. Brewing and viticulture are important industries. The region is an important tourist destination, with a number of hotels and spas, and several areas for outdoor camping.

According to the General House and Population Census of 1980, the municipality had 30,540 inhabitants, who represented 2.6% of the state population 0.04% percent of the national population, and was (somewhat) disproportionately young. The density of population as of that census was 9.9 inhabitants per square kilometer. The city grew at an annual rate of 5.2 percents for the decade of 1970–1980. The urban population represents two thirds of the municipal population and it is concentrated, mainly, in the City of Tecate. By the time of the General House and Population Census of 2000, the municipality had grown to 77,795 inhabitants (mostly in the city), now representing 3.1% of the population of the state.

The increase in population has brought upward pressure to the housing stock. Housing is predominantly provided via the private sector. According to the General Census of Population and Housing of 2000, the municipality had 19,020 dwellings, 90.9% of these were private properties. Most of the houses surveyed had electrical service, but water and sewer service were provided at a lower rate than elsewhere in the State. While the housing materials included concrete, block, and brick, wood frame housing was most common. The city provides electrical power, public lighting, police, and fire in addition to a range of social services.

Although all *colonias* were originally located outside the city, many are relatively close to the city and some have been annexed by it. This pattern of annexing relatively poor, substandard residential pockets of poverty on the periphery of cities has produced an urbanization pattern in which these pockets of settlements provide inadequate tax resources and relatively large population density, making the increase in services required extremely difficult to satisfy. For example, the 1990 census reveals that water service was inconsistently provided in *colonias* within the city, with 23% of owner-occupied units reporting no treated water in the house. The use of untreated water for drinking, washing,

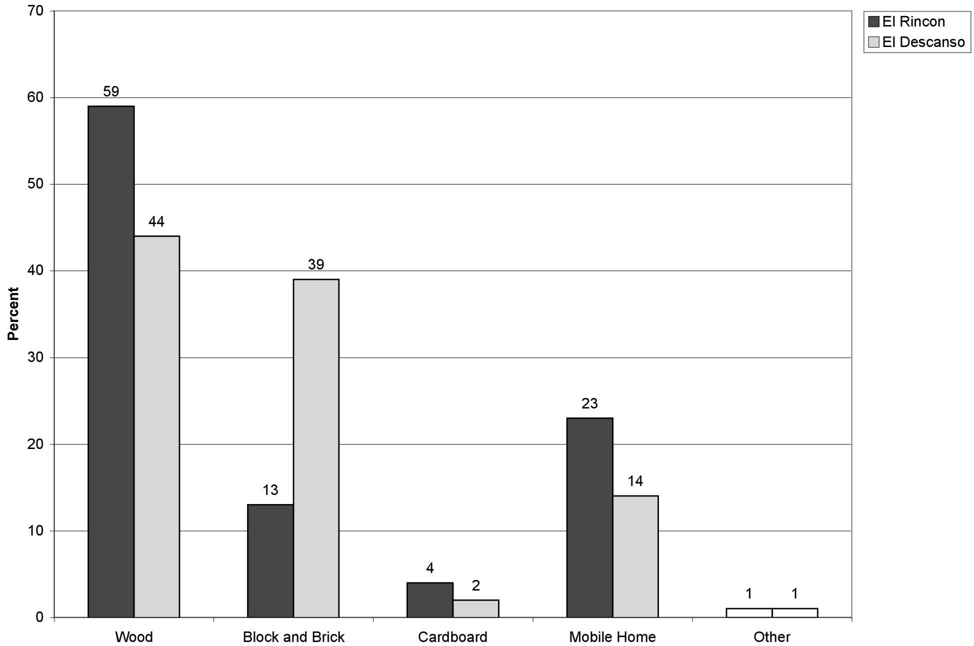


Figure 22: Primary Materials Used in House Construction in El Rincon and El Descanso

bathing and cooking ranged from 4% to 13% of households. The 1990 Census further indicates that approximately 50% and 20% of houses in rural and urban *colonias*, respectively, had incomplete plumbing facilities while 40% and 15% lacked complete kitchen facilities.

Site observations taken in 2004 in two Tecate *colonias*, El Rincon and El Descanso, revealed the methods and materials of construction of dwellings; the availability of services to the dwellings; the climate control methods employed; the regulatory policies that applied to construction standards; the capabilities of the local construction workforce; and, the general function of the construction services sector, as well as the construction materials supply chain. This provides insights into the production system currently in place in Tecate and the resulting housing and settlement products.

El Rincon Community

This residential area was characterized by substandard living conditions based on a sample of 175 houses. Of the houses in the El Rincon area, 59% were composed primarily of wood, 13% of brick or concrete block, 4% of paper carton, and 23% were pre-manufactured (mobile homes or recreational vehicles), with the small remaining fraction consisting of amalgamations of found materials (Figure 22). Most dwellings seemed to have been built with local materials. There were some hardware outlets located close to this area and some, smaller scale ones were attached to dwellings within El Rincon.

The quality of the wood varied considerably in the majority of the houses which were built with wood products. A significant number incorporated a used garage door into the building envelope, and could only be described as informal constructions. Other wooden houses in the area had a more formal appearance, but were old and deteriorated. Houses ranged from about 25 to 100 square meters. Some homes had portable air conditioners installed in a window or through the wall.

A few houses were in the process of construction. These did not have a visible (required) construction permit issued by the authorities. Residents of this area said that the local authorities do not inspect construction within El Rincon. Houses constructed with wood were often stuccoed, with a layer of paper and a layer of metal lath used for backing. Insulation and climate control equipment were not observed on these homes. Construction seemed to be conducted by the residents, sometimes with the assistance of family or friends.

The majority of dwellings in the colonia did not have a sewer connection although residents reported that a main sewage system was installed to serve the area two years ago. Reportedly only a few dwellings actually completed a sewer connection as they lacked the financial means. Residents who were not connected to a sewer system used latrines for the disposal of human waste. Latrines varied considerably in terms of quality of construction. Virtually all were situated in dense, rocky soil a few feet from the dwelling, although only a few houses seemed to have their latrines incorporated into the dwelling. Houses with a sewer connection typically had piped water, while houses without a sewer connection relied on buckets and water tanks. The majority of the residents in this area had arranged to have some type of electrical connection, although many of these were informally obtained from nearby overhead wires.

A pilot study to capture the sensibilities of El Rincon residents was made by distributing disposable cameras to ten residents and asking them to take pictures of the home and surroundings to document what they liked, were concerned about, and would like to change, in their immediate neighborhoods (Figure 21). This study indicated that 68% of residents placed a high priority on improving their dwellings, while 20% expressed a high priority for improved services. Other wishes were more parks and playgrounds (5%), more schools or churches (3%), and cleaning up the Tecate River (3%).

El Descanso

The El Descanso area exhibited better planning and housing conditions. Some of the streets were paved, and had curbs and gutters to control storm water. A sample of 175 houses was observed in order to obtain a breakdown of the construction materials used in existing housing units in the area (Figure 22).

Approximately half of the houses made out of brick, block, or concrete were two stories. In some of these houses, the second floor was made out of wood. Houses made using brick, block, or concrete were supported on stone foundations. This material is abundant in Tecate. Roof construction and maintenance was clearly a significant problem in the region. Significant numbers of residents and/or contractors were observed performing roof repairs during the visit.

In contrast to El Rincon, in El Descanso the dwellings observed under construction were being built by contractors. In most cases these were informal arrangements with individual tradesmen, and it appeared that typically two to three construction tradesmen were hired to perform the construction. Based on interviews and observations, it appeared that the work was performed without plans or any formal building inspection process. Workers reported that they built the houses according to owners' specifications, usually communicated verbally on a frequent basis. Several homes were observed being enlarged; construction of a small starter structure by a contract labor force, with later expansion, appeared to be a common technique.

El Descanso has electricity, storm drainage and piped fresh water. The majority of the houses in the area had a sewer connection. Residents who were not connected to a sewer system used latrines for the disposal of human waste, although latrines were rarely seen in this zone.

Materials Used in Housing Construction and Sustainability

The lines of small San Diego bungalows waiting to cross into Tijuana by truck (Cruz, 2006) are emblematic of a flow of used and reused materials, appliances, equipment, manufactured homes and recycled houses and house parts which filter across the border and serve to provide shelter and homes to residents south of the border. An examination of the characteristics of the residential housing production system currently in place in Tecate reveals similar flows of materials and structures.

The 2000 Mexican census (INEGI, Instituto Nacional de Estadística, Geografía e Informática), estimated that there were more than 3.9 million homes in the six states of northern Mexico. Many of these houses were located in irregular, or non authorized settlements lacking services and offering extremely poor living conditions. The statistical information compiled by INEGI on housing construction materials used in homes in the six Mexican states bordering the U.S. includes the category “other materials”, meaning many irregular, recycled, reused materials ranging from cardboard, resold older mobile-homes, old resold campers, scrap wood and other salvaged materials. 20% or roofs and 14% of walls of homes in these states are made of such “other materials”.

INEGI data for the state of Baja California reveals that 25% of homes use wood in the walls and 61% use it in roofs. This lumber consists mostly of salvaged materials and the walls and roofs lack insulation, creating severe thermal discomfort in the homes. The problem of using wood in the U.S.-Mexico border region is the extreme climate where temperatures commonly reach highs of 40º C or more in the summer, and lows below freezing in the winter. This climate makes small houses very warm most of the year and quite cold in the winter. In addition over 70% of low-income colonia houses along the Mexican border built with blocks and bricks use ones that are only 14 cm wide. Although concrete blocks have good thermal and mass properties they are still not sufficiently thick to moderate indoor temperatures. Most irregular settlements like El Rincon do not conform to any construction codes. Most of the housing is of poor quality and provides very poor thermal protection which is even worse than un-insulated brick homes. The typically low (2.1 meter) average ceiling height compounds heat problems in the summer by greatly concentrating and trapping heat. Not only are residents’ comfort levels low but there are resulting health problems.

Source of Construction Materials in Tecate

Few construction materials are produced locally in Tecate. Materials are largely brought in from Mexicali and, more significantly from Tijuana. Much of Tecate’s commercial activity is clustered in and around the city of Tecate, the rest of the municipality having virtually no commercial activity apart from small tienditas (small local grocery stores). Most of the businesses in Tecate limit themselves to the basic goods of daily consumption and a very small fraction of the business community is involved in selling construction goods. There are approximately five hardware stores, only one of which specializes in the sale of wood and lumber.

The formal construction industry still uses mostly traditional materials for housing. Managers of construction materials stores and local developers who were interviewed reported that brick and concrete are the material of choice. They noted that the reason most low-income families use wood on roofs is because it is cheaper and requires less time to construct than is required for pouring concrete roofs. Over 90% of families temporarily build their homes, completely or in part, using wood, with the objective of rebuilding, as soon as they can afford to, with construction materials, such as brick and concrete. INEGI reports nearly 61% of wood roofs statewide. In the community of El Rincon the research team found almost 59% of homes utilized wood as the primary material of construction. Homeowners in the community reported that as soon as their land occupancy was regularized and legalized they would start to rebuild with concrete and block or brick.

Information obtained from the five major hardware and construction material stores in Tecate (Ferretodo [2 stores], Materiales Jimenez, Materiales Gomez and Tarimas del Toro) indicated that over 80% percent of the wood used for low-income housing is salvaged from construction sites in the United States. Some businesses buy truck loads of old disposed wood and sell it in Mexico for multiple uses such as the construction of housing, for forms needed for concrete construction and even furniture. This trade in recycled wood from the United States does not benefit local businesses that sell traditional materials nor those that sell wood and similar kinds of materials locally.

EL RINCON

The El Rincon community consists of approximately 1000 inhabitants, about 300 low-income families. Housing and settlement conditions are irregular and out of code. During the time of the field survey local and federal governments were in the process of deliberating whether to grant the irregular component of the community full legal land tenure. The residents cooperated with and were eager to participate in the survey as they hoped to be able to implement some of the design parameters that would be suggested in improving their housing if tenancy rights were obtained. The housing conditions of El Rincon needed attention at every level from urban planning, house design to material selection. The sample of 175 houses surveyed to determine the types of materials used in construction (Figure 22) reveal that the majority of the materials used for housing construction on the unregulated settlement of El Rincon were salvaged materials that do not offer any substantial thermal mass and/or good thermal properties. Many of these houses were built with single layers of plywood, old doors, second-hand lumber boards and cardboard. None of the materials used met construction codes and/or city regulations. The main conditions for thermal comfort are air temperature, radiant temperature, air speed and humidity, To achieve healthy indoor comfort, a combination of good thermal mass and insulation is needed. None of the needed thermal conditions were met in any of the surveyed homes. Single layer material for walls and roofs that allow air infiltration are a basic problem in these improvised houses. Examples of the types of materials that are being used in home construction in El Rincon are illustrated in Figures 23–26.

