Master Plan for Longju Sustainable Village in Guanghan, Sichuan Province, China

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Summary

This report presents the master plan of a model sustainable village in Longju Village, Guanghan City, Sichuan Province, China.

Guanghan's land reform law promotes the centralization of rural villages to (1) conserve agricultural land and (2) improve the quality of life for people in Guanghan's rural areas. In conformity with this law, Guanghan officials asked the Energy for Sustainable Communities Program of Asia-Pacific Economic Cooperation to help design a model village for 100 households (approximately 355 people) on 66 acres of land that would:

- Improve the quality of life for residents in the village.
- Incorporate advanced technologies and innovative ways of integrating agricultural production and other economic activities.
- Be "sustainable."
- Serve as a model for the design and construction of other sustainable villages in Guanghan and other areas of China.

The master plan for Longju Village described in this paper is consistent with these guidelines.

First, it improves the quality of life of Longju residents, providing access to telephones, televisions, the internet, and improved medical services. It reduces the exposure of residents to emissions from coal and straw used in cooking. The plan also promotes the creation of new business enterprises and, thus, more economic opportunities for residents.

Second, the master plan introduces new technologies, such as:

- an integrated bio-energy system;
- a fuel cell;
- applications of solar technologies;
- a geothermal heat pump; and
- communication technologies (e.g., the internet).

Third, the master plan promotes sustainable growth by:

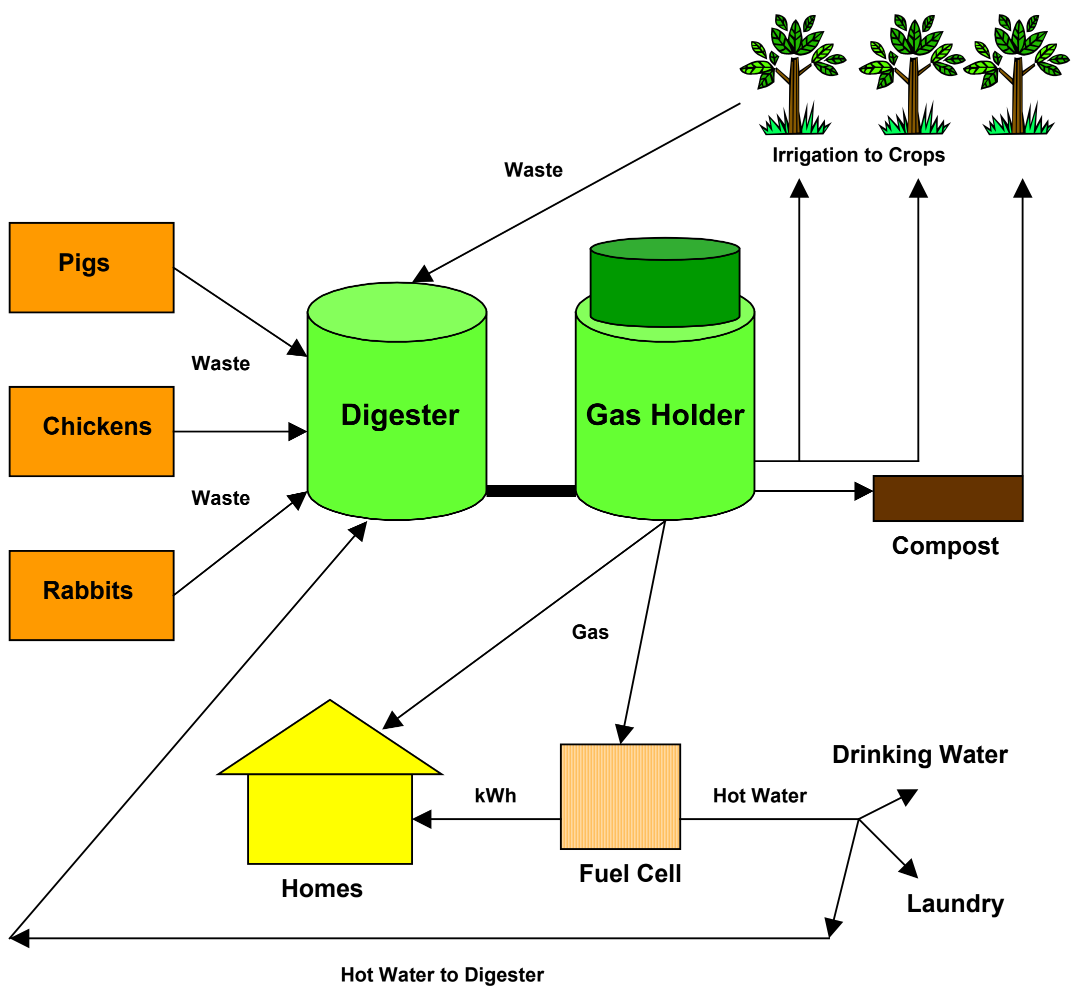
- exploiting local resources to the greatest extent practical, creating new commercial enterprises in construction and habitation of the village and minimizing damage to the environment.
- maximizing the re-use of waste.
- integrating infrastructure by exploiting advances in the miniaturization of technologies for infrastructure development such as energy, water, communications, and transport systems.

Fourth, the master plan can be adapted for use in other rural communities in Guanghan and the rest of China. Conditions different from those in Longju Village indicate the extent to which the Longju Village master plan must be changed for application in other communities.

Figure S.1 illustrates the integration of infrastructure in the village. Two renewable energy technologies, an anaerobic digester and a fuel cell, are the heart of the central energy infrastructure. Animal and agricultural waste is the feedstock for the anaerobic digester. Liquid and solid wastes are by-products of producing gas in the digester. The liquid waste irrigates

agricultural crops and possibly a timber plantation, complementing the existing irrigation system in the village. Solid waste from the digester is used for composting agricultural crops. The anaerobic digester produces cooking gas for households and is also an energy source for the fuel cell. The fuel cell is a self-contained power source for the village that produces electricity for households and other end uses, including electric vehicles. As a byproduct, the fuel cell also produces hot water for (1) drinking, (2) a new commercial laundry enterprise, and (3) a heat source for the digester.

Figure S.1
Schematic of the Central Energy System



The 200-kW fuel cell can theoretically service all of the electric needs of the village. However, solar energy is also an integral part of the village's energy system. Each of the 100 homes will be fitted with piping for solar water heaters and wiring for photovoltaic (PV) systems so that families can easily adopt solar water and PV systems if their income permits. Although air-conditioning and heating are not currently used in the village, they will be employed in the community center. A ground source (geothermal) heat pump similar to ones currently deployed in other parts of China will provide space conditioning for the community center.

The principles for designing and constructing buildings in the village are sustainable. Buildings are designed using passive solar principles, including:

- high thermal mass walls;
- ceiling insulation;
- cross ventilation;
- Southern orientation, letting sun in the windows in winter and shade in the summer; and
- roof overhangs on windows to block the sun in summer.

Local resources will be used for construction materials to the greatest extent possible. The exterior walls of houses will be constructed with compressed earth bricks. These bricks do not require firing, and do not require a factory to produce. This eliminates a large amount of pollution, not only in the firing of the bricks, but also in the transportation required to move bricks and raw materials. Moreover, instead of Portland cement, the soil stabilizer in the bricks will be one of the new cement-like stabilizers that do not require firing in the production process. Compressed earth bricks are easily produced using a hydraulic press. Moreover, their production will be the source of a new micro-enterprise in the village.

A community center will be a catalyst for social interaction in the village. On the exterior, the center includes a plaza and parking spaces for vehicles. The interior includes:

- a kindergarten;
- a cultural center or library for books and other resources;
- a clinic;
- an office for administration of the village;
- a hall for social events and other gatherings; and
- telephones, computers, and internet hookups.

National and local regulations in large measure prescribe the road network both in and around the village. A third-class road (11 meters wide with two-meter bike lanes on either side) will span the eastern side of the village. It will be the primary thoroughfare, linking Longju Village with other villages in Guanghan. A third-class road will be constructed around a portion of the village, facilitating commercial transactions. Fourth-class roads (5.5 meters wide) will be constructed inside the village.