Climate and Weather

The municipality of Tecate can reach extreme temperatures over the summer and winter seasons. In September 1972 it registered a record of 34.9° C and then in August 1985 another record of 35.6° C. In February 1972 the Comision Estatal de Aguas (CEA State Water Commission) registered a low of -1.2° C. In winter these low temperatures can be exacerbated by rain. From November to March the region can get up to 337.8 mm of rainfall, which makes for very uncomfortable living conditions for people living in homes which lack proper insulation and sealed, non-leaking roofs. Weather conditions must be factored in order to make appropriate selection of construction materials. Average temperature readings over the year for the City of Tecate are shown in Figure 27.

Environmental Comfort

Indoor temperatures in the types of structures observed in El Rincon are not ideal for achieving an acceptable and healthful environment. It is important to understand thermal comfort so that recommendations on construction materials can be developed. Figure 28 delineates the periods during the year when temperatures in Tecate fall above 81° F (dark yellow) or below 68°F (blue) which is the comfort range defined by ASHRAE. The diagram illustrates that both heat and cold must be contended with in Tecate and shows the time of the year when heat or cold is a problem.

The thermal environment can be evaluated with simple calculations or by using computer simulation models. Full-scale laboratory testing could be developed to evaluate real operational temperatures for the existing houses in the El Rincon community. However information gathered from a sample of 30 heads of family revealed the thermal comfort levels that were experienced by the residents. The survey corroborated what the comfort zone chart (Figure 28) indicates. Most of the families surveyed stated that both low and high temperatures were a major problem in their community. The PPD indicator, or percentage of people dissatisfied, recorded rates of over 90%, especially among the elderly and minors. Cold temperatures were reported as the main discomfort factor. Residents reported that warmer temperatures could be reduced by using electric fans, and manipulating fenestration (opening and shutting doors and windows at appropriate times).

Figure 29 illustrates the different environmental factors within a house that affect El Rincon families the most. Most of the thirty




Figure 23: House Constructed of Second-Hand Salvaged Doors
Figure 24: Interior Side of Exterior Wall Constructed of a Single Layer of Plywood Board
Figure 25: House Constructed of Used Plywood Sheets and Wood Boards
Figure 26: Outhouse Constructed of Single Layer of Recycled Wood Boards

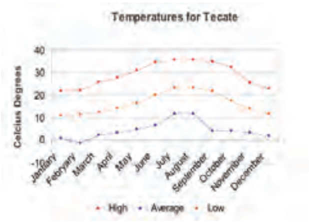


Figure 27: Average Temperature Readings for the City of Tecate Source: La Puerta station from CEA

Figure 28: Tecate Comfort Zones Source: Ernesto Fonseca

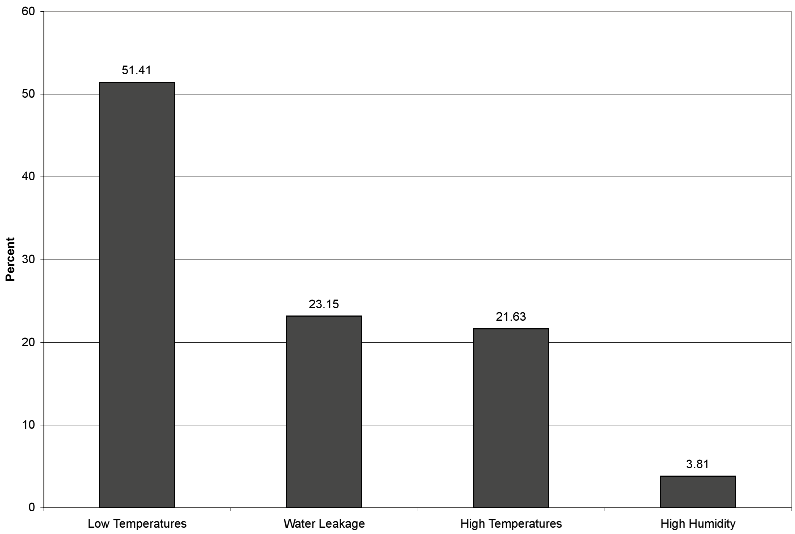


Figure 29: Factors Causing Environmental Discomfort in Homes

households interviewed reported that it was much easier to adapt and/or to tolerate warm and high temperatures, but that it was not possible to tolerate or protect against extreme low temperatures. Humidity was not reported as an important issue, but some people reported that even though it was not a major problem, it would be useful to design housing taking into consideration humidity rates during the summer.

It is clear that inhabitants of the two communities studied would benefit from housing designed to maximize comfort under the climatic conditions that exist in Tecate. Sustainable design for these dwellings would minimize the use of energy and use appropriate materials. Concepts and applications for such design and material use are provided in the next two chapters.

CHAPTER FOUR

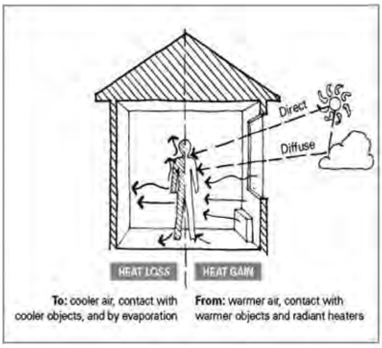
Energy Efficiency through Housing Design

A passive design approach to energy efficiency and climate control is preferred when designing for lower-income populations needing affordable housing, as it generally entails fewer maintenance and replacement costs. The existing literature in planning, architectural design, materials and technology, and infrastructure reveals a variety of physical solutions that integrate design and planning decisions to achieve physical comfort using nonmechanical systems that have low energy consumption. In conceptualizing applications for settlements such as El Rincon in Tecate, passive approaches are useful as they offer a blend of choices to achieve sustainability yet meet the criteria of affordability, climatic responsiveness and social acceptance. The guidelines and approach to housing and community design described here can assist in making selections from a variety of possible technical options for efficiency. Choices need to be sensitive and to respond to the economic and cultural context of the U.S.-Mexico border. The criteria applied to assess sustainable housing solutions are:

- Capacity to generate affordable solutions.
- Capacity to meet minimum aesthetic characteristics which are in accordance with community preferences and social norms.
- Capacity to respond to Tecate's local climate.

The different stages in the design of a building and its neighborhood move from a general approach to settlement layout to the details of designing units. Passive energy conservation aspects are evaluated in terms of their energy savings, comfort capacities, feasibility of application, as well as their ability to be combined with other approaches. Aspects to be considered are:

- Community layout.
- House design.
- Construction materials.
- Waste and water management.



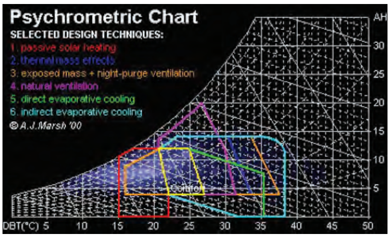


Figure 30: Schematic of Passive Heat Gain and Loss (Source: Australian Greenhouse Office 2004)
Figure 31: Psychrometric Chart for Passive Design Techniques
(Source: A.J. Marsh. Cardiff University, Welsh School of Architecture)

Human Thermal Comfort

Protection of the fragile human body from the natural surroundings is necessary for survival, and thus shelter is understood to be a basic human need. Access to adequate and secure housing is perceived as a fundamental requirement for physical and psychological health and comfort. Human beings are physically comfortable within a very narrow range of conditions. The human body temperature must remain at a constant 36.9º C. The body generates heat—even while at rest. It must lose heat at the same rate as it generates it. Factors which influence human comfort are: temperature, humidity, air movement (both positive breezes and negative drafts), exposure to radiant heat sources, and available cool surfaces to radiate heat to when cooling is desired.

Human settlement in climate zones that are outside human comfort zones rely heavily on energy-consuming systems of climate control within human shelter. In developed countries mechanical techniques of heating, cooling and air ventilation are applied to achieve comfort, an approach unaffordable in a less-developed context. The need for passive systems and smart design to attain those levels of comfort is an essential component of the vision for a sustainable future. To be effective, the design of the envelope of human shelter must be tailored to suit a particular climate, significantly improve comfort levels, and reduce heating and cooling expenses (Figure 30).

The specific environmental characteristics that influence construction patterns in Tecate include:

Climate:	Hot dry, warm winter.
Rainfall:	Distinct wet and dry seasons. Low rainfall and low humidity.
Temperature:	Hot summers are common and there is significant diurnal (day/night) range. In winter mitigating against cold is important.

Passive Design

Homeowners pay considerably more in heating and/or cooling when they do not take advantage of inexpensive heating and cooling from passive design. Passive design systems are ones that that do not require mechanical systems for cooling and/or heating, but instead take advantage of natural energy flows to maintain thermal comfort. Using less power to perform needed functions is energy efficient. Passive design for energy efficiency aims to reduce energy consumption, maintenance and capital costs; produce less environmental impact; and enhance occupant comfort and health (US DOE 2004). Efficient use of energy helps to reduce fuel expenses and reduces atmospheric emissions of gases caused by the burning of fossil fuels. It thus helps to combat climate change and improves air quality (Energy Saving Trust 2003).

The systems that use passive design solutions are grounded in the basic understanding of heat flows through materials and air. Essentially there are three mechanisms by which temperature is transmitted: conduction, convection, and radiation. Conduction is the molecule-to-molecule transfer of kinetic energy where one molecule becomes energized and, in turn, energizes adjacent molecules. Convection is the transfer of heat where molecules physically move from one place to another. Radiation is the transfer of heat through space via electromagnetic waves. A passive design solution needs to turn to the most effective strategies suitable in any given climate. Attaining sustainability must be considered at the starting point of every design.

The Psychrometric Chart, Figure 31, (Marsh, 2005) assists in modeling, for a specific location, the range of temperatures for which passive design techniques using high energy-efficient materials and systems in the exterior envelope of buildings can offer significant benefits. Adoption of passive design principles helps reduce undesired gains or losses of temperature inside the building. The advantage is gained primarily by shifting peak load conditions or in actually reducing overall heat gain or loss. These benefits depend on where the building is located, how it is designed, and how it is operated. The regional significance of a material in terms of efficiency and the ways it meets desired performance standards guides the design process. Reducing heat gain can be achieved by reflecting heat (i.e., sunlight) away from the house, blocking the heat, removing built-up heat, and reducing or eliminating heat-generating sources in the home.

Community Layout

"A home designed to respond to site conditions can optimize lifestyle, improve energy efficiency and protect the quality of the natural environment." (Australian Greenhouse Office, 2004)

Identifying the design characteristics of a community which improve its ability to adapt to climatic conditions of a particular region is key in ensuring long-term vitality and moving to energy sustainability. Layout and design which improve the capacity of a community to achieve solar energy gain during the cold winter and protect it during the hot summer are key. These include orientation and placement of building, streets and vegetation. Several aspects of community layout planning follow.

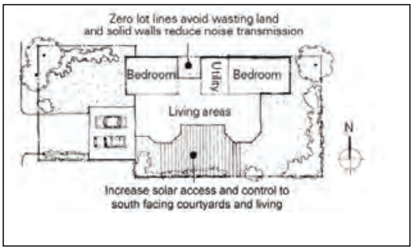
Efficient Land Use and Increased Density

Efficient planning and land use reduces embodied and operational energy costs for individual units, families, and, the entire community. Good design of a building and its footprint can reduce negative impacts on the environment as well as increase energy efficiency of the building itself. Increasing density has several benefits for achieving sustainable housing including reducing distances, and, therefore a variety of costs of providing services. Density increase needs to be achieved so as to reduce the exposure of the surface of the building(s) to direct sun. Use of rectangular lots usually permits the most efficient land use, particularly when the lots are small and less than 300 square meters. Designing site coverage and building footprint to optimize the area available for landscaping allows more storm water to be absorbed on site and generally reduces site impact.

Zero Lot Line

Building to the boundary, to a "zero lot line", improves layout efficiency by maximizing the amount of useable outdoor space. Wasted space in the form of a narrow side passage is traded for space on the other sides of the house. If the house is built to the north boundary it will increase the amount of open space that has a south orientation. Zero lot line construction can also help increase density and provide shade for sidewalks (Figure 32).

This concept of zero lot line is particularly useful in the design of multifamily dwellings. The ongoing pressures for housing in the U.S.-Mexico border area make this an option to consider seriously. Resulting land use efficiency helps to preserve open space, reduce costs of services such as sewers and water and is more efficient in energy consumption. This technique



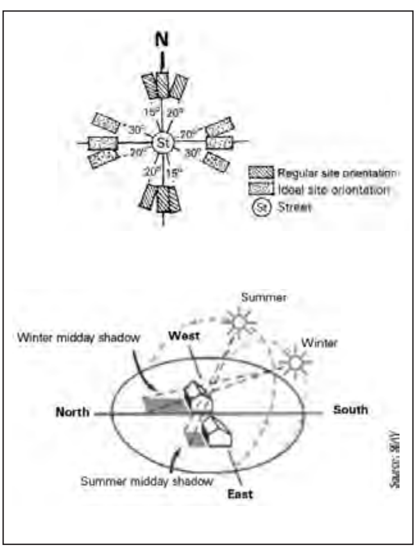


Figure 32: Illustrative Example of a Zero Lot Line House Layout (Source: Australian Green house Office 2004)
Figure 33: Habitat 67, Montreal
Figure 34: Orientation of Housing for Passive Climate Control

Source Figures 32, 33 & 34: Australian Greenhouse Office

allows for the creation of comfortable outdoor spaces which are useful in multifamily dwellings where common outdoor spaces are more likely to be used.

The financing challenges to this approach are many as it requires several families to agree to this type of layout. Families in Tecate have clearly indicated their preference for detached single-family units. As was noted earlier the percentage of people in Tecate living in apartments or attached housing in 2000 was only 7.8% of the total population of the municipality (INEGI 2004). Gaining community acceptance of a zero-lot line typology in the layout might require some effort. There is an example of lower income, accessible housing being developed in the surrounding areas of Tecate by private housing development corporations that use a terrace-house layout where individual housing units share side walls and have little or no front and side yards. The extent of such housing developments is quite significant. The economic efficiency of these units is proven by their viability in the market. However, the orientation and layout design of these “affordable housing units” take little or no account of factors which enhance energy and environmental sustainability.

SMART VOLUME AND SHAPE

Compact housing forms are more energy efficient because they reduce external surfaces which are exposed to maximum heat gain. They reflect an efficient energy design approach by reducing the amount of building surface exposed to direct sun and by self shading interior and exterior spaces. Two storey houses, where the upper storey overhangs and shades the lower, or generates shade over interior spaces could help in energy efficiency in Tecate. Moshi Safdie’s Habitat 67 project in Montreal Canada, was an attempt to incorporate these principles of design (Figure 33).

ORIENTATION

Orientation for passive heating involves orienting building to maximize entry of winter sunlight into the buildings and keeping unwanted summer sun out. This can be done with relative ease on northern elevations by using shading devices to exclude high angle summer sun and admit low angle winter sun.

In hot humid climates and hot dry climates with no winter heating requirements, the orientation of a building should aim to exclude sun year round and maximize exposure to cooling breezes (Figure 34). The following orientation guidelines should be considered:

Sites running N-S are ideal because they receive good access to southern sun with minimum potential for being shaded by neighboring houses. In summer neighboring houses provide protection from low east and west sun.

N-S sites on the south side of the street allow north-facing living areas and gardens to be located at the rear of the house for privacy. They should be wide enough to accommodate an entry at the front as well as private north-facing living areas.

Sites running E-W should be wide enough to accommodate north-facing outdoor space. Overshadowing by neighboring houses is more likely to occur on these sites.

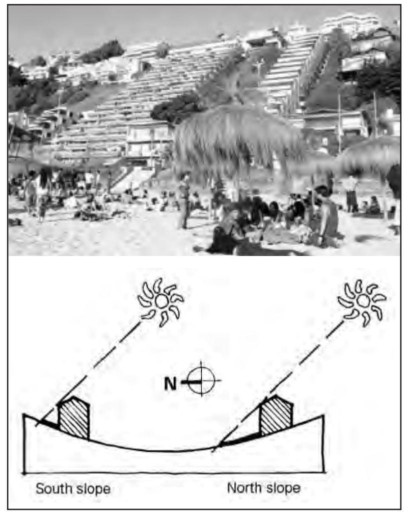
Sites located on slopes should take advantage of the diverse heights to capture sun as illustrated in Figure 35.

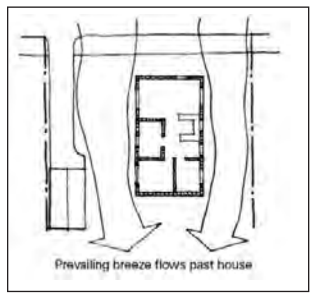
NATURAL VENTILATION

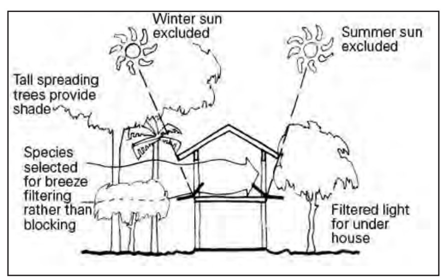
The smart use of wind flow allows cooling of spaces between buildings, and reduces the reflected heat from the ground and from vertical parapets. The location of the main body of buildings should be in line with wind movements (Figure 36). Streets needing more ventilation should run east–west. The use of trees with high canopy and little understory growth facilitates a flow of breezes at the level of the house (Figure 37). Trees planted in a line north to south help screen morning and afternoon sun and provide shade. A well-designed landscape also helps control noise and air pollution.

DESIGNING LANDSCAPES FOR SHADE AND HEAT REDUCTION

Shade from vegetation can improve the fit of housing to environment. Shading is the most cost-effective way to reduce solar heat gain (Figure 38). It can also reduce the need for, or, cost of running air conditioning units. In







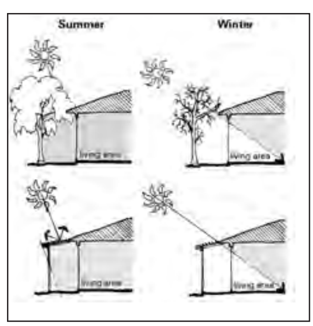
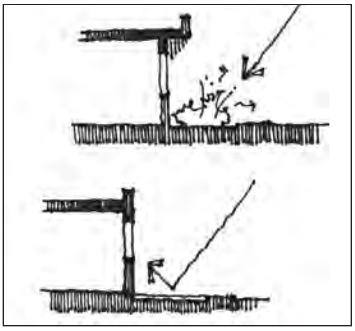
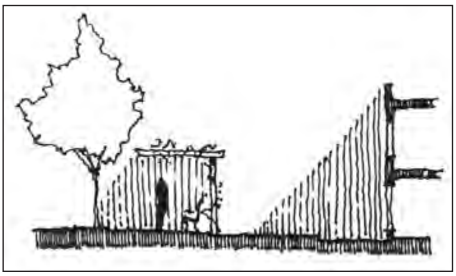
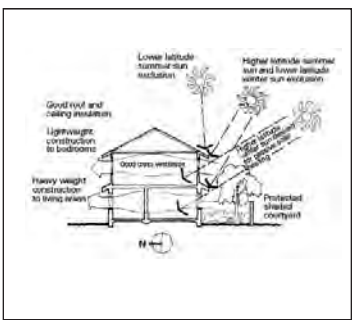


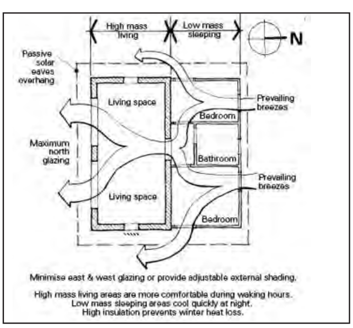
Figure 35: Sloping Site and Diagram of Shade on South and North Facing Slopes
Figure 36: Site Design to Facilitate Air Flow Around Buildings (Source: Australian Greenhouse Office 2004)
Figure 37: Landscaping for Shade and Sun
Figure 38: Designing and Landscaping for Heat Reduction in Summer and Heat Gain in Winter

Source Figures 35, 36, 37 & 38: Australian Greenhouse Office









Figures 39: Landscaping Ground Surfaces to Reduce Heat Gain
Figures 40: Landscaping for Shade
Figure 41: Design Guidelines for Passive Cooling in Building
Figure 42: High Mass and Low Mass Enclosure for Passive Cooling
Source Figures 39, 40, 41 & 42: Australian Greenhouse Office

colonias the use of old, recycled unit air conditioning equipment can be observed. Older units are far less efficient then newer models. Proper shading of a house can increase the efficiency of mechanical systems such as Air Conditioning units or coolers by 10% to 25% with a return of costs in less than 8 years. The returns in savings may be even higher in colonias where recycled, reused, less efficient units are in use.

The use of landscape materials on ground surfaces surrounding a house is a key design element to reduce heat gain. A grass-covered lawn is usually 10° F (6° C) cooler than bare ground in the summer. Concrete pavements are considerably higher in terms of heat gain. In arid climates the use of native ground cover that requires little water is recommended (Figure 39). In lower density *colonia*s residents do plant fruit trees and vegetables when they have some security of tenure. Placing these and other types of flowering vines and shrubs for shading can help reduce heat gain (Figure 40).

Incorporating the design guidelines for achieving a sustainable community layout described above must occur in the early stages of planning a community. A thoughtful layout can deliver several energy benefits and increase the quality of life of residents. Constructing communities consisting of a mix of housing types so as to yield higher density may face resistance in terms of community acceptance. A multifamily dwelling typology is not found in the Tecate region. But new private sector developments which are in high demand are developing more dense layouts for housing. In designing sustainable community layouts the community must be studied in its context and the design solution must be sensitive to how the community is inserted in the existing urban fabric. The settlement should strive to both maximize the benefits it can derive from its surroundings and what it can offer and contributes to its surroundings (Figure 41). Design suggestions for this include:

- Optimize land use to reduce distances for obtaining services and utilities through compact site plans and increasing the amount of useful open areas.

- Increase cross ventilation to reduce heat gain from the ground and reduce heat gain in the building.
- Increase the amount of shade by reducing areas of building and ground surface exposed to direct sun by increased density and compact design.
- Design the landscape and locate vegetation so as to block heat and noise.

House Design

> *A house should operate independently of any inputs except those of its immediate environment. (Vale and Vale 2000)*

PASSIVE COOLING

Designing the functional arrangement of a house in relation to use of spaces in the daily cycle of day- and night-time occupancy can serve to enhance comfort levels within the home (Figure 42). The main elements of house design for passive cooling are:

- Orientation to maximize exposure to cooling breezes.
- Increasing natural ventilation by reducing barriers to air paths through the building.
- Effective shading of the external surfaces including use of plantings to reduce heat gain.
- Providing fans to increase ventilation and air movement in the absence of breezes.
- Providing adequate levels of appropriate insulation.
- Choosing construction materials with high thermal mass in regions which experience a significant diurnal range.

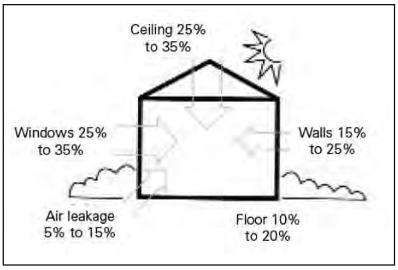
EVAPORATIVE COOLING

Evaporative cooling units are generally lower in initial and running costs. They have several energy and sustainability advantages. The principle of evaporative cooling is relatively simple. Air moving past water will cause the water to evaporate. The heat necessary to cause evaporation is drawn out of the passing air stream and cools the air. Modern evaporative coolers draw outside air through wet filter pads. Impurities in the air are screened by the air filters, moisture content is increased and air temperature lowered by the evaporation of water in the pads. Cooled air is distributed through the building (See The Evaporative Cooling Site.). Evaporative cooling works better in dry climates and has the following advantages over a refrigerated system

- Generally lower (up to 50% less) initial purchase costs than refrigerated systems.
- Lower peak energy usage (up to 90% less), which means lower wiring costs, poten tially useable with solar energy and fewer requirements for additional power stations.
- Lower (typically 80% less) running costs than refrigerated systems.
- Lower energy usage (typically 80% less).
- Less greenhouse gas production (typically 80% less).
- No CFC's or HFC's hence no contribution to ozone depletion.
- In dry areas higher humidity is better for human comfort levels. Refrigerated systems dehydrate the air more.
- Allows flow-through ventilation with plenty of fresh air.
- Wet filter pads filter the air and improve air quality.

HOUSE LAYOUT

A thoughtful configuration of rooms in a house is a simple way to avoid spaces becoming overheated during the times they are in use. Reducing exposure of any surfaces of the room—walls, flooring and roof—to direct sun and managing thermal mass capacity in balance with climate and needs is necessary in the design of sustainable houses. Design of the vertical configuration of the house for passive climate control involves locating some rooms at ground level to protect them from heat gain. In the case of hot and arid zones spaces which are used daily such as living rooms should remain on the first floor and their direct exposure to sun reduced, by projection of upper stories, to cast a shade on lower ones. An intrinsic insulating air layer is also provided. Courtyards provide design opportunities to allow or block solar penetration, and also create protected outdoor areas. Public spaces located on lower floors should have high thermal mass, so heat gain can be delayed and heat released at nighttime when those spaces are not



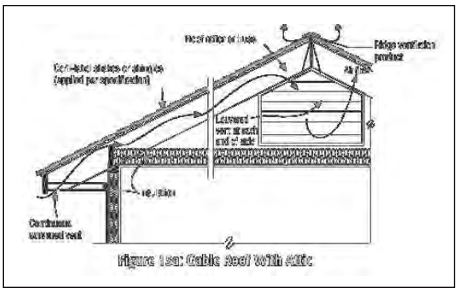


Figure 43: Building Envelope
Figure 44: Roof Treatment

Source Figures 43 & 44: Australian Greenhouse Office

occupied. In the case of horizontal zoning, optimum design decisions include maximizing indoor/outdoor relationships and providing appropriate, screened, shaded, rain protected outdoor living spaces, adjacent to long term uses to the south. Short-term uses can be placed to the west.