Although traditional transport modes such as cars and motor bikes will continue to be used both in and outside of the village, electric vehicles will also be introduced. Electric tractors and bicycles are the most promising.

Water will be supplied to villagers via a central system. However, this supply will be supplemented by rainwater. Systems for rainwater collection on village houses will provide nearly one-third of a typical household’s water requirements.

The agricultural strategy emphasizes production of high-value crops and livestock. Agricultural enterprises include:

- grains, oils, and staples (rice, wheat, rape seed, and corn);

- livestock and poultry (swine, rabbits, chickens, ducks, and geese);
- fruits and vegetables;
- aquaculture (carp/perch, mullet, prawn, catfish, and turtle);
- greenhouse production (high-value vegetables such as cherry tomatoes, chinese cucumber, and asparagus and selected ornamentals such as anthurium and heliconia); and
- agro-forestry (Italian poplar and black walnut).

Agriculture will continue to be a major source of income for residents of the village. However, tourism will increase in importance after the village is constructed. Indeed, the village itself will be a major tourist attraction. Also, construction and habitation of the village will create opportunities for new business enterprises such as:

- an enhanced service sector (shops, restaurants, and cafes);
- construction enterprises such as a (1) compressed earth brick enterprise to service not only the construction of Longju village, but other villages and towns in surrounding areas and (2) wall-board enterprise using agricultural wastes;
- agro-processing enterprises;
- agro-forestry enterprises;
- a solar marketing and service enterprise;
- livestock enterprises to provide both waste for the anaerobic digester and products for local markets;
- a commercial laundry;
- an internet-based enterprise;
- an electric enterprise (sales of electricity from a fuel cell); and
- a bio-energy enterprise (sales of biogas).

Construction and habitation of the village will promote economic development and growth and social cohesion with minimum damage to the environment. The energy, water, transport, and agriculture systems are integrated to maximize use of local resources to the greatest extent practical, including the use of waste streams from these systems.

1. Introduction

1.1. The Process of Designing and Constructing a Sustainable Village

In March 1999, government officials of Guanghan, China asked Asia-Pacific Economic Cooperation's (APEC's) Energy for Sustainable Communities Program (ESCP) to help the city design and construct a sustainable village as part of ESCP's community outreach project in Guanghan.[1] City officials required that the village be designed and constructed in conformity with Guanghan's recently approved land reform law, enacted in response to the national government's Land-Management Law of 1998.[2] Officials also provided four other guidelines for design of the village:

1. The quality of life of village residents must be improved. An improved standard of living will be an incentive for villagers to remain in the countryside.

2. The design of the village must incorporate advanced technologies and innovative ways of integrating agricultural production and other economic activities. If proved feasible, these technologies and methods will be deployed in other Guanghan villages.

3. The village must be "sustainable."

4. The design must be replicable and serve as a model for other sustainable villages in Guanghan and other parts of China.

The U.S. Department of Energy (USDOE) agreed to fund ESCP's work on designing and constructing the model sustainable village in Guanghan.[3] USDOE sponsored a design charrette for the model village in Golden, Colorado in February 2000.[4] The charrette brought

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[1]APEC, a consortium of 21 Pacific-rim economies, implements its activities through 10 groups, one of which is the Energy Working Group (EWG). The Energy for Sustainable Communities Program (ESCP) is part of EWG. One of ESCP's major activities is a community outreach project in which ESCP works with communities in participating APEC economies on sustainable development. Guanghan is one of the communities in China.

[2]Guanghan's law, approved by the provincial capital in April 2000, will change the structure of rural areas. The key to the plan is centralizing rural communities. Currently, rural areas consist of either scattered houses or "natural villages" in which families construct houses adjacent to one another. The objective of Guanghan's land-management plan is to reverse this historical rural land-use process by centralizing rural houses into 200-house villages in a 200 square-meter area. In these communities, the commute from home to farmland will not exceed 500 meters and a "green belt" consisting of irrigation, roads, and telephones will be the centerpiece.

[3]Andre Van Rest (U.S. Department of Energy, Washington, DC) is the USDOE program manager for the Guanghan effort. Xu Chunlong (Energy Manager, Guanghan) is coordinator of Chinese counterpart activities.

[4]The charrette was hosted by USDOE's Regional Support Office in Golden, Colorado.

together Chinese and American experts for two days to (1) discuss sustainable development in general and (2) identify design characteristics of the Guanghan village in particular.[5]

As a result of the charrette, ESCP developed a seven-phase program to assist Guanghan in designing and constructing the model village:

1. Needs assessment
2. Conceptual design
3. Master plan
4. Design development
5. Construction documents
6. Actual construction
7. Monitoring and evaluation

A USDOE-sponsored team visited Guanghan in August 2000 to conduct the needs assessment and initiate the conceptual design of the village.[6] A five-person Chinese expert team served as counterparts for the eight-person USDOE-sponsored team.[7] The August 2000 visit resulted in a needs assessment and conceptual design of the village. The conceptual design provided several technical options on eight features of the village for Guanghan authorities to consider:[8]

- Building design
- Building construction
- Water system
- Wastewater system
- Community center
- Transport system
- Energy system
- Agricultural system

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[5]A report on the conceptual design of the village lists the attendees at the charrette and presents a summary of it. See U.S. Department of Energy, *Conceptual Design of a Model Sustainable Village: Guanghan, Sichuan Province, China*, Prepared for Energy for Sustainable Communities Program, Asia-Pacific Economic Cooperation, March 2001.

[6]Participants in the site visit included: Huston Eubank (Rocky Mountain Institute; Snowmass, Colorado); Pliny Fisk (Center for Maximum Potential Building Systems, Austin, Texas); Larry Hill (East-West Center; Honolulu, Hawaii); Jack Jenkins (U.S. Department of Energy; Golden, Colorado); Will Kirksey (Civil Engineering Research Foundation; Washington, DC); Shuqin Liu (Beijing Environment and Development Institute; Bejing, China); Terry Rahe (Cascade Earth Sciences; Albany, Oregon); and Desheng Xiao (Valmont Irrigation; Beijing, China).

[7]The Chinese team included: Xu Bin, agricultural expert; Zhou Wenji, architect; Liu Xianxin, structural engineer; Liao Chuangui, urban planner; and Wei Bin, environmental engineer.

[8]U.S. Department of Energy, o*p. cit*.

Building on the foundation laid in the conceptual design, a second ESCP team visited Guanghan in June 2001 to develop a master plan for the village.[9] Working with Chinese expert counterparts and government officials, the team narrowed the options of the conceptual design and produced a master plan for the village. This report documents the master plan.

1.2. Principles Used to Design the Sustainable Village

A study conducted under the auspices of the United Nations provides the most widely used definition of sustainability or sustainable development:[10]

> ". . . development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

When applied in practice, this definition suggests that the natural relationships among the economic, environmental, and social sub-systems of a community be nurtured to ensure that they do not deteriorate over time. Stated another way, the habitation of any community or village can be viewed as a natural system with inter-related economic, environmental, and social sub-systems. Six basic principles, taking into account the economic, environmental, and social sub-systems of a village or community, follow from this definition and should be used in the design of any sustainable community:

1. The village must be treated as a natural system, consisting of:

    - village residents and the community;
    - energy;
    - water and sanitation;
    - transportation;
    - agriculture; and
    - business enterprises

2. Natural resources in the village must be used to the greatest extent practical without depleting the capacity of the village's natural systems to be sustainable.

3. Natural living systems must be protected by not polluting the water, air, and soil.

4. Waste must be re-used to the maximum extent possible.

5. Efficiency of all systems in the village must be maximized to the greatest extent possible.

6. Community organizations must be created and operated for the benefit of all villagers.

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[9]The team consisted of: Larry Hill (International Sustainable Development Foundation; Portland, Oregon), David Holmberg (National Taiwan University; Taipei, Taiwan), Shuqin Liu (Environmental Defense Fund; Bejing, China), Samuel Scott (Alcorn State University; Alcorn City, Mississippi), John Spears (International Center for Sustainable Development; Gaithersburg, Maryland), and Andre Van Rest (U.S. Department of Energy; Washington, DC).