Tecate is in a climate zone of hot summers and cold winters. Therefore rooms facing south are protected from the heat in the summer since the sun is higher, and benefit from solar warming in winter when the sun is lower. Living rooms should have a southern orientation. A north orientation has no sun exposure and is suitable for secondary uses such as kitchen, bathrooms, and storage (Roaf et al., 2003). However, in arid climates bedrooms may be located to the north to maintain coolness and avoid heat gain during the night. The east has morning sun which can also be good for bedrooms. The west is the least desired orientation because of strong afternoon sun. Bathrooms and other short-term uses can be located there.

BUILDING ENVELOPE

Once the general plan for a community has been laid out and the building volumes have been designed, the next step is the definition of the building envelope, which is the layer of the building in direct contact with the exterior environment. The envelope consists of the roof, the walls and the floor. Through these heat is gained or lost. Therefore energy can be managed by controlling the way the envelope is designed to reflect, insulate, or absorb heat (Figure 43).

Roof

Insulation and reflection of heat are the main thermal properties provided by a roof. Insulation can be provided by specific materials or air layers. An efficient way to avoid heat absorption from the roof is to use air gaps to ventilate the structure. This technique can be applied in many ways including using aerated thin spaces with roof vents (Figure 44) to the provision of entire detached roofs. Higher reflectivity of the roof also helps minimize the absorption of heat into the roof. Light colors and non-absorbent materials also increase reflectivity. In *colonia* housing, placing a sheet metal roof on poles where a second storey might later be built serves to provide shade, reduce heat gain, and provide covered space for various activities.

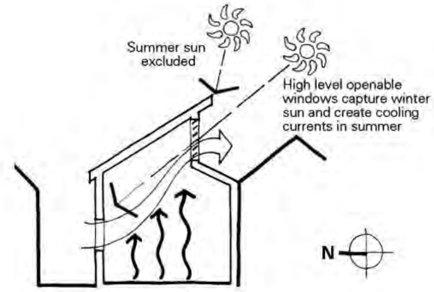
Facade

The appropriate design of building elevations can control and optimize the amount of sunlight which is captured in various rooms. Facade elements can adapt to different conditions throughout the day through control of openings and the creation of shade in facades. Moderating the size of openings is the simplest way of controlling exposure to direct sunlight—the smaller the opening to a house the less the direct exposure. Avoiding the exposure of big surfaces of glass to the sun will also reduce the reflection of light and heat to the outdoors ground surfaces and/or adjacent buildings. Figure 45 illustrates the ways in which the design of the building envelope provides good opportunities to manage the entrance of light and the flow of air currents through the house.

The design suggestions include the following directives: reduce heating of principal rooms by location and layout; reduce heat exposure through control of openings, elevation design, and air layers; avoid reflecting materials that will return heat towards outdoors or on to adjacent buildings; and increase thermal mass capacity of the building envelope.

An Illustrative Case Study: Iquique, Chile

Housing construction in the city of Iquique, located in the north of Chile provides an illustration of housing design which reflects responses to opportunities in its immediate region. Adoption of materials, layout and design in Iquique optimized and utilized opportunities and made for appropriate and sustainable design. The city of Iquique is surrounded by the Pacific Ocean and the Atacama Desert, which is the world's driest desert with less than 0.1 inches of annual rainfall. The city has a rich history which influenced and shaped its particular architecture and its climatic adaptation. Iquique developed in the late 19th and early 20th Centuries as an exporting seaport for saltpeter to Europe and North America. Most of its housing and public buildings were constructed with Oregon pine brought in the ships as ballast. The houses were built with a balloon frame structures and expressed a blend between immigrant architectural ideas, drawn especially from San Francisco, and the local climate, which required shade from sun. The result was a housing typology that used balconies and detached aerial roofs (Figure 46). This design solution provided good ventilation for buildings as well as a covered extension on top for homes. This served to relieve space needs given the small and tight lots. Currently these buildings have been designated a historic patrimony and developed as an attraction for tourism.



ORIENTATION	SUGGESTED SHADING TYPE
SOUTH	fixed or adjustable shading placed horizontally above window
EAST & WEST	adjustable vertical screens outside window
SE & SW	adjustable shading
NE & NW	planting

Figure 45: Designing Façade Elements for Passive Climate Control
Figure 46: Building type in Iquique, Chile

Source Figures 45 & 46: Australian Greenhouse Office

CHAPTER FIVE

Selecting Energy Conserving Housing Materials

Selecting the right materials during the design of a house is key to enhancing its energy efficiency. Appropriate decisions regarding choice of materials, if made during the design, layout, and detailing of the home, can lower the energy costs of attaining desired comfort levels.

When outside air temperature is higher than the desired indoor temperature, heat gain through the envelope of the structure occurs. In this situation, mass in the envelope structure absorbs heat during the hottest part of the day and releases it to the internal spaces when temperatures cool thus operating as a moderator of the outdoor climate. A comprehension of heat flow in various materials is essential in making a proper selection. The most common reference to heat flow is "R-value," or resistance to heat flow. The higher the R-value of a material, the more resistance the material offers to heat flow, either heat gain or heat loss.

Heat capacity is another property of materials which can affect a material's energy performance in certain situations. Heat capacity is a measure of how much heat a material can store. The property is most significant with heavy, high-thermal-mass materials. As typically used in computer modeling of energy performance, heat capacity is determined per unit area of wall. For each layer of material in a wall system, the heat capacity is found by multiplying the density of that material, by its thickness, by its specific heat (specific heat is the amount of heat a material can hold per unit of mass). Typically there are various layers in the construction of a wall. Total heat capacity of such a wall is found by adding up the heat capacities for each layer, for example, drywall, masonry block, and stucco. The heat storage or thermal capacity of the materials in the building envelope will define how much energy is required for a wall to change temperature. Heavier mass will be more efficient in the collection and use of solar heat than thermally light structures. The effects of thermal mass on the energy demand of a house are significant. Appropriate materials selection has allowed for a 40% reduction in energy demand (Vale and Vale, 2000).

The main benefit of thermal capacity of a material is the ability to store, in its own mass, the heat gained during the day and the delayed transmission of that heat when it is needed during cooler parts of the day. Designing to utilize the thermal capacity of a material is more relevant when the approach is combined with other strategies to enhance comfort. Understanding the time frames in which materials gain heat and release heat and the time frames in which particular rooms and spaces in a house are scheduled to be used can result in the design of a house which is much more efficient in passive energy conservation and enhancing thermal comfort. For example, in a cold climate a room such as a bedroom with high-thermal walls facing south would gain heat during the course of the day, while not in use, and release that warmth later in the evening and night when the bedroom is occupied. In a warm climate a room used in the daytime with high-thermal walls facing south would gain temperature during the course of the day, while it is in use, and release that warmth later in the day when it is empty.

Different options which emphasize combined systems and articulate their basic principles are described in the literature. This section will review these and identify which materials are suitable for use in different components of a house such as roofs, walls and pavements. Comparisons will be made between the commonly used materials, new materials and alternative techniques.

Recycled Materials

In a global context the impact of construction is dramatic, since almost 10% of the world total economy is dedicated to the building and construction industry. Meanwhile 20% to 40% of the world's wood, minerals, water and energy are used in the manufacture and the transportation of construction materials. Alternative techniques such as the use of recycled materials become important as a fundamental strategic choice to mitigate the negative and polluting aspects of this activity. A sustainable approach to housing development has been defined as one that takes into consideration present needs of society without compromising the needs of future generations through resource depletion. The current concerns about pollution and resource depletion are based on measurable factors such as the levels of contaminants in the air and water, or consumption of a resource compared with its reserves (Vale and Vale 2000). The use of recycled materials in activities such as home construction, if effectively done to create energy efficient structures, is a contribution to sustainable development.

Wall Construction

The thermal structure of a wall is understood as the distribution of thermal resistance and capacity in its volume. Results in experimental simulations have lead to the conclusion that the material configuration of the exterior wall can significantly affect the annual thermal performance of the whole building. However, this effect depends on climate type. Walls that incorporate mass on the internal surface and insulation on the outer surface show the best thermal performance in warmer climatic zones. Differences in total energy demand between the configuration "all insulation inside" and the most effective configuration (from the point of view of energy savings) "all insulation outside" may exceed 11% for a continuously used residential building.

Concrete Construction

As a whole, concrete construction provides structural integrity, termite protection, and thermal storage, and it helps reduce air infiltration in buildings. It also readily absorbs heat, making it ideal as thermal mass in passive solar building design. Producing cement uses a great deal of energy, so finding a waste product that can substitute for cement makes good environmental sense. Burning coal to make electric power creates a great deal of waste fly ash, and a smaller amount of slag is created when producing iron in blast furnaces. Coal fly ash, blast furnace slag and other mineral admixtures can substitute for cement in concrete mixes for buildings, saving energy, disposing of a waste product, improving the quality of the concrete, and reducing cost. Cement substitutes should be distinguished from concrete additives, such as plasticizers and air entrainment agents; and from aggregate substitutes, such as ground glass or ground scrap rubber (NAHB Research Center 2004).

There are many concrete products which offer options for construction materials for homes. They include:

- Masonry
- Precast
    - Autoclaved Aerated Concrete (AAC)
    - Insulated Concrete Forms (ICF)
- Cast in Place

MASONRY

Masonry is concrete blocks assembled with mortar. The design of a building provides opportunities to manipulate the layering of masonry blocks in a way to generate systems which have great energy efficiency levels thus increasing the level of sustainability of the building.

PRECAST CONCRETE

Manufacturers construct precast concrete walls or panels off-site. Most of these are also pre-insulated with rigid foam board. Additional insulation can usually be added inside the wall cavity to achieve a high R-value. The panels typically come in lengths of up to 16 feet and in standard heights of 4, 8, and 10 feet. Once formed and cured in a factory location, they are transported to the building site. A crane is needed to lift them into place. Precast concrete walls have been shown to be very effective in passive solar design.

Precast concrete panels are typically made with fiber-mesh reinforcement and a concrete mix that is much stronger than concrete block or poured concrete walls. The concrete mixture has a low water/cement ratio, resulting in a dense material that prevents water penetration through the walls. However, specific details and quality control vary with the manufacturer. High tensile strength of the panels helps resist lateral forces from outside the wall. Reinforced panel beams uniformly distribute the weight of the superstructure of the house.

Precast concrete systems are competitive with block walls. Walls made with these systems go up more quickly, offering savings in labor costs. Footers are usually not required. Construction in cold weather is simpler because no pouring or curing of concrete is required. Waterproofing is simplified due to the material's resistance to water penetration. Companies and their licensees are regional, located mainly in the Northeast. Shipping costs may be high, depending on location and if erection equipment is needed for on-site lifting.

Autoclaved Aerated Concrete (AAC)

AAC is a precast, manufactured building stone made of all-natural raw materials. It is economic, environmentally friendly, cellular, lightweight but structural material that features thermal and acoustic insulation as well as fire and termite resistance. These units are much lighter than traditional concrete blocks because they use a special mixture of sand, limestone, cement and an expanding agent. Although it has been a popular building material in Europe for over 50 years, AAC has only been introduced to the U.S. in the past few years. Autoclaved aerated concrete comes in plank or block form (U.S. Department of Energy, 2004). Portland cement is mixed with lime, silica sand, or recycled fly ash (a byproduct from coal-burning power plants), water, and aluminum powder or paste. It is poured into a mold. Steel bars or mesh can also be placed into the mold for reinforcing. The reaction between aluminum and concrete causes microscopic hydrogen bubbles to form, expanding the original concrete volume about five times. After evaporation of the hydrogen, the now highly closed-cell, aerated concrete is cut to size and form and steam-cured in a pressurized chamber (an autoclave). The result is a non-organic, non-toxic, airtight material that can be used in non- or load-bearing exterior or interior wall, floor, and roof panels, blocks, and lintels. According to the manufacturers, the production process generates no pollutants or hazardous waste (NAHB Research Center 2004). AAC is available in a variety of forms, ranging from wall and roof panels to blocks and lintels. Panels are available in thicknesses of 3" to 16", 24" wide, spanning up to 20'. Blocks come 24"L × 3"-12"W × 8"H.

FlexCrete, a fiber-reinforced aerated concrete, a product of FlexCrete Building Systems, LC was used in the construction of both the houses built by ASU Stardust Center in Nageezi Navajo Nation and in Guadalupe, Arizona (see Chapter Six, p.53). The web site for FlexCrete http://www.flex-crete.com states that the product, "features ease of construction, high fire resistance, excellent insulation, cost effectiveness" and goes on to describe the material as follows:

> "Building with FlexCrete provides many advantages over other traditional concrete construction alternatives. All FlexCrete materials are formulated using high volumes of fly ash, a recovered resource that is in abundant supply wherever coal is burned for generating electricity or for other industrial uses. In contrast with other forms of aerated concrete, because of the unique physical properties of fly ash, FlexCrete is cured at low temperatures and ambient pressure, thus eliminating the use of energy intensive autoclaves. Available in block, floor and roof panels, and in FomeStone Thin Unreinforced Panels, FlexCrete is suitable for use in all types of commercial, industrial and residential applications. Used as a stand-alone building system, or in combination with FlexCrete floor & roof panels, FlexCrete block is suitable for load bearing and non-load bearing walls in all types of commercial, industrial and residential applications."

These attributes and the price point of the material were persuasive and 6", 8" and 12" FlexCrete blocks are installed and performance is being evaluated in the Nageezi, Navajo Nation house. FlexCrete block has also been used in the Guadalupe house.

Insulating Concrete Forms

To construct an insulating concrete form (ICF), builders pour concrete into a foam form. The form then stays in place to provide insulation. Builders construct walls by stacking ICFs, cutting them where needed to fit windows and corners, etc. They also place steel rebar horizontally and vertically within the form to provide strength. Although all ICFs are identical in principle, the various brands differ widely in the details of their shapes, cavities, and component parts (NAHB Research Center, 2004).

ICFs come in one of three basic form types, which differ by the size of the units and the way they connect to one another. Panel systems are the largest units, available in sizes from approximately 1'-3"× 8'-9" up to 4' × 12'. Panel systems allow a large section of wall area to be erected in one step, but may require more cutting in the field. The panels have flat sides and are connected to one another with metal or plastic ties. They can be shipped flat. (NAHB Research Center, 2004). However the insulation on the inside negates much of the mass effect, which will diminish much of the thermal benefit of the mass. Also concrete pumping equipment is usually needed for ICF construction.

Cast-in-Place Concrete

Cast-in-place framing construction involves setting up removable or temporary forms for the pouring of concrete walls. Rigid foam board insulation is usually placed between the removable forms. Steel rebar is also generally used to add strength to the wall (U.S. Department of Energy 2004).

Wood Construction

Builders can choose from a variety of wood sheathing products that range in cost, strength, insulation value, and ease of installation. Of the options available, plywood and oriented strand board (OSB) are the strongest and most durable. Wood sheathing panels add shear and racking strength, important characteristics that are engineered to help a structure withstand the forces of high winds and earthquakes. Wood-sheathed walls are also easy to build and easy to insulate for high R values.

Structural insulated panels (SIPs)—which commonly consist of rigid foam board sandwiched between structural wood sheathing (plywood and OSB)—can be used in place of stud-framed construction for both walls and ceilings. While manufactured wood products often perform as well as or better than lumber, the glues used in the manufacturing process can cause indoor air quality problems. Engineered wood products made with exterior-type glues (phenolic resins) and urethane (polyurea) adhesives give off some of the lowest emissions. Because they are susceptible to damage from termites and dry rot, some wood products also are pressure-preservative treated. These products can also sometimes negatively affect indoor air quality if not used properly (U.S. DOE 2004).

Wood structures usually require additional insulation to acquire comfortable thermal characteristics. Foam insulation typically is more expensive than fiber insulation. But it's very effective in buildings with space limitations and where higher R-values are needed. Foam insulation R-values range from R-4 to R-6.5 per inch of thickness (2.54 cm), which is up to 2 times greater than most fiber insulating materials for the same thickness. Foam insulation is often made with one of three materials: molded expanded polystyrene (MEPS), extruded expanded polystyrene (XEPS) or polyurethane, polyisocyanurate, or a related chemical mixture. Some are installed as a liquid while other types come as factory-made panels called rigid foam boards. (U.S. DOE 2004)

Earthen Construction Techniques

Earthen construction techniques, while housing over 50% of the world's population, are not generally considered mainstream approaches in the United States. More recently higher lumber prices and the potential for lower overall environmental impact have further increased interest in using earthen construction techniques. Adobe, super adobe, "cast" earth, PISE, cob, rammed earth, and wattle and daub are examples of these earth-based construction approaches. (U.S. DOE 2004) Earth as used in walls of buildings has a low compressive strength with large wall thicknesses generally in the range 230mm-400mm. Earthquake loads are critical for most earth buildings and this height limitation recognizes the limits of the material and the current state-of-the-art in understanding modern earth buildings in seismic areas.

Reinforced Adobe

Adobe is air dried “mud-bricks” made from a puddled earth mix cast into a mould. The earth mix contains sand, silt and clay and sometimes straw or a stabilizer which is also used to mortar the walls. Richard Walker from the Department of Civil and Resource Engineering, at The University of Auckland (New Zealand) has developed ways to improve the structural response of adobe walls. Three New Zealand Standards for earth building have been developed. The standards cover adobe (sun dried brick), rammed earth and pressed brick construction including reinforced and unreinforced walls. Few performance based standards have been developed internationally. Simple and low cost materials tests were adopted to establish that earth wall materials meet the building code requirements.

High-Tech Adobe

Although the basic sand to clay ratio is the same as adobe an asphalt emulsion is added to the mix. Asphalt emulsion is an oil by-product commonly used in road construction. It is mixed with water and then sand and clay. The end result, depending on the amount of emulsion used, is an adobe which is either water resistant (semi stabilized), or totally water proof (fully stabilized). For an exterior patio or courtyard wall the addition of the emulsion makes sense. The adobe purists cringe at the idea of adding an oil by-product to what they see as a beautiful, natural building material. There is also a concern about the possibility that the material might give out harmful gasses. All building materials release some fumes from the components used in the making of the material.

Rammed Earth Construction

The principle behind rammed earth construction is to turn soil into sedimentary rock walls in just minutes. Using high pressures and heavy equipment drastically shortens these geologic processes. The resultant rammed earth buildings have strong, thick walls that require little maintenance. Several rammed earth buildings in France, Germany, and England built in the 1500s are still occupied. Rammed earth walls are created using soil, water, formwork, and tamping equipment. The result of rammed earth construction is a massive structure that will temper the interior space against outdoor temperatures. Solar radiation is absorbed by the walls, travels slowly through the structure, and is released indoors or re-radiated to the nighttime sky. The buildings are slower to heat up in the summer sun, and retain heat because the thermal mass is very slow to give up its heat. Typical insulation values for rammed earth walls are R-0.25 per inch or R-4.5 for a typical 18-inch wall. The real energy efficiency lies not in the insulation value, but in the massive structure's ability to reduce interior temperature swings.

Rammed earth construction usually starts with a foundation of stone or concrete. In dry climates on stable ground, however, a foundation can be nothing more than beginning the base of the rammed earth wall a certain depth below grade. The irregular surface of a stone foundation serves as an area where a strong mechanical bond can be made with the wall.

The ideal soil for rammed earth construction is a mixture of roughly 70 percent sand and 30 percent clay, although non-ideal soil can be enhanced with stabilizers such as Portland cement or other additives. With the right soil material, unstabilized rammed earth is allowed as long as exterior walls are well protected from moisture damage, through the use of hard plaster or stucco finishes. Other plasters that are stabilized with softer materials such as asphalt emulsion can protect exterior walls semi-covered by overhangs.

Custom forms are used to create window and door openings. Windows and doors are installed by drilling holes into the jambs and header. Concrete bond beams typically are used to tie the system together and to anchor the roof. A sill plate is bolted to the top of the bond beam for roof attachment. The roof may also provide structural stiffness to the building. Deep window wells resulting from the thick walls provide an opportunity for passive solar benefits.

Building materials for rammed earth construction are widely available and inexpensive. Unlike adobe that is made of small blocks and may require 30 days to cure, a rammed earth wall is monolithic and cures in situ. Rammed earth wall construction is about $60 per linear foot for a 9-foot wall. Cost will depend greatly on the ratio of wall area to floor area and exterior and interior finishes. Stabilized rammed earth does not need interior or exterior finish, which can reduce costs of construction.

Public perception of earthen buildings is not always good in regions familiar with common timber-framed housing. Accordingly, infrastructure-regulators, financing, mortgage groups, insurers, developers, builders, realtors are poorly equipped to accommodate earthen construction. Earth-building methods are almost always very dirty, labor intensive, and take extended time for construction. Care must be taken to avoid breakage of plumbing lines embedded in earthen walls.

STRAW BALE CONSTRUCTION

Straw bale construction uses baled straw from grain such as wheat, oats, barley, rye. The walls are covered by stucco. Straw bales are traditionally a waste product, which farmers sell for animal bedding or landscaping as it is durable.. Straw is the dry plant material or stalk left in the field after a plant has matured, been harvested for seed, and is no longer alive. Hay bales are made from livestock feed grass that is green and alive. Hay bales are not suitable for this type of construction.

Straw bale technique for constructing walls has recently been revived as a low-cost alternative for building highly insulating walls. The technique was practiced in the Plains states in the latter 1800s and early 1900s. Many of the early structures are still standing and in use. The technique has been applied to homes, farm buildings, schools, commercial buildings, churches, community centers, government buildings, airplane hangars, well houses, and more.

Straw is also currently used as a building material in sheet materials such as sheathing and wall panels. From a regulatory standpoint straw bale construction is a new technique and cities such as Austin, Texas have recently passed straw bale construction building codes. Walls of straw bales can be built by unskilled labor, and the low costs of the bales make this technique economically attractive. However the cost of straw bales differs depending on what time of year they are harvested and how far they must be transported. They are cheaper at harvest time and if they are transported a shorter distances. Bales must also be protected from moisture and from getting wet. Costs also depend on the type of stucco finish selected and its method of application. A mud plaster made from site soil, applied by the owner/builder, and maintained by the owner is quite inexpensive, but may take a long time to apply. Cement stucco applied by a contractor is quick and lasts a very long time without maintenance, but it also costs more. As with any construction the more labor input an owner/builder can make and the less that is done by a contractor, the lower the cost of construction.

OTHER ALTERNATIVES

Earth and recycled materials have also been used as low cost construction alternatives. For example, used tires can be filled with earth and stacked like bricks. Once the tires are packed, they are very difficult to move and form quite a dense wall. The walls are load bearing and provide thermal mass, which is an important attribute to any energy efficient house. Once the walls are in place, the walls are quite often plastered over and appear very similar to an adobe style house. This type of construction provides a large amount of thermal mass which helps keep the house cool in the summer and warm in the winter. Most homes of this type have been built in the southwestern part of the United States (Daycreek.com). One of the advantages of this construction is that can be owner-built. Although there is extensive labor involved, a house of this type could be built with just a couple of workers. Basic carpentry, plumbing and electrical skills are required.

ROOFS

Roofs play a key role in protecting building interiors and their occupants from weather, primarily moisture. The roof, insulation, and ventilation must all work together to keep the building free of moisture. Roofs also provide protection from the sun. In fact, if designed correctly, roof overhangs can protect the buildings exterior walls from moisture and sun. Different roof designs and materials are used for residential and commercial buildings. Roof design can impact the building's thermal performance. For example, in a metal-framed building, the metal eaves can act as thermal fins, moving heat out of the building.

A number of roofing choices are available for high-performance buildings. New roof shingles on the market today even produce electricity using solar technology. Reflective roofing materials or coatings help send the heat back into the sky rather than into the building. And recycled content shingles are available that look like slate or wood (U.S. Department of Energy 2004). The roofing industry is developing products that reuse waste from other industries. For instance, waste from manufacturers of car hoses, shoes, tires, and other rubber products is now being directed to the manufacturing plant of EcoStar Inc., which makes a 100% recycled lightweight rubber "slate" tile. Another recycled product, the eco-shake , looks like wood and contains reinforced vinyl and cellulose fiber. A number of roofing materials are available including: asphalt: metal; wood; concrete and tile; single-Ply; solar Shingles; and coatings.

ASPHALT ROOFS

Asphalt is the most commonly used roofing material. Asphalt products include shingles, roll-roofing, built-up roofing, and modified bitumen membranes. Asphalt shingles are typically the most common and economical choice for residential roofing. They come in a variety of colors, shapes, and textures. There are four different types: strip, laminated, interlocking, and large individual shingles. Laminated shingles consist of more than one layer of tabs to provide extra thickness. Interlocking shingles are used to provide greater wind resistance. And large individual shingles generally come in rectangular and hexagonal shapes. Built-up roofing (or BUR) is the most popular choice of roofing used on commercial, industrial and institutional buildings. BUR is used on flat or low-sloped roofs and consists of multiple layers of bitumen and ply sheets. Components of a BUR system include the roof deck, a vapor retarder, insulation, membrane and surfacing material. A modified bitumen membrane assembly consists of continuous plies of saturated felts, coated felts, fabrics or mats between which alternate layers of bitumen are applied, either surfaced or unsurfaced. Factory surfacing, if applied, includes mineral granules, slag, aluminum or copper. The bitumen determines the membrane's physical characteristics and provides primary waterproofing protection, while the reinforcement adds strength, puncture resistance and overall system integrity.

METAL ROOFS

Most metal roofing products consist of steel or aluminum, although some consist of copper and other metals. Steel is invariably galvanized by the application of a zinc or zinc/aluminum coating, which greatly reduces the rate of corrosion. Metal roofing is available as traditional seam and batten, tiles, shingles, and shakes. Products also come in a variety of styles and colors. Metal roofs with solid sheathing control noise from rain, hail, and bad weather just as well as any other roofing material. Metal roofing can also help eliminate ice damming at the eves. And in wildfire-prone areas, metal roofing helps protect buildings from fire should burning embers land on the roof. Metal roofing costs more than asphalt, but it typically lasts two to three times longer than asphalt or wood shingles (U.S. DOE).