[10]Brundtland, G., Editor, 1987, *Our Common Future*, The World Commission on Environment and Development, London: Oxford University Press.

Operationalizing these principles, the master plan for Longju sustainable village:

1. Promotes sustainable *economic growth* by:

- promoting the efficient use of all resources.
- strengthening the physical infrastructure of traditional agriculture.
- creating new industries from constructing the village.
- creating new industries from inhabiting the village.
- creating a promenade that promotes commercial activity.
- using advances in technology to integrate the infrastructure of the village (energy, water, transport, and communications) to the greatest extent possible.

2. Minimizes damage to the *environment* by:

- reducing environmental emissions to the lowest extent possible.
- balancing consumption with existing resources in the village to the greatest extent possible.
- maximizing re-use of waste of human and economic activity to the greatest extent possible.

3. Fosters a sense of *community* by:

- allowing maximum flexibility for individual choice in living conditions.
- constructing a "community center" that promotes the personal interaction of village residents.
- accounting for the village's cultural heritage in the design of the village.
- using advances in internet technology to promote the village's cultural heritage.

2. Land-Use Plan

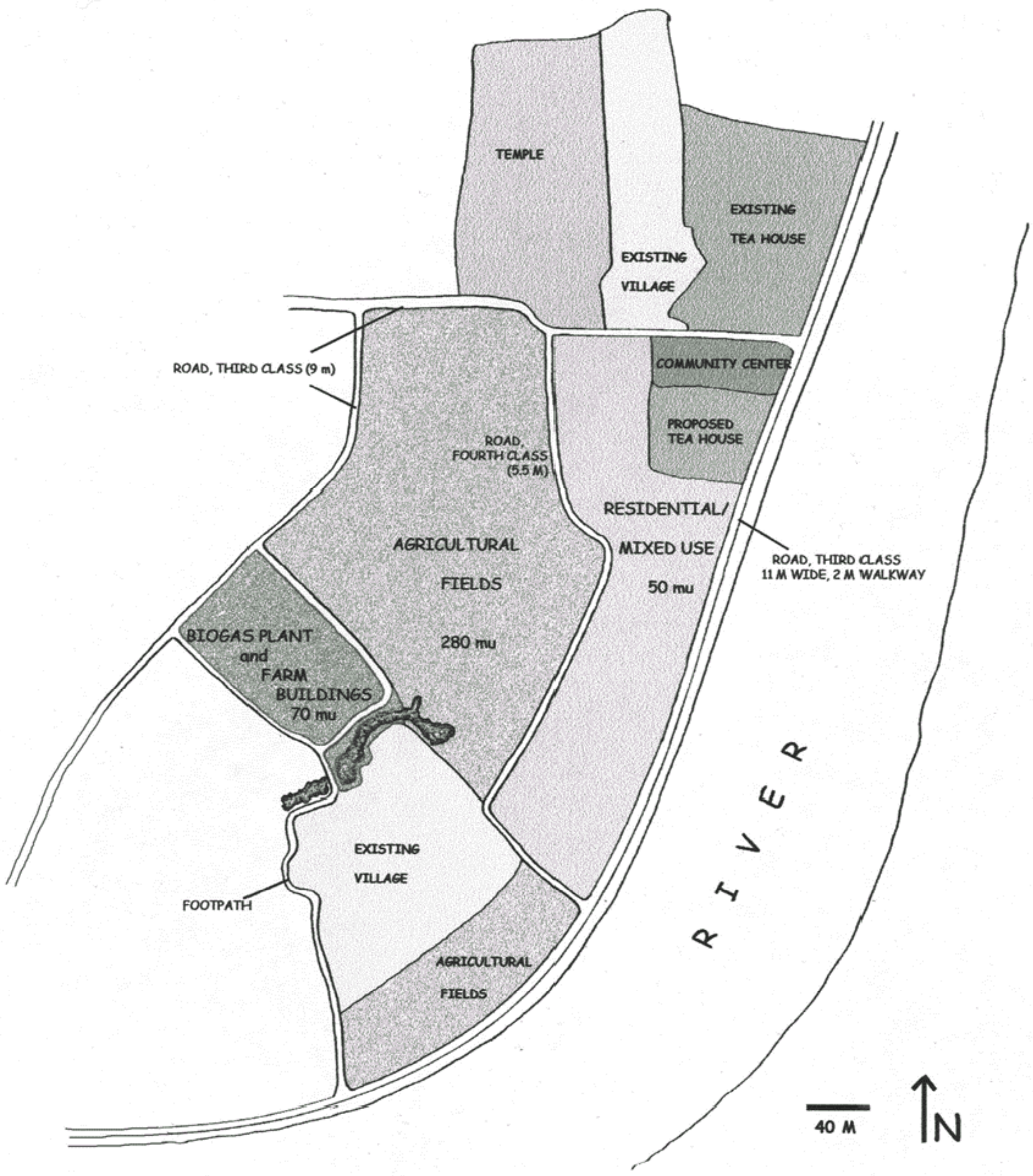
Figure 2.1 shows the land-use plan of the sustainable village and its surrounding area. The site of the model village itself is South of the Class III road shown at the top of the figure, below the temple and existing village and tea house.

The Longju Temple, a Buddhist temple constructed more than 300 years ago, lies immediately North of the village site. The temple is an important site for tourists to Longju Village, attracting more than 200,000 visitors in 2000. An existing natural village separates the Longju Temple from the Longju Garden Tea House. Construction of the latter was finished in early 2000. Tea houses of this kind are common in Guanghan. They are rural recreational enclaves, attracting urban dwellers to experience rural lifestyles. They promote tourism in rural areas and are very profitable for local entrepreneurs.

A levee separates the model village site from a river on its East side. An improved, concrete road, 8.9 meters wide, is part of the levee on the East side of the Longju Garden Tea House. This road extends to the West in front of the Longju Temple. Currently, the road on the levee bordering the model village site is seven meters wide and unimproved. Plans are to widen and pave the road and connect it with the existing improved road to the North in the near future.

The levee to the East of the "residential/mixed use" site will form a promenade after the village is constructed. The promenade will serve both economic and social functions for the village. Households along the promenade will be able to configure a portion of their houses as shops to engage in commercial activity on the promenade. The promenade is expected to be a major center of commercial activity in the village.

Figure 2.1
Land-Use Plan of Longju Village



The area of the model village site is approximately 400 mu (65.87 acres).[11] The design allows for the following allocation of land in four functional areas:

[11] 15 mu = 1 hectare = 2.47 acres.

Residential Housing/Mixed-Use	50
Biogas Plant and Farm Buildings	70
Agriculture	210
Other	70
Total	400 mu

2.1. Residential Housing/Mixed Use

After construction, the village will contain both old and new residential housing. Old houses include the natural village with approximately 20 households ("existing village" in the Southern part of the model village shown in Figure 2.1) and an additional 10 to 15 houses that currently exist in the "residential/mixed use" area. New residential housing will be constructed in the "residential/mixed use" area shown in Figure 2.1.

The initial plan was to construct 100 new houses in the village. However, two factors complicate determining the precise number of new houses that actually can be constructed. First, limits on the amount of available land for residential housing prohibit constructing 100 new houses without demolishing some of the existing houses on the model village site. And, the number of households willing to demolish their existing houses and purchase new ones is not known. Second, the size and configuration of the new houses will be determined by the preferences of individual households, city officials, architects, and engineers. Without knowing those preferences beforehand, it is not possible to quantify the number of new houses. It is still possible, however, to make three general statements about residential housing.

First, housing design techniques based on passive solar principles will be prescribed for each new house. Section 3.1 discusses these techniques.