WOOD ROOFS

Wood shakes offer a natural look with a lot of character. Because of variations like color, width, thickness, or cut of the wood, no two shake roofs will ever be the same. Wood offers some energy benefits, too: it helps to insulate the attic, and it allows the house to breathe, circulating air through the small openings under the felt rows on which wooden shingles are laid. A wood shake roof, however, demands proper maintenance and repair, or it will not last as long as other products. Mold, rot, and insects can be a problem. The life cycle cost of a shake roof may be high, and old shakes can't be recycled. Most wood shakes are unrated by fire safety codes. Many use wipe-on or spray-on fire retardants, which offer less protection and are only effective for a few years. Some pressure-treated shakes are impregnated with fire retardant and meet national fire safety standards. Installing wood shakes is more complicated than roofing with composite shingles, and the quality of the finished roof depends on the experience of the contractor as well as the caliber of the shakes used. The best shakes come from the heartwood of large old cedar trees, which are difficult to find. Some contractors maintain that shakes made from the outer wood of smaller cedars—the usual source today—are less uniform, more subject to twisting and warping, and don't last as long. A recycled content roofing material, the eco-shake, looks like wood and contains reinforced vinyl and cellulose fibers.

Environmental Rating Systems for Residential Buildings

During the design, construction, and operation of a home, site design, energy and water efficiency, resource efficient building materials and indoor environmental quality are all taken into account in assessing the energy utilization, efficiency and hence sustainability of the house. In the U.S. there are primarily two national environmental rating systems for residential buildings: the National Association of Home Builders (NAHB) Green Home Building Guidelines and the U.S. Green Building Council's (USGBC) LEED for Homes. NAHB's Green Home Building Guidelines are voluntary guidelines designed to move environmental-friendly home building practices into the mainstream. The guidelines are organized into six primary sections:

- Site Preparation and Design
- Resource Efficiency
- Energy Efficiency
- Water Efficiency and Conservation
- Occupancy Comfort and Indoor Environmental Quality
- Home Owner Guidance on How to Optimally Operate and Maintain a Home

Described in each section are ways home builders can incorporate green building practices into a project. Points are given for meeting the criteria and projects are given a bronze, silver or gold rating. Since the NAHB guidelines were designed to be customized and administered by local home building associations they may lend itself to being customized by a community like Tecate. The NAHB guidelines can be downloaded from: www.nahb.org/gbg.

USGBC's LEED for Homes is also a voluntary program designed to recognize the top 25% of homes with best-practice environmental features. It is a national consensus-based, market-driven building rating system designed to accelerate the development and implementation of green building practices. It is nationally administered by the USGBC which will also providing training workshops, professional accreditation, resource support, and third-party certification of home performance.

LEED-H reward points are given to homes that:

- Use energy resources efficiently;
- Use water resources efficiently;
- Use building construction resources efficiently (through improved design, material selection and utilization, and construction practices),
- Use land resources efficiently, and
- Use materials and practices designed to safeguard occupants' and workers' health.

Buildings can a receive certified, silver, gold or platinum rating. LEED for Homes is a national environmental rating system across the US, and is not customized. This may render it not an ideal environment rating system for a community like Tecate. However it could still be useful in guiding the design.

Applications to Tecate

With temperatures in Tecate reaching highs of 104° F and lows of 30° F it is extremely important to design urban layouts and homes so that they are energy and resource efficient and also responsive to the economic conditions of the community they serve. In Mexico, especially along the border, income limitations in communities such as El Rincon can be challenging when designing homes for affordability and sustainability. Housing projects which are affordable are often limited in their access to technical and material resources. Historically, low-income urban developments in Mexico's borderlands are not a priority in city development plans. In addition, as in El Rincon, a fair number of these communities are self-built with poor or little knowledge of what works best for the climate in which they are located and are illegally occupying land they do not own or to which they do not have tenancy rights.

In contexts such as El Rincon the need to reach ideal thermal comfort levels is great, however, attaining it with mechanical heating and cooling equipment can be very expensive. In addition access is often limited to basic services such as electricity, sewer service and potable water, so relying on attaining desirable thermal comfort levels with mechanical systems is not realistic. Appropriate and sustainable design solutions must focus on inexpensive strategies, such as the passive strategies described in Chapter Four, in order to make them appealing to lower income self builders as well as government officials. In lower income communities the design of a house and the layout of the community must take optimal advantage of passive and low-energy strategies. Creating a pleasant environment by maximizing energy efficiency through building orientation, material selection, and, architectural form can create a climatically and culturally responsive architecture.

The design principles described in Chapter Four can be applied to home design in the Tecate region. Lower-income owners of self-built homes can construct more energy efficient, climatically responsive homes. Passive and low-energy use strategies can make houses more affordable when costs are calculated over the life cycle of the house.

Challenges and Solutions for Housing design in Tecate:

The climatic factors affecting the design of houses in Tecate are:

- Mild to hot summers reaching 104° F
- Cold winters with lows of 30° F
- Low humidity all year round
- Low rainfall (13 inches annually)
- Elevation 1650 feet

SUMMER TEMPERATURES

In climatic conditions like these of Tecate, using thermal mass for cooling is essential. Typically nights are cooler than days. Mass provides a building the opportunity to store night time cold for longer periods of time thus reducing cooling loads during the day or eliminating them entirely. In the summer time storing night-time cooling can bring enough cooling into a house to keep the residence within thermal comfort limits during the day without the assistance of mechanical systems. If night-time cooling does not cool the house mass enough to keep indoor temperatures within comfort limits, stack ventilation can assist the cooling. Stack ventilation allows buildings to constantly flush warm air through clear story windows while pulling more cool air through lower fenestrations. Trees and native low-maintenance plants can bring enough shade and evaporative cooling to lower temperature by three to ten degrees.

WINTER TEMPERATURES

Purposive orientation has always been a key design element of most indigenous architecture. It works efficiently although not always achieving the comfort levels which are deemed ideal today. Carefully orienting buildings can maximize solar heat gain, exposure to cooling breezes and increase wind protection. It can help reduce dust and noise pollution. Passive heating is very effective in warming small to medium buildings from solar heat gain on exterior walls. In smaller structures there is a high external wall surface to internal volume. South-facing walls can be designed so as to be excellent gateways to bring in sunlight through the use of large windows with regular double pane systems which reduce heat loss. The summer solar heat gain can be reduced with a well designed trellis which casts shadows and provides shade. Mass is as essential in winter time as it is during the hot season. Mass provides day-heat-gain storage that will then be released during the cold night. Insulation is also important. Designing compact communities with housing units which share a common party-wall reduces the surface area and the need for insulation. Exterior walls need to have mass and two to three inches of exterior insulation.

Wall Construction and Thermal Transmittance

The three wall types illustrated in Figures 47–49 demonstrate how appropriate selection of materials, construction and use of insulation in a concrete block wall can decrease the thermal transmittance (a reflection of the rate of heat transfer) of a wall assembly and make it more useful in passive cooling or heating. Note that with increasing insulation, transmittance of a concrete block wall was lowered nearly by half as observed experimentally (from 1.9 to 1.04 W/m^2K). Standard recommendations for such walls issued by American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) are also shown.

Alternative to Adobe Wall Construction

Professor De La Fuente at La Universidad Autonoma de Colima has designed an alternative to adobe wall which uses bagged earth blocks to construct walls (Figure 50). His research suggests that this is a feasible option for wall construction in low-income housing. The wall provides great thermal properties especially for extreme weather. There has been a resurgence of interest in this type of construction, generically termed earth bag construction, since architect Nader Khalili, Cal-Earth Institute, began experimenting with bags of adobe soil as building blocks for creating domes, vaults and arches (Figure 51). The Cal-Earth Institute trains people in the technique of building with earthbags that are laid in courses with barbed wire between them (Green Home Buildings: 2006).

How finished a wall constructed with alternative adobe looks after the application of stucco plaster is illustrated in Figure 52. Walls like these can attain simple compression strengths of 20 kilograms/square centimeter in fourteen days and this strength increases over the next fourteen days. Professor De La Fuente has completed full testing on this alternative material including market pricing and manufacturing costs. Given the prevailing building standards in Mexico, this alternative adobe represents a viable material and construction method to create affordable housing.

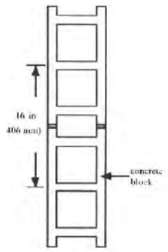


Figure 47: Wall Construction 1

20.3 cm medium-weight concrete block wall with a 28.9° C mean temperature.

Description:
20.3×20.3×40.6 cm medium weight hollow core concrete block, 1842 kg/m³ and 0.753 W/mK

10 mm wide mortar joints and 0.86 W/mK

Experimental Results
Thermal transmittance; 1.99 W/m²K
Mean Temperature; 28.9° C
Temperature Difference:
Air-to-air 12.2° C and
Surface-to-Surface 8.9° C.
ASHRAE recommended value:
Thermal Transmittance: 2.48 W/m²K

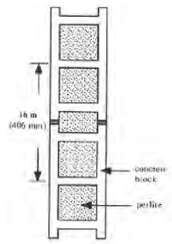


Figure 48: Wall Construction 2

20.3 cm Medium weight concrete block wall with perlite insulation cores with a 37.6° C mean temperature.

Description:
20.3×20.3×40.6 cm medium weight hollow core concrete block, 1842 kg/m³ and 0.753 W/mK
10 mm wide mortar joints and 0.86 W/mK
Perlite insulation, 97.7 kg/m³ in cores and 0.049 W/mK

Experimental Results
Thermal transmittance; 1.44 W/m²K
Mean Temperature; 36.7° C
Temperature Difference:
Air-to-air 28.3° C and
Surface-to-Surface 24.4° C.
ASHRAE recommended value:
Thermal Transmittance: 1.34 W/m²K

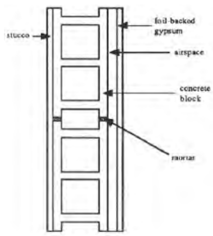


Figure 49: Wall Construction 3

20.3 cm normal weight concrete block wall with reflective air space with a 37.9° C mean temperature.

Description:
20.3×20.3×40.6 cm normal weight hollow core concrete blocks (2 per block), 1842 kg/m³ and 0.72 W/mK
10 mm wide mortar joints and 0.864 W/mK
19mm reflective air space,
12.7 mm foil-backed gypsum wall-board (emittance of 0.05) and 0.16 W/mK

Experimental Results
Thermal transmittance; 1.04 W/m²K
Mean Temperature; 37.9° C
Temperature Difference:
Air to air 28.3° C and
Surface-to-Surface 24.4° C.
ASHRAE recommended value
Thermal Transmittance: 1.02 W/m²K

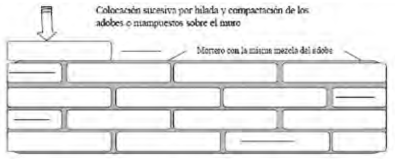


Figure 50: Alternative to Adobe Construction

Figure 51: Forming Alternative Adobe Block

Figure 52: Alternative Adobe Wall Before and After Application of Stucco

ASU's Stardust Center for Affordable Housing and the Family has utilized FlexCrete block walls in two prototype houses built in the United States. One is in a rural location on the Navajo Reservation in Nageezi, New Mexico (see Figure 35 in Chapter Six) and the other is in an urban location in Guadalupe, Arizona (see Figure 36, Chapter Six), a small Yaqui and Hispanic community in metropolitan Phoenix. These houses are in climatic and socio-cultural contexts which are similar to those found in the U.S.-Mexico border region. They illustrate how quite different houses result from the application of design principles described here. Consideration has been given to site and location, community, socio-cultural attitudes and expectations, materials, and the price of factors of production (the price of land, labor and materials) as well as the regulatory environment and real estate values. Such a tailoring of housing and settlement design to client, context and energy conserving construction can create environmentally friendly and sustainable housing.

CHAPTER SIX

Building Sustainable Housing in colonia Border Communities

Building sustainable housing results not just from informed and appropriate technical choices in the design of layout, orientation and envelop of buildings, but also from putting contextual, systemic and institutional aspects of housing, such as land tenure, home ownership, finance, infrastructure, services and transportation in place. Even in this era of globalization, where the dominant economic force in communities is the private sector, government at all levels must play a key role in facilitating the access of poor families to finance and land (Smith, 2006). The El Rincon community's aspirations for land rights where they have located proximate to jobs, city amenities and schools, is a universal one expressed by poor families who move to the city for economic opportunity. As Smith point out, markets alone will never satisfactorily house a nation's poorest citizens. Building spontaneous communities such as El Rincon consisting of self-built or informally built homes, Smith argues, is the economically sensible option of the poor, left alone in the marketplace to find housing. And, he notes, it has been this way for over two centuries. If one is to improve the conditions of housing for those living in these settlements government must respond. Policy and regulation must deal with the issue of access to land and finance in ways that are enabling of the poor.