Second, many of the new houses will border the levee. The houses along the levee will be part of a commercial center on the promenade that extends across the length of the village site. Owners of the houses will have the flexibility to design them to accommodate commercial trade along the promenade. Business enterprises will be integrated into the homes of the villagers. These business enterprises along the promenade will complement those located near the temple and community. However, the enterprises along the promenade should be distinct from the others. Whereas most of the current business enterprises use a steel roll-up door design, the promenade should have a different construction plan, making it an aesthetically appealing area. This will in turn promote tourism.

Third, the homes along the promenade (as well as along the street across from the temple) will be high density to maximize business opportunities. Small, family gardens can be located behind the homes. Alternatively, family gardens could be located in the southern part of the village (presently garden vegetable area) with some of the land behind the new homes left as rice fields.

2.2. Biogas Plant and Farm Buildings

Figure 2.1 shows that energy facilities will be located in the Southwestern portion of the village. These facilities include an anaerobic digester, two "farm units" to feed the digester, and a fuel cell.

The digester produces gas that is used for home cooking and a fuel source for the fuel cell. Two “farm units,” consisting of animals and their barns (discussed in detail in Section 4.1.2), provide sufficient waste for the anaerobic digester to produce the gas. A 200-kW fuel cell provides sufficient electricity for the entire village. The farm unit/ biogas facility/ fuel cell facilities are located near the transformer on the electric utility’s grid, simplifying connection to the grid.

2.3. Agriculture

Each house will have sufficient space for household members to raise livestock and agricultural crops both for their own use and sale in traditional markets. In addition to these family plots, the village has two areas allocated for agriculture. In the major agricultural area shown in Figure 2.1, 210 mu are allocated for agriculture: grains, oil crops, fruits and vegetables, and other staples.

Animal and aquaculture facilities and a composting site will be located in the Southwest corner of the village as part of the biogas facilities. This will allow for the construction of centralized run-off for waste into the biogas plant. Surrounding the western tip and close to the class III road to be built will be the packinghouse/post-harvest facility and the greenhouse. This will allow for ease of movement of products to the designated markets after harvesting.

2.4. Community Center

The community center will be the focal point of social life for the villagers. From Figure 2.1, it will be located at the Northeast entrance of the village. An arch across the road in traditional Chinese style will welcome tourists. Because of the large number of tourists visiting the temple and the commercial activity around the temple and along the promenade, the Northeast corner will be the most congested part of the village. Besides serving the villagers, the community center can welcome visitors and display the village design with exhibits describing the history of the village and its innovative design. Section 3.3. discusses the community center in more detail.

3. Buildings

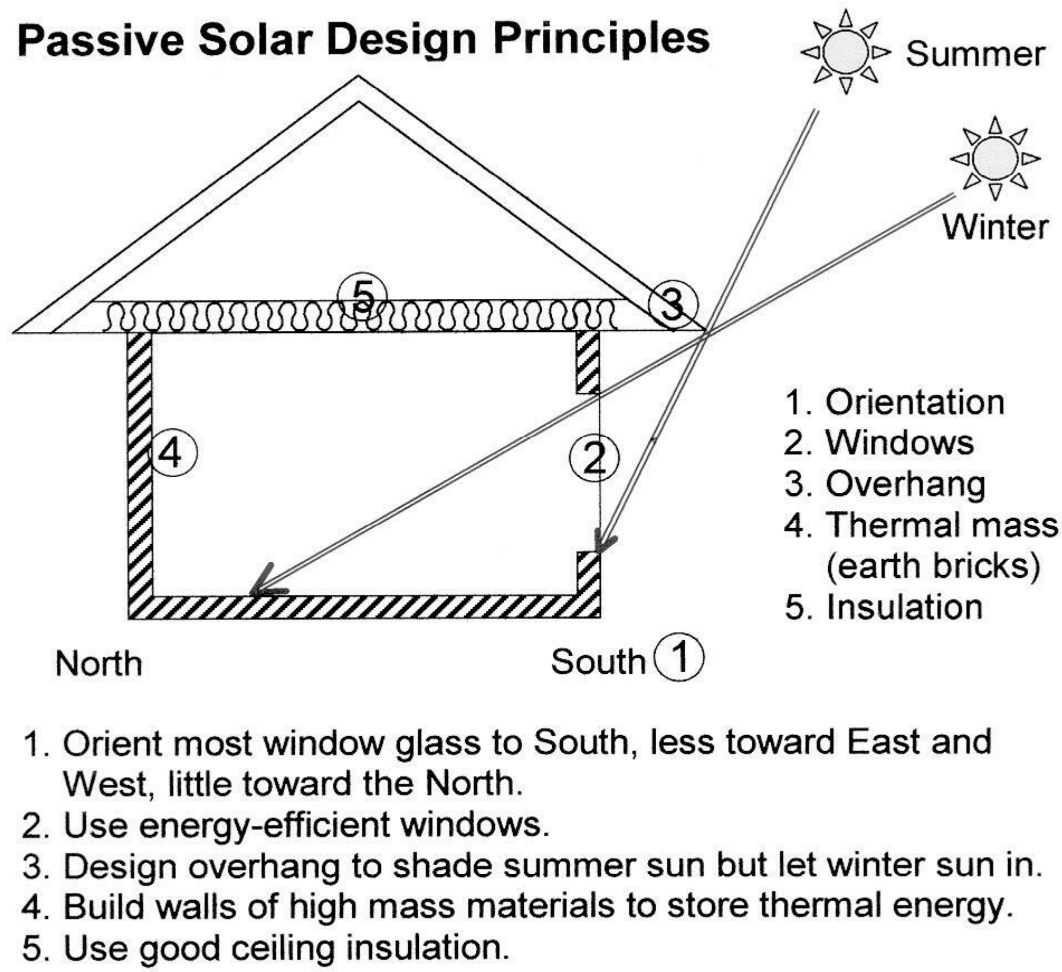
3.1. Housing Design Techniques

The residents of Longju village can select a housing size and room configuration based on their individual preferences and income level. Residents with homes along the levee have the opportunity to select a housing style that uses one or more of their rooms as a shop and thus facilitate commerce on the promenade.

Despite individual decisionmaking on size and configuration, all houses will be constructed within specific design parameters. As a general rule, houses in the village will be designed to efficiently provide indoor comfort throughout the year. Houses will be cool in the summer and warm in winter. This can be accomplished in the mild climate of Guanghan without a heating or cooling system. If the building remains comfortable without the need for a heating or cooling system, the building will be very energy efficient, inexpensive to operate, and simple to maintain.

Passive solar design techniques will be used to attain this heating and cooling comfort level. Figure 3.1 illustrates passive solar design principles. The major characteristics of a passive solar house are:[12]

Figure 3.1
Passive Solar Design Principles



- Thermal mass in the walls significantly contributes to interior comfort levels. The high-mass materials of the walls take time to heat and cool, effectively shielding the home's interior from outside temperature extremes. Therefore, with enough thermal mass, the home's internal temperature follows the outdoor average temperature—cooler during the day and

[12] These techniques have been investigated and refined over the past 30 years at U.S. national laboratories, including the Florida Solar Energy Center, National Renewable Energy Laboratory, and Oak Ridge National Laboratory. All of the techniques suggested here are refined to their essence via physical testing and numerical verification, and tuned to the Guanghan climate (similar to Florida's climate).

warmer at night. The brick walls used in the construction of houses in Longju Village (discussed in Section 3.2) will contribute significantly to high thermal mass, leading to higher comfort levels for residents of these houses.

- In Guanghan's climate (hot and humid in the summer, cool in the winter, but relatively mild), insulation on the walls is not necessary as long as the occupants live without heat in the winter and air conditioning in the summer. The earth brick walls are poor insulators of heat. Therefore, if constant heating or cooling of house air is desired, a layer of insulation on the outside of the home is necessary.

- Ceilings in the homes should be installed with a layer of insulation equivalent to R-30. This degree of insulation prevents heat gain from a hot roof in the summer. In addition, attic space should be designed to allow natural convection cooling: soffit vents as air inlets, and vents under the eaves to allow hot air to escape. This system of ceiling insulation and attic cooling will greatly reduce the summer heat entering the house. Ceiling insulation will also help keep the house warm in winter.

- The homes will be oriented so that the roof ridge is along an east-west axis, with most windows on the south side and as few as possible facing north, east, and west. The south windows should be shaded by a roof overhang protecting the indoors from the summer sun, but not the winter sun. This design allows the home to receive light in the summer and winter, but only to receive direct sun in the winter to help warm the house. Fewer windows on the east and west sides mitigate the possibility that direct sunlight will heat homes during the summer. Trees adjacent to the house should also be used for shade in the summer and wind barriers in the winter.

- Windows should be carefully placed to allow good cross-ventilation, taking into consideration prevailing winds in the village. Windows should also be located high on the walls (or open from the top) to allow hot air in the upper part of rooms to escape.

- Energy conservation measures include high thermal mass walls, insulation, south-facing orientation, shaded southern windows, and cross ventilation. Single-pane windows, although not very energy-efficient in a heating or cooling climate, should be sufficient in the Guanghan climate. Other factors will affect energy consumption (whether gas or electric) on a daily basis in village homes. The village should install fluorescent lights and not use incandescent lights. As noted above, if air-conditioning or heating is used regularly, the house owner should probably insulate house walls to conserve energy. In general, a fan can increase comfort in a home in the summer at lower cost than running an air conditioner. For those who want hot water in the home, a solar water heater would be preferable since it requires no gas or electric power to heat the water. If a solar heater is not available, then a gas water heater should be used rather than electric.

3.2. Construction Materials

In designing the village, the following were considered possibilities as construction materials:

- Fly ash and bottom ash of nearby coal plants for house frames (columns, beams, and floors) and shells (wall and roof panels);
- Wood chips for wall and roof panels;
- Straw residue from rice for wall panels;

- Fired bricks for outside walls;
- Concrete blocks for outside walls;
- Earth blocks for outside walls; and
- Compressed earth bricks for outside walls and foundations.

After weighing environmental and economic factors, we recommend that compressed earth bricks be used for the outside walls of houses.

Fly ash from coal plants was considered, but is not a viable construction material in Guanghan. Chinese regulations on radiation in fly ash prevent its use as a substitute for Portland cement. Fired bricks and concrete blocks were eliminated from consideration on environmental grounds. They are produced in brick factories and require baking in coal-fired ovens. Not only does a brick factory require land area, but the oven-firing operation consumes a large amount of energy. Moreover, the dirty coal used to fire the oven produces a large amount of air pollution that affects the area around and surrounding the production facility. Earth blocks for constructing walls have been used in China for millennia, whether in humble dwelling places or in the Great Wall of China. These traditional adobe bricks are made by mixing mud with straw and then pouring the mixture into molds that are dried outdoors in the sun. Adobe bricks are not stabilized (can be eroded by water) and thus must be plastered with mud and maintained regularly.

Compressed earth bricks provide greater strength than earth blocks and do not require wet mixing and drying. Adding a stabilizer to the earth (such as Portland cement or newer types of bonding agents such as CeraCrete that do not require Portland cement) solidifies the compressed bricks and makes them strong and stable in water--similar to fired commercial bricks. Compressed earth bricks do not require firing, and do not require a factory. This eliminates a large amount of pollution, not only by eliminating the need to fire the bricks, but also eliminating transportation required to move bricks and raw materials. In Longju Village, compressed earth bricks can be manufactured on the construction site with a mix of earth from housing sites or from the aquaculture excavation sites with a small percentage of cement (two to ten percent). The cement controls the compressive strength of the bricks.

The quality of compressed earth bricks has steadily improved over the years (Figure 3.2). State-of-the-art machines can now produce high-strength, durable, and attractive bricks with a tongue-and-groove shape that allows for interlocking wall construction without using mortar. The compressed-earth bricks can be immediately configured into a wall where they cure in place (Figure 3.3).

Although perfectly suitable for one-story buildings, tongue-and-groove, interlocking wall construction may not be appropriate for multi-story buildings with higher levels of stress on the walls. In this case, compressed earth bricks are appropriate, but the structural engineering of the building changes. Depending on the application in multi-story buildings, post and beams with compressed earth brick infill can be used. Or, alternatively, compressed earth bricks can be constructed with holes in the center. Rebars can then be used as structural reinforcements for the bricks.

With some training, brick production and wall construction can be performed by local villagers, creating a new micro-enterprise. With a crew of five people, three bricks can be produced per minute. One cubic meter of sub-soil mixed with two to ten percent of cement results in 110 blocks, each 9 kg in mass, with dimensions of 204mm x 102mm x 255mm. Tests show that the compressive strength of blocks with these specifications is 1600 pounds per square inch (psi) (11.0 MPa), assuming 5% added cement content. The sub-soil in Longju village has the required clay content to meet these specifications (between 5% and 20%).

Figure 3.2
Compressed Earth Bricks

Figure 3.3
Wall from Compressed Earth Bricks

A portable compressed-brick GreenMachine can be used to produce the bricks (Figure 3.4). It is a portable (930 kg trailer), hydraulic press, powered by an eight horsepower gasoline engine. Portability of the hydraulic press allows bricks to be produced at the construction site. The portability of the machine also allows it to be used at construction sites other than in Longju Village or Guanghan. As such, it provides a micro-enterprise business opportunity for villagers.

Figure 3.4
Portable Compressed-Brick GreenMachine

The portable machine that is shown in Figure 3.4 costs approximately $40,000. Larger machines producing more bricks are also available. For example, a larger machine with a retail price of $160,000-$200,000 produces up to 800 blocks per hour.

Typically, Portland cement is used as the stabilizer for compressed earth bricks. However, Portland cement requires firing to manufacture, is expensive, and contributes to air pollution. In the place of Portland cement, we recommend CeraCrete, a new cement-like stabilizer that does not require firing.

The outside walls should be insulated with 2.5 cm of foam and stucco. Foundations of the houses will be constructed using conventional slab on grate.

The inner walls and ceilings of houses will be constructed using straw board. Because of timing considerations in beginning a straw board enterprise, however, the inner walls of the first houses constructed in Longju Village may be compressed earth bricks.

There is a sufficient amount of straw (from rice) in Longju Village and its environs to start a new straw board enterprise. That enterprise could initially serve the construction needs of Longju Village, but then broaden its market scope to include other villages and towns in Guanghan.

The Enviro Board Corporation Building System is an example of a process that could produce straw boards. The system includes basic mill design and the compressed fiber panel concept. The mill is a semi-automatic fiber-processing machine. It compresses agricultural fiber into a dense core that is then covered with a durable paper membrane. The machine can be operated almost 24 hours per day with a minimum of five semi-skilled workers per shift. Almost any type of agricultural waste fiber (e.g., wheat straw, rice straw, sugar cane) can be transformed into low-cost building panels in a variety of lengths and thickness.

3.3. Community Center

The community center will be a catalyst for social interaction and commerce in the village, used not only for social gatherings but also for administration, and a new business enterprise. The community center itself will be constructed with materials similar to those used in constructing houses in the village. Outside walls will be constructed using compressed earth bricks, with stucco and 2.5 cm of foam insulation. The foundation will be constructed using conventional slab on grate. Inner walls and ceilings will be constructed with straw board.

Outside, the center will include a plaza and some parking spaces to help with the parking needs of tourists and the limited number of cars owned by village residents. The parking spaces will be at the road level, perhaps with the second floor of the community center built over a row of parking spaces. Additionally, the Northeast corner of the village (next to the village community center) will be used for a small outdoor square with benches around the perimeter and an open square in the center. This mini-park serves as a rest area for tourists and a community gathering point for dancing and other activities.

Based in large measure on local regulations, the center will include a(n):

- kindergarten for village children;
- cultural center and library for books and other resources;
- health clinic for residents;
- office for administration of the village;
- hall for social events and other gatherings; and
- telephones, televisions, computers, and internet hookups.