A Mexican and U.S. Challenge

The need for access to affordable, decent, housing and security of tenure, which the tiny El Rincon community has attempted to attain with little success, is a critical issue not only on the Mexican side of the U.S.-Mexico border but on the U.S. side too. In a special issue of Planning (December 2006) a magazine of the American Planning Association (APA), dedicated to the theme "Housing Choice and Affordability", Paul Farmer, Executive Director of APA reminds the planning community that the

HOUSING IN *COLONIA* DESIGNATED COMMUNITIES IN YUMA COUNTY, ARIZONA.

HOUSING IN *COLONIA* DESIGNATED COMMUNITIES OF IMPERIAL COUNTY, CALIFORNIA

NILAND CALIFORNIA

SEELEY CALIFORNIA

BOMBAY BEACH, CALIFORNIA

Figure 53: Pictures of Housing in Yuma County, Arizona and Imperial County, California

Source: Melina Dempsey

Congressional pledge of 1949 to create a decent home for all Americans is still unmet and there is a need for the planning profession to respond with creativity. The special issue describes encouraging efforts across the country. They include architect Teddy Cruz's application of south-of-the-border concepts to U.S. housing in San Ysidro, a lower income district in San Diego close to the border and dominated by immigrant families (Downey, 2006). The two projects by Cruz for family and senior housing have yet to obtain required zoning changes to build at the higher densities and lower parking provision they are designed to provide. But Cruz argues for a higher density that brings people together. He argues against the prevalent low density of the U.S. suburb describing it as helping to build impenetrable walls between people and separating them on income lines. The non-profit advocacy group Casa Familiar partners with Cruz and has suggested an overlay zones for affordable housing as an approach, partly to cope with nonconforming uses and partly to enable construction of new units of affordable housing.

The Census 2000 data on housing stock and income levels in Imperial County, California and Yuma County, Arizona bordering Mexico reveal other aspects of the housing need. In these counties the total Hispanic origin population is 72% and 51% respectively of total population; Population below poverty is 23% and 19%; and Hispanic or Latino population below poverty is 26% and 39%. The counties have a homeownership rate of 58% and 72%. There is thus a bleak reality of poverty and housing need in the northern, U.S. side of the U.S.-Mexico border region as well as to its' south. This fact is reflected in the housing stock to be found in the settlements which have been designated as *colonia*s in the two counties. As designated *colonia*s they are eligible for federal funding under the *colonia* program. In Arizona this consists of 10% of Community Development Block Grant (CDBG) funds are set aside for *colonia*s. However, Arizona has not created a specific program structure through which to allocate funding directly to the *colonia*s (Dempsey, 2005)

As a photo documentation and windshield survey (July 2005) reveals housing in *colonia* designated areas of Yuma County, Arizona and Imperial County, California illustrate how housing conditions north of the U.S.-Mexico border are not dissimilar to conditions South of the border in settlements such as El Rincon (Figure 53). Overall the houses are relatively of better stock, consisting of relatively newer manufactured homes and better recycled materials. But these homes are by no means high in comfort, energy efficient or good demonstrations of sustainable construction. The older manufactured homes that are in place have little in the way of passive systems of climate control and are energy consuming for heating and cooling functions. A filtering down process is apparent where recycled construction materials, manufactured homes, heating and cooling equipment move to the U.S. side of the border and then across the border at later stages in their life cycle, when they are even less effective in efficiently providing climate control and shelter.

The Non-profit Sector

The non-profit sector in the U.S. has been active in seeking solutions to meet the immediate needs for housing of families in poverty conditions. For instance they have partnered with and provided support and technical assistance to community groups and individuals involved in self-building of homes. Building homes quickly and simply on a low budget using sustainability principles has been another strategy demonstrating an approach and providing know how. One example of this is to be found on the web site of Necessary Housing where one can find a video of the three-day house built in Mexico, with labor input of six workers. (Necessary Housing: 2006.) The Green Home Building and Sustainable Architecture web site features articles that emphasize sustainability approaches in building housing and Builders Without Borders construct demonstration homes in various parts of the world. Thus the non-profit sector is extremely important in enabling poor communities to organize and in guiding them to good and reliable technical information and professional support. These organizations embrace the approach to sustainable housing construction to varying degrees.

Private Sector Housing

The fact that there is a real and growing need for housing that is accessible and affordable for those in the lower strata of incomes has not escaped the attention of the private sector. Private sector housing developers building in the Tijuana-Tecate region are constructing a large number of units of "workforce" housing. These companies, some of who are constructing housing on the edges of the Tijuana fringe close to Tecate and on the edges of Mexicali, are building densely packed terrace and row housing with little or no yards, landscaping, nor any apparent effort to design in passive climate control. There is a significant opportunity for influencing outcomes here. The private construction sector may be induced to build sustainably by providing technical know-how and also subsidy/incentives for using passive energy conserving materials and design. Private developers as a group are in a position to implement the theoretic approach and design guidelines developed in academic research into market driven housing. One way to bring in this community might be through demonstrations of design effectiveness and provision of supportive data on energy sustainable housing units developed as prototypes.

In this context the Stardust Center for Affordable Homes and the Family, Arizona State University has constructed two prototype houses which are designed on principles of passive energy efficiency. The demonstration houses can potentially provide carefully collected data on efficiencies gained through building with sustainable, passive energy conservation in mind. The housing prototypes are suitable for the U.S.-Mexican border region. They were built through engagement of ASU faculty, student teams, and community providing input and participation in construction. The ongoing monitoring of these prototypes promises to yield good information on energy efficiency and design utility. This evaluative data on these prototypes promises to be applicable and useful in approaches to housing construction in the U.S.-Mexico border region as they have been designed for similar climatic conditions, and social/cultural contexts.

Prototype Houses

The Stardust Center for Affordable Housing and Families at ASU states the following about the Nageezi home.

"The Stardust Center's first design/build project, the Augustine residence, was completed in July of 2005 for a Navajo family of elders on allotted land of the Navajo Nation. It was intended as a model of affordable, sustainable and culturally responsive housing. The project was designed and built with the participation of Navajo students in the ASU College of Design and evolved into a partnership with the Navajo Housing Authority. The house was the first house built on the reservation using Navajo Flex-Crete, an aerated flyash concrete block produced by the Navajo Nation, and the design responds to the climate and culture of the Navajo people. The project is being monitored remotely by the Center for one year to determine its climatic performance. Thus far the home is meeting or exceeding predictions and demonstrating a 60 percent reduction in energy use than if the home were built with conventional materials. The Center is working with Indigenous Community Enterprises to build thirty similar homes on the reservation."

The Stardust Center for Affordable Housing and Families at ASU states the following about the Guadalupe House:

"The 2006 Design/Build project is being build in partnership with Guadalupe YouthBuild and a construction team that includes volunteers and ASU students. The design, developed in a workshop process involving community members, accommodates a multi-generational household and allows expansion for the future. The traditional courtyard design minimizes energy use through the use of passive solar heating and cooling techniques, day lighting, a photovoltaic system. Navajo FlexCrete aerated concrete walls and a structural insulated panel roof provide a desert-responsive enclosure. The project is designed as an infill prototype for the Town of Guadalupe, and will be built on multiple sites by the YouthBuild program and Self-Help program."

On a similar note California State Polytechnic University's departments of Architecture, Landscape Architecture and Lyle Center for Regenerative Studies in the College of Environmental Design have developed a prototype house for Tijuana. To be built in the grounds of the Lyle Center, the design emphasizes the use of local materials and technology appropriate for the cultural and economic conditions of the community in Tijuana. These include inexpensive solar heating systems, waste and water systems. The plan is one that allows for incremental growth with additions of rooms moving it from a single room with toilet to a U shaped layout with multiple bedrooms and a flexible layout. Materials with high thermal capacity are used for passive heating and cooling. (La Roche et. al.:2006)

A prototype house designed for the El Rincon settlement would have involved community and been developed on site with the residents of the settlement. Since the community was not successful in obtaining land rights this component of the research remained incomplete. A simulation of a possible design for this community (Figure 56) reflects housing which is higher density, designed for passive heating and cooling, allow for incremental build out, and landscaped for water conservation and climate control. The simulation illustrates that the sustainable housing that might evolve on the railroad right of way would be aesthetic, appropriate to the context and sustainable.

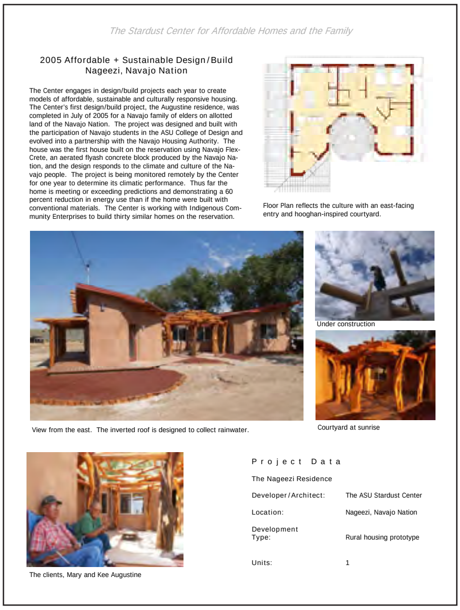


Figure 54: Prototype House, Navajo Reservation in Nageezi, New Mexico
Figure 55: Prototype House Guadalupe, Arizona

Source Figures 54 & 55: The Stardust Center for Affordable Housing and the Family, ASU

Figure 56: Simulation of a Prototype Design for El Rincon

Source: Claudio Munõz Whiting

Conclusions

This work provides support to individual owners, communities, institutions, private and public sector organizations who are seeking to construct sustainable housing and settlements in the U.S.-Mexico border region. The primary focus of this work is on ways to improve housing conditions in colonia settlements which are responsive to the economic, social and cultural needs of the community. The benefit of successfully doing this accrues not just to the communities receiving improved housing but to the general population in the region as the negative environmental impact of rapid growth of informal settlements is reduced. To have an increasing proportion of a population living without decent housing, infrastructure, sanitation and water diminishes the quality of life for those caught in these conditions and those who coexist with them. This work provides technical information and a conceptual approach which is useful to individuals and communities who are engaged in housing and community development, with lower income people who are living in *colonia*-like conditions.

Ways to reduce the environmental impact of rapidly growing informal housing and settlements in the U.S.-Mexico border region in the particular context of Tecate, Baja California, Mexico are presented. The primary body of research which informs this monograph was supported by the Southwest Center for Environmental Research and Policy (SCERP) and culminated in a technical report, Housing and Sustainable Communities in Rapidly Urbanizing Border Regions. In this an analysis of housing in informal communities and the technical options for building sustainable housing are presented. The research team of three faculty and four graduate assistants aspired to implement the concepts and approaches to creating sustainable housing in a prototype colonia in El Rincon, city of Tecate, Baja California, Mexico. Although this became untenable as the political support for the undertaking diminished during the time the research was executed, the effort has yielded some useful information which is broadly useful beyond the specific context. Described here are the concepts and technical choices related to settlement layout, housing design and building construction which can result in sustainable, environment-friendly, human settlements for lower-income people living in this region.

Sustainable housing is context and site specific, derived from local factors of climate, natural resources, culture, history, community, economy, productive capacity, skills, structures of governance and regulation and distribution of power. Given a supportive context, sustainable housing can be attained through judicious choices in the design of the housing units themselves; in their orientation and configuration of layouts; in the materials of construction and their assembly and finish; and in the choice and location of landscaping and ground cover. Choices which can lead to sustainable housing are made by institutions in both the private and the public sectors and by individuals and the community. In short, building sustainable housing requires multiple actors and multiple commitments.

This research intended to introduce sustainable housing approaches into an informal community or *colonia* settled on the railroad right of way in El Rincon, city of Tecate, Baja California, Mexico. It identified a number of challenges to providing housing for the very lowest-income workers in border areas. Chief among these are a lack of: a reliable income and low income; the secure tenancy or ownership rights to land for homes; political support from the larger community and decision makers for providing this; and services and amenities. A number of principles and approaches were identified, however, that can serve as a basis for future projects which aim to improve housing and build housing which is sustainable over the longer term.

These include:

1. Developing communities and a sense of belonging to the region that will promote the development of a border identity and commitment to the region. Developing a sense of permanence, of being rooted, of community well-being.

2. Providing technical choice of materials, layout, design and construction of housing in the context of the particular climate, local materials and skills available of the region and within the prevailing cultural/historical affinities and desires.

3. Designing for passive heating and cooling strategies that minimize energy costs and are low maintenance.

4. Selecting materials so as to optimize for passive climate control. In particular to reduce the use of wood, especially second-hand, low quality salvage wood, and increase the use of materials which enhance passive climate control.

5. Forging creative partnerships between individuals and the community needing housing and non-profit agencies, financial institutions, and local and regional governments to provide finance and land rights.

6. Involving the community needing housing in efforts to design and construct the housing units. Educating the community and introducing sustainable housing principles and design elements so that they are embraced and maintained if not enhanced by the residents and the community..