By housing computers with internet connections, the community center can breed new economic opportunities for the villagers. An example is the adoption of the internet-based GreenStar program. GreenStar currently provides electricity, electronic commerce, water, education, and telemedicine to villages in many parts of the developing world. In Longju Village, GreenStar can bring local products--including art, music, photography, and storytelling--to world markets through the Internet:.

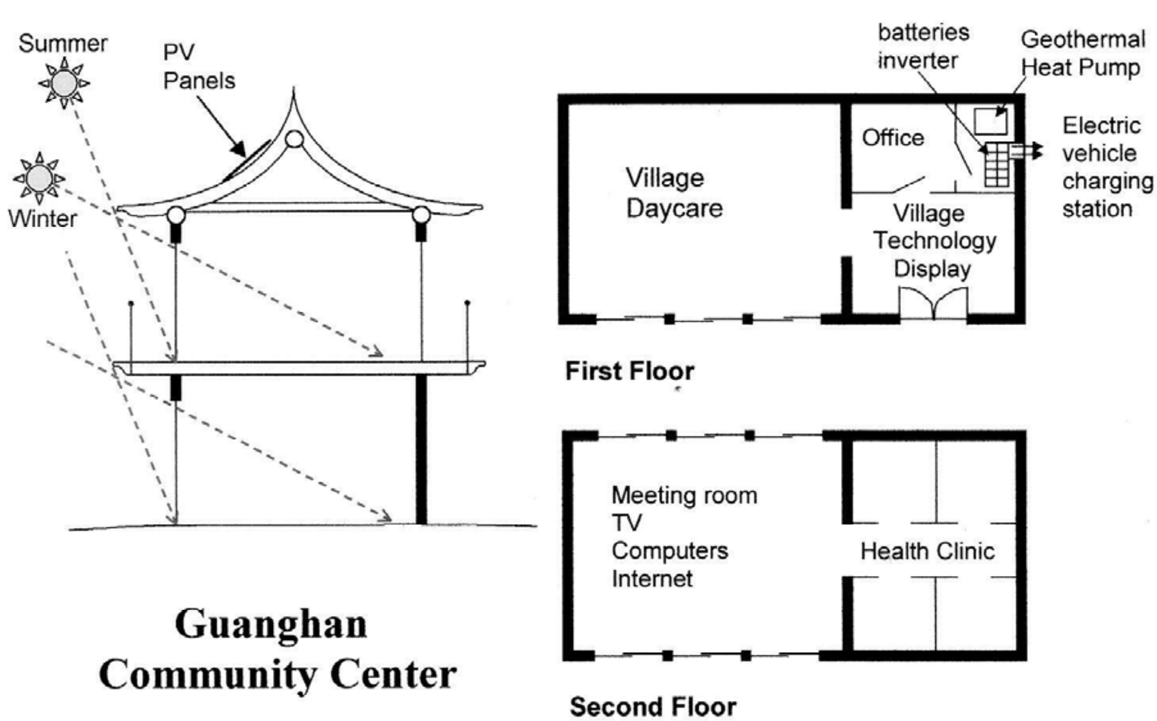
The community center will be technologically advanced, designed in part to demonstrate advanced technologies and techniques, including:

- energy efficient design techniques;
- passive solar building construction (discussed in Section 3.1 above);
- photovoltaic (PV) panels for power production (discussed in Section 4.3);
- rainwater collection with cisterns (discussed in Section 5.1);
- ground-source (geothermal) heat pump for heating, cooling, and water heating (discussed in Section 4.4); and
- electric vehicle charging outlet.

Finally, a visitor's "Innovative Technology in Longju Village" display in the community center will highlight and describe the use of innovative technologies and techniques in the village.

Figure 3.5 presents a schematic layout of the community center.

Figure 3.5
Schematic Layout of the Community Center



4. Energy System

The village will use local energy resources to the greatest extent practical, minimizing energy imports into the village and substituting renewable energy resources in the village for fossil fuels. An energy policy based on these principles will improve the local environment, reduce energy-related health threats, and promote growth of the local economy.

The four main indigenous—and also renewable--energy resources in the model village are human and animal waste, biomass (primarily rice residue), geothermal, and the sun. Additionally, modern energy forms are abundantly available in the area. Every household in rural Guanghan has access to electricity from the local power company. Natural gas is also plentiful in the area and the gas infrastructure is already extensive. Of the 120,000 people living in Guanghan's urban center, for example, 100,000 use natural gas. According to city officials, the gas distribution network is within 10 kilometers of Longju Village at the present time. Guanghan also is conducting a demonstration project using compressed natural gas in buses and automobiles.[13]

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[13] Sichuan Province has the largest amount of natural gas reserves in China. Within Sichuan, Guanghan and Chongqing have the largest amount. However, Guanghan does not own its underground reserves. Only provincial and national corporations can explore, develop, and sell natural gas in China.

Longju Village's energy strategy must provide for the energy-consuming sectors and end uses in the village. These include households (lighting, cooking, water heating), an enhanced business/commercial sector, transportation, agriculture, and a new public lighting system along the promenade.

The *total* energy system in the village consists of:

- primary energy sources (animal and agricultural waste; the sun; and geothermal);
- energy conversion facilities (anaerobic digester, fuel cell, photovoltaic cells, and geothermal heat pump);
- energy outputs (electricity and gas);
- energy by-products (liquid waste for irrigation; solid waste for composting; and hot water for drinking, a laundry, and use in the digester; and
- energy consumers (households, community center, micro-enterprises, electric vehicles, and street lighting).

Figure 4.1 characterizes the *central* energy system in the village (the total system without photovoltaic panels and the geothermal heat pump).

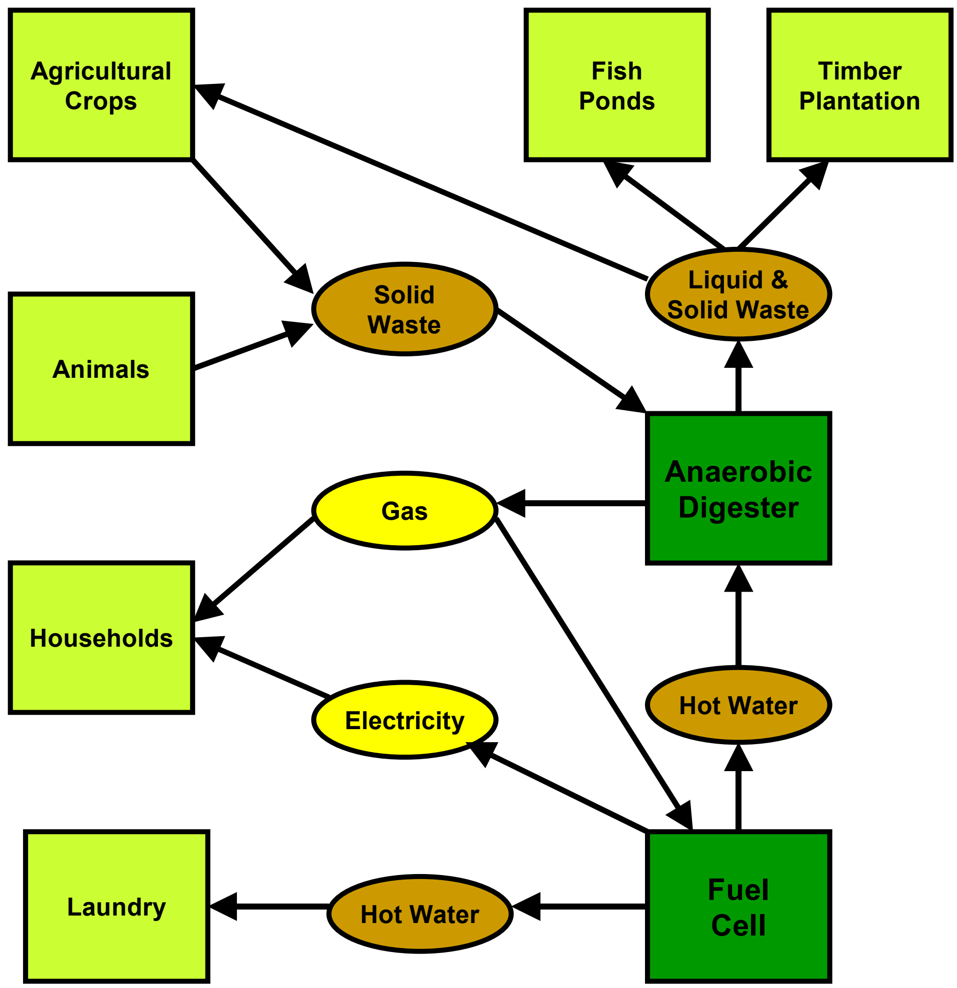
The bio-energy system forms a closed-loop system that supplies the village with gas, processes waste, protects the environment, and improves the economic and social well-being of the villagers. In this system, agricultural and animal wastes are inputs to the anaerobic digester. Inside the heated digester, bacteria continually digest the waste stream in an anaerobic reaction that produces biogas (primarily methane and carbon dioxide) as well as a post-digestion effluent. This effluent is separated into solid and liquid components. The solids are composted and used as fertilizer in the fields. The high-nutrient liquid will be used in the aquaculture ponds, agricultural fields, and timber plantations (if enough land area is available for agro-forestry enterprises).