Over the long term the problems associated with rapid urbanization and housing growth particularly in colonia settlements will persist in the U.S.-Mexico border region. Delineating an approach to intervening in this process needs to elicit the collaboration of public and private actors who are associated with the system of housing construction and involve the residents of the housing. This will make it possible to create housing that is “green”, sustainable, and has a gentler, smaller footprint on the environment. As the economic and cultural pressures along the U.S.-Mexico border spur rapid urbanization and growth of *colonias* it is critical that members of both the private and public sectors, together with members of the communities involved, work together to see that this housing provides the basics of health, safety and quality of life. With the use of proper materials and design tailored to the local climate, this can be achieved, to the betterment of the entire region.

References

Alegria, Tito and Jose Luis Castro Ruiz, "Urban Structure and Infrastructure of Tecate" in Ganster et al., *Tecate, Baja California: Realities and Border Challenges in a Mexican Border Community.* Institute for Regional Studies of the Californias. San Diego CA: San Diego State University Press. 2002. pp. 207-227.

Arreola, Daniel D. and James R. Curtis. *The Mexican Border Cities: Landscape Anatomy and Place Personality*. Tucson: The University of Arizona Press. 1993.

Australian Greenhouse Office. Your Home Technical Manual: Passive Design. Australian Government, Department of Environment and Heritage, http://www.greenhouse.gov.au/yourhome/technical/index.htm (cited August 26, 2006)

Builders Without Borders, http://www.builderswithoutborders.org/

Current Housing Situation in Mexico 2005, Centro de Investigación y Documentación de la Casa (CIDOC) and Sociedad Hipotecaria Federal. http://www.jchs.harvard.edu/publications/international/som2005.pdf (cited December 5, 2006)

Canales, Alejandro. "Industrialización, Urbanización y Crecimiento Demográfico en la Frontera" BorderLines, Vol. 7, no. 7, August 1999. http://americas.irc-online.org/borderlines/1999/bl58/bl58dev.html (cited December 6, 2006)

Cisneros, Ariel. "Texas Colonias: Housing and Infrastructure Issues," Federal Reserve Bank of Dallas, Dallas, Texas. June 2001. http://www.dallasfed.org/research/border/tbe_cisneros.pdf (cited November 25, 2005).

Consejo Nacional de Población (CONAPO). La situación demográfica de México, 2004. México, D.F. http://www.conapo.gob.mx/publicaciones/inicios/001.htm (cited December 6, 2006)

Cruz, Teddy. "Border Postcard: Chronicles from the Edge," Knowledge Communities American Institute of Architects: 2006 http://www.aia.org/cod_lajolla_042404_teddycruz (cited December 6, 2006.)

Cuamea Velázquez, Felipe and James Gerber, "Economic Activity in Tecate" in Ganster, et al., *Tecate, Baja California: Realities and Challenges in a Mexican Border Community:* Institute for Regional Studies of the Californias. San Diego CA: San Diego State University Press 2002 pp. 67-81.

Dandekar, Hemalata. Shelter, women and Development: *First and Third World Perspectives.* Ann Arbor: George Wahr. 1993.

Dandekar, Hemalata and Surabhi Dabir. "Innovating Financing Strategies for Affordable, Self-Help Housing in Rural Areas of the USA." Lincoln Institute of Land Policy Course "Irregular Settlement and Self-Help Housing in the United States: Memoria of a Research Project," CPO1BO5. 2001. http://www.lincolninst.edu/pubs/pub-detail.asp?id=578.

Dandekar, Hemalata, Paloma Giottonini, Claudio Munoz Whiting, and Araceli Frausto. *Urban Eco-Parks: Tecate, Baja California, Mexico.* School of Planning and Landscape Architecture, Arizona State University. 2004.

Daycreek.com. "Earthship." http://www.daycreek.com/dc/HTML/DC_earthship.htm (cited December 6, 2006)

Davidhizar, R. and G.A. Bechtel. "Health and Quality of Life Within Colonias Settlements Along the United States and Mexico Border," Public Health Nursing, 16 (4), 301-306. 1999.

De Schiller, Silvia, Vanessa Gomes da Silva, Norman Goijberg and Cesar Treviño. "Sustainable Building: Implementation in the Latin American Context." PLEA 2003 (The 20th Conference on Passive and Low Energy Architecture), Santiago,Chile. 2003.

Dempsey, Melina, “Funding Implications for *Colonia* Housing in Yuma County Arizona and Imperial County California.” Unpublished Manuscript: 2005.

Downey, David. “At the Border,” *Planning* 72: 26-29. December 2006.

El Bordo, Retos de Frontera, Editor: Ungerleider Kepler, David. http://www.tij.uia.mx/elbordo/vol01/ (cited December 6, 2006)

Energy Savings Trust. Scottish Community and Householder Renewable Initiative. 2003. http://www.est.org.uk/schri/resources/news.cfm (cited August 26, 2006)

Ganster, Paul, Felipe Cuamea Velázquez, José Luis Castro Ruiz, and Angélica Villegas. *Tecate, Baja California: Realities and Border Challenges in a Mexican Border Community.* Institute for Regional Studies of the Californias. San Diego CA: San Diego State University Press. 2002

Green Home Building: Building Today for Tomorrow. Greenhomebuilding.com. http://www.greenhomebuilding.com/index.htm (cited December 6, 2006)

Gidwitz, Lydia, “Earthdome in front of List Art displays sustainable housing efforts.” The Brown Daily Herald: December 6, 2006. http://www.browndailyherald.com/media/storage/paper472/news/2006/04/10/ArtsCulture/ (cited December 6, 2006.)

Hernández, Ricardo. “Cross-Border Links: Where the Action Is.” BorderLines (Volume 1, Number1, October 1992. http://americas.irc-online.org/borderlines/1992/bl1-main.html (cited December 6, 2006).

Huntoon, Laura and Barbara Becker, “Colonias in Arizona: A Changing Definition with Changing Location” Lincoln Institute of Land Policy Course “Irregular Settlement and Self-Help Housing in the United States: Memoria of a Research Project,” CP01B11. http://www.lincolninst.edu/pubs/pub-detail.asp?id=584.

INEGI (Instituto Nacional de Estadística Geografia e Informática). http://www.inegi.gob.mx/inegi/default.aspx 2000.

Koerner, Mona. “Colonias in New Mexico: Rethinking Policy Approaches to Substandard Housing Problems,” Proceedings, Constructing Urban Space, Spring 2002 Urban Issues Colloquium, held at the University of Texas at Austin April 6, 2002, pp. 1-27.

La Roche, Pablo, Irma Ramirez, Kyle Brown, Kristian Whitsett, Kim Wehinger, Mauricio Carranza, Leslie Lum and Sonya Reed, "A Very Low Cost Sustainable Housing Prototype for Tijuana, Mexico." *PLEA 2006 – The 23rd Conference on Passive and Low Energy Architecture*, Geneva, Switzerland: 2006. Available at http://www.unige.ch/cuepe/html/plea2006/proceedings.php (Cited December 6, 2006)

Méndez Sáinz , Eloy, 2003. Espacio Físico Y Espacio Social En La Frontera México-USA. Scripta Nova (Vol.VII. 146(142), August 1, 2003. Barcelona: Universidad de Barcelona. http://www.ub.es/geocrit/sn/sn-146.htm (cited October 26, 2004).

Mukhija, Vinit and Paavo Monkkonen, "Federal Colonias Policy in California: Too Broad and Too Narrow" Housing Policy Debate, Forthcoming: 2007.

National Association of Home Builders (NAHB) Research Center, 2004
http://www.nahb.org/page.aspx/generic/sectionID=96 (cited August 26, 2006)

Necessity Housing – A Non-Profit Organization Devoted to Sustainable Living. "Necessity Housing Recent Projects: Mexico." http://www.necessityhousing.com/ cited December 6, 2006)

Pacific Northwest Pollution Prevention Resource Center (PPRC) Green Buildings Codes and Standards,
http://pprc.org/pubs/greencon/index.cfm (cited December 6, 2006)

Peach, J., and J. Williams. "Population and Economic Dynamics on the U.S.-Mexican Border: Past, Present and Future." Pages 37-72 in The U.S.-Mexican Border Environment: A Road Map to a Sustainable 2020. SCERP Monograph Series No. 1, Paul Ganster, ed. San Diego CA: San Diego State University Press. 2000. http://scerp.org/pubs/mono1.htm

Peach, J., and J. Williams. 2003. "Population Dynamics of the U.S.-Mexican Border Region." Unpublished, forthcoming SCERP Monograph. San Diego: SCERP/SDSU Press.
http://www.scerp.org/population.htm

Planning, "Housing Choice and Affordability" Vol. 72, No. 11, December 2006.

Roaf, Susan, Manuel Fuentes and Stephanie Thomas. *Ecohouse 2: A Design Guide.* Oxford:Architectural Press. 2003.

Ruiz Vargas, Benedicto and Patricia Aceves Calderón. "Pobreza y Desigualdad Social en Tijuana." El Bordo: Retos de Frontera, Vol. 2 http://www.tij.uia.mx/elbordo/vol02/ (cited October 22, 2004).

Ruiz, Ramón Eduardo. *On the Rim of Mexico: Encounters of the Rich and Poor.* Boulder: Westview Press. 1998.

Sadalla, Edward, Tod Swanson, and Jose Velasco. "Residential Behavior and Environmental Hazards in Arizona-Sonora Colonias". 1998. SCERP.Project Number: EH98-2, available at http://www.scerp.org/az.html (cited 25 November 2005).

Scottsdale Green Building Program, http://www.ci.scottsdale.az.us/greenbuilding/ (cited December 5, 2006).

Skolnick, Andrew A. Along US southern border, pollution, poverty, ignorance and greed threaten nation's health. The Journal of the American Medical Association, 273 (19): 1478-1482. 1995. (May 17)

Smith, David A., In "Housing the World's Poor; The Four Essential Roles of Government" *Harvard International Review* 2006 (June 3) http://hir.harvard.edu/articles/1434/ (cited December 6, 2006)

The Evaporative Cooling Site. http://www.coolmax.com.au/evaporative-cooling/index.htm (cited December 6, 2006)

Transborder Shelter Network (1998a), "Private Sector in Matamoros Builds Wooden Houses as an Affordable Starter Home," August/September 1998, available at http://new-web99.whc.net/tsn/practic.htm (cited 25 November 2005).

Transborder Shelter Network (1998b), "Baja California's Progressive Housing Prototype 'VIT'," August/September 1998, available at http://new-web99.whc.net /tsn/practic.htm (cited 25 November 2005).

Transborder Shelter Network (1998c), "Premier Communities of Geo-Beazer Homes, El Paso," October/November 1998, available at http://new-web99.whc.net/tsn/practic.htm (cited 25 November 2005)

U.S. Census Bureau, 2000 Census. http://www.census.gov/main/www/cen2000.html

U.S. Department of Energy. 2004. Home Energy. (cited August 26, 2006) http://www.energy.gov/energyefficiency/homes.htm

U.S. Department of Energy. “Metal (Roofs)” http://www.eere.energy.gov/buildings/info/components/envelope/roofing/metal.html?print – end (cited December 6, 2006)

Vale, Brenda and Robert Vale. The New Autonomous House: Design and Planning for Sustainability. New York: Thames & Hudson. 2000.

. Any brief overview of the demograp
ic and economic forces propellin
growth in the U.S.-Mexico border r
gion around the city of Tecate revea
that this is a region that is und
tremendous pressure of change. T
editor of *El Bordo, Retos de Frontera*,
website where numerous scholarly a
ticles are presented by academics an
investigators, (Ungerleider Kepler, u
dated), describes the rationale for th
effort as follows: "*Creemos que exis*
una gran necesidad, aquí en la fronte
norte de nuestra nación, de estudios y tr
bajos serios de investigación que pueda
esclarecer y/o cuestionar la compleja r
alidad socio-económica y política que e
tamos viviendo. Por tanto, lo que pr
tendemos es fomentar la discusión, el d
bate y el diálogo en torno a los problem
que nos conciernen como académicos
fronterizos." . (We believe that a majo

complete socio-economic and politic
reality [in which] we are living. Ce
tainly, what we propose is to fome
discussion, debate, and dialogue regar
ing the problems that concern us as a
ademics and inhabitants of the borde

There are implications of the
changes for the quality of housin
and the quality of life enjoyed by re
idents in the U.S.-Mexico border ar
a window of opportunity to set
place regulation, guidelines, incentiv
and assistance to protect what a ci
such as Tecate enjoys currently. The
are additional forces related to cultu
identity, a sense of belonging, an
ownership as well as security which al
have great implication for the kind
housing individuals, families and co
munities chose to live in and buil
Some of these are explored here with
view to determining their importan
and implications in building sustai
able housing.

The cultural identity of the Mexica
continues to be discussed some 50
years after the Spanish conquest. T

SCHOOL OF PLANNING, ASU

very much alive in th
border region, where most of the po
ulation arrived as recently as the 1950
This is particular true of the populati
in the western states of Baja Californi
Sonora and Chihuahua. Local cultu
and traditions in this region consi
largely of a mix of several cultur
brought by the new immigrants
this region. The result is often in co