The gas from the digester has two uses. First, biogas will be piped directly to individual homes and used for cooking. Second, biogas will be used as an energy source by the fuel cell. The state-of-the-art fuel cell produces electricity for the village and, as a byproduct, hot water that can be used in (1) the anaerobic digester to maintain the temperatures required to sustain a digestion reaction, (2) a laundry, and (3) for drinking (not pictured in Figure 4.1). The fuel cell also serves as the connection point of the utility power grid to the village homes. The fuel cell produces power as needed by the village. If biogas production decreases, village electricity needs can be met by the local electric utility. If the fuel cell produces more power than needed, excess power can be sold to the grid.

The central energy system shown in Figure 4.1 will be supplemented by two other renewable energy sources: the sun and geothermal (ground source) energy. To demonstrate their effectiveness and reliability, photovoltaic (PV) panels will be deployed in the community center to harness the sun's energy and provide electricity for the center. One demonstration house will also be fitted with PV panels and a solar water heater. All other houses will be fitted with the infrastructure to deploy PV panels and solar water heaters. The decision to purchase them will be at the discretion of individual households. A ground source heat pump will provide heating and cooling for the community center.

Each of the energy conversion facilities in the village will be discussed in greater detail below.

Figure 4.1
Schematic of the Central Energy System



4.1. Integrated Bio-Energy System

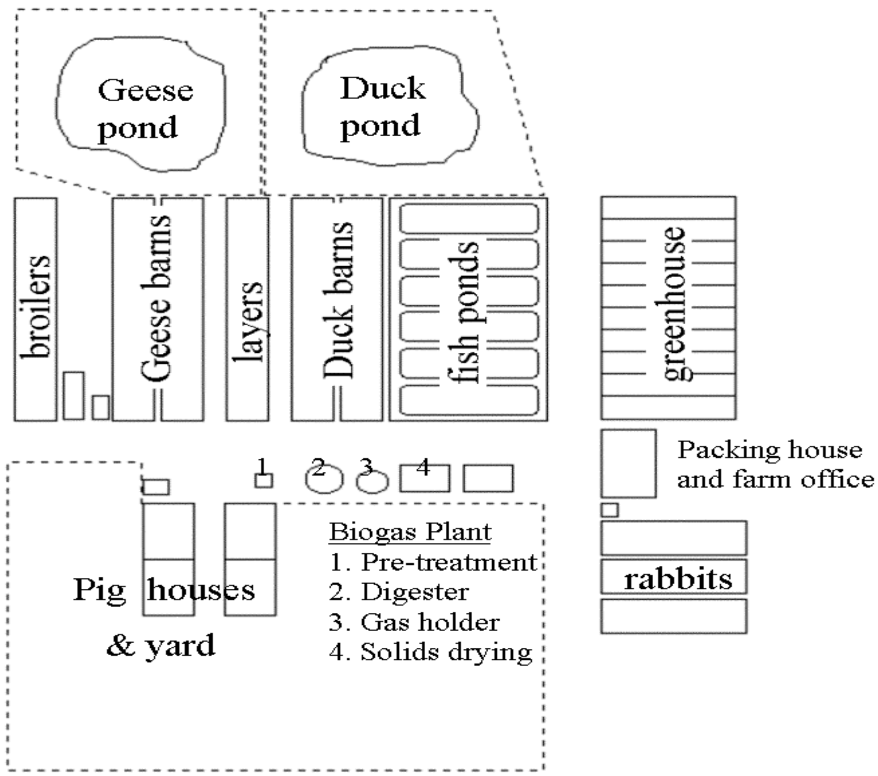
Figure 4.2 shows the layout of the biogas plant and its supporting infrastructure. Waste from 23,220 animals in 13 barns will provide sufficient gas for the cooking needs of 100 households (one “farm unit”). Additional buildings support other agricultural activities (e.g., greenhouse, packing-house) in the vicinity. Appendix A contains detailed design specifications for all farm buildings shown in Figure 4.2.

The biogas facilities, located near the center of the complex, consist of the following:

- pre-treatment facilities;

- a digester;
- a gas storage tank; and
- a drying facility

Figure 4.2
Schematic of the Integrated Bio-Energy System



The two geese and duck barns and one layer barn are on the north side of the pre-treatment collection point. The barns are designed to make for easy collection and transfer of the bird droppings to the pre-treatment facility. The pig houses (two barns) are also located next to the pre-treatment facility to facilitate waste transfer. The animal residue can be collected by gravity—and some automation—to feed the residue into the pre-treatment facility. To minimize the amount of odor to residents of the village, the broiler (meat chicken) barn is located on the west side and the pig barns on the south side of the complex. The broilers will be on a litter system. Their waste (mixed with litter) will be composted rather than fed to the digester. A greenhouse, a vegetable packing house (with farm office), and three rabbit barns are located on the east side of the biogas system. Geese and duck ponds (and surrounding pasture) are on the north side of the duck and geese barns.

4.1.1. Biogas Facilities

The biogas facility shown in Figure 4.2 consists of four components. In the pre-treatment facility, animal excreta are collected, mixed, and controlled for water content, temperature, acidity, carbon-nitrogen balance, settlement of solid particles, and liquid/ solid separation. The digester is a standard anaerobic digester with a 20-30 day holding retention time. It is operated at warm (mesophyllic) temperature with an insulated tank and some additional heating. The gas storage facility is a standard design. Gas will be treated in the storage facility to remove sulfur and tar. Effluent from the digester will be separated into liquids and solids. The liquids will be used for irrigation. The solids will be sent to a drying area, from where they can then be delivered to agricultural fields along with other composted materials.

Chinese and U.S. experts will jointly design the digester.[14] The biogas facility will be larger and more technologically advanced than a typical household unit, but not as large as a specialized facility designed for a large farm. The elements of the facility will adhere to a standard design, using pre-manufactured "off-the-shelf" components rather than site-built and site-specific. The biogas facility will be insensitive to type of input because of careful pre-treatment, allowing for the use of some agricultural wastes and cow and/or other animal excreta. There will also be standard options for effluent usage, such as pre-sized fish farm operations, rice seedling fields, and tree farms (if enough land is available).

4.1.2. The Concept of a Farm Unit

Small, intensive animal farms provide the major inputs for the anaerobic digester. Termed "farm units," these animal farms will be economic enterprises owned and operated by villagers. Two variants of the farm unit will be used in the village.

The first "farm unit" will be sufficiently sized to produce enough gas to supply approximately 100 families with cooking gas. This unit will incorporate at least one barn of all of the animal types preferred by villagers. The waste from this farm unit will produce approximately 200 m^3/day of biogas when the system operates efficiently. Table 4.1 provides details on the number of animal barns, the number of animals by type, and residue and biogas estimates for this farm unit. Some additional small buildings (e.g. feed storage and composting) required for efficient operation are not shown in the table.

The second farm unit will be pig-intensive and produce enough biogas to operate the 200-kW fuel cell. This unit will have 960 pigs (six barns with 160 pigs each) using 30 mu of land area.

4.2. Fuel Cell

A fuel cell is equivalent to a battery. The primary difference between a fuel cell and a battery is that a fuel cell has a continuous supply of reactants that are supplied externally to the cell. A battery has internal reactants that are depleted over time. A fuel cell produces direct current (DC) power via an electrochemical reaction. An inverter is required to convert DC power produced by the cell to alternating current (AC).

Figure 4.3 illustrates the operational principles of fuel cells. A fuel cell consists of two electrodes sandwiched around an electrolyte. Oxygen passes over one electrode and hydrogen over the other, generating electricity, water and heat.

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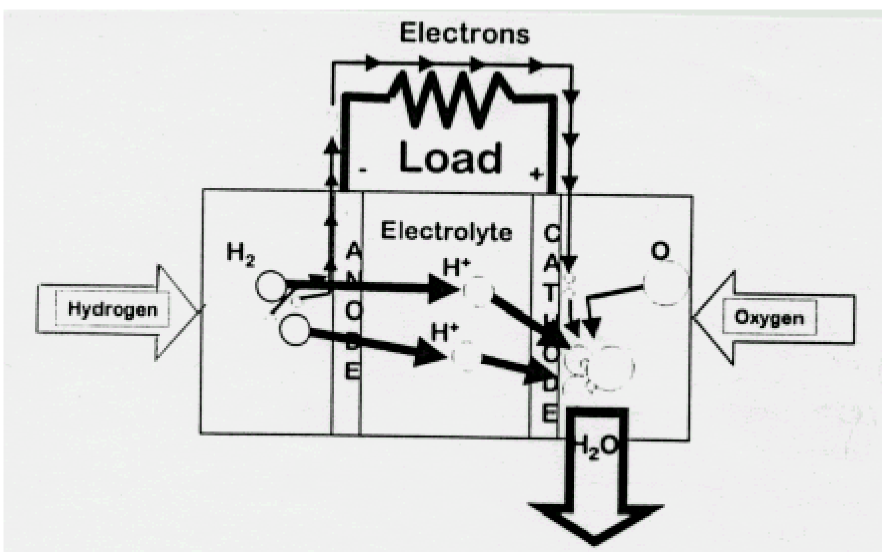
[14]The farm and biogas facility will be designed using the best technology and methods available in both China and the United States, with a view toward replicating the design in other Chinese villages. The Chengdu Biogas Training and Research Center, other Ministry of Agriculture resources in China, the National Renewable Energy Laboratory, and other U.S. research laboratories will participate in the design of the facility.

Table 4.1
Inputs and Outputs of a Farm Unit

Animal	Barns	Animals per Barn	Total Animals	Barn Size	Wet Dung	Total Dung	Total Liquid Input to Digester	Biogas per Animal	Total Biogas per Day
				(m x m)	(kg/day/animal)	(kg/day)	(l/day)	(l/day/ animal)	(m^3/day)
Pig	2	160	320	11 x 15	4	1280	2560	240	76.8
Rabbit	3	300	900	9 x 34	0.5	450	900	10	9
Duck	2	2000	4000	9 x 61	0.1	400	800	8	32
Geese	2	1000	2000	9 x 61	0.3	600	1200	25	50
Layer	1	10,000	10,000	9 x 61	0.075	750	1500	8	80
Broiler	1	6000	6000	9 x 61	0.075	450	N/A	sent to compost	
Total	13		23220	5000m^3		4.0 t/d	7.0 m^3/day		250 m^3/d

Figure 4.3
Schematic of the Operational Principles of Fuel Cells



Hydrogen fuel is fed into the “anode” of the fuel cell. Oxygen (or air) enters the fuel cell through the cathode. Encouraged by a catalyst, the hydrogen atom splits into a proton and an electron, which take different paths to the cathode. The proton passes through the electrolyte. The electrons create a separate current that can be utilized before they return to the cathode, to be reunited with the hydrogen and oxygen in a molecule of water.

A fuel cell system that includes a "fuel reformer" can utilize the hydrogen from any hydrocarbon fuel: natural gas to methanol, and even gasoline. Since the fuel cell relies on chemistry and not combustion, emissions from this type of a system are much smaller than emissions from the cleanest fuel combustion processes.

Although there are four major types of fuel cells, the phosphoric acid fuel cell is the only one commercially available at the present time. Eventually, fuel cells will be available commercially in multiple sizes. At the present time, however, a 200 kW cell is the smallest size available for the Longju application.

The operation of the fuel cell must be closely synchronized with the fuel supply source. In the case of Longju village, a reformer must be used with the methane gas from the anaerobic digester to ensure the efficient operation of the cell.

4.3. Photovoltaics

Photovoltaic (PV) cells convert sunlight directly into electricity. PV cells are made of semiconducting materials similar to those used in computer chips. When these materials absorb sunlight, the solar energy (photons) is a catalyst for separating electrons from their atoms, allowing the electrons to flow through the material to produce electricity. PV cells are typically combined into modules that hold about 40 cells; about 10 of these modules are mounted in PV arrays that can measure up to several meters on a side.

There are several PV applications in the model village. Each home will be designed to easily adopt PV and solar water heaters. The necessary piping for the solar water heaters and wiring for the PV systems will be embedded in the design of each house. The use of the solar infrastructure by individual households depends on the financial circumstances and preferences of each household. If adopted, the PV system consists of a small PV array on the roof of the home with a small battery bank and an inverter.

The community center will also be fitted with PV arrays of sufficient capacity to service the electricity needs of the center. The arrays will be part of the technology demonstration function of the community center.

Finally, solar-powered street lights will be placed on the levee along the promenade on the Eastern side of the village.

The sale and service of all solar systems could be done by a village-owned enterprise. The village-owned enterprise may be eligible for financing to set up and run the business.

4.4. Geothermal Heat Pump

A ground-source heat pump (geothermal heat pump) is a highly efficient renewable energy technology that is used for space heating and cooling and water heating. Its primary environmental advantage over other forms of space conditioning and heating is that it works by concentrating naturally existing heat, rather than producing heat through the combustion of fossil fuels. The technology is based on the relatively stable ground temperature beneath and surrounding a building. This temperature is warmer than the air above it during the winter and cooler in the summer. The geothermal heat pump takes advantage of this difference by transferring heat stored in the earth or in ground water into a building during the winter, and transferring it out of the building and back into the ground during the summer. The pump transfers energy to and from the ground using an underground loop in which fluid is circulated.

The ground acts as a heat source in winter and a heat sink in summer. The heat pump can also be used for heating water by transferring excess heat from the pump's compressor.

5. Water and Human Waste System

5.1. Water Supply

Because of the increased density of housing that accompanies centralization of households in the model village, we recommend that a community water system replace individual wells for water supply.[15] The advantages of a community system are obvious: (1) lower construction costs and (2) increased ability to provide both chemical and microbiological treatment of the water. Cost advantages arise because it is less expensive to lay water pipe between housing units than it is to construct a well at each dwelling. Also, it is cheaper to chemically or microbiologically treat water in a single large treatment facility than it is to do so at individual dwellings.

The community system could use local water resources or extend the current city water system in central Guanghan to Longju Village. In a central community system, Guanghan authorities would make the initial investment in the system and charge customers the capital and operating costs of the water system on a monthly basis. Cost is the major consideration in deciding between using local water resources or extending the city system. It is less costly to supply water from local water resources.

This central supply system should be supplemented by rainwater. Depending on preferences and finances, individual households could opt to use a cistern for rainwater collection to supplement the central water supply. Based on local climatic conditions (106 centimeters of rain per year), approximately one third of the annual water demand for a family of three can be supplied by rainwater (assuming each person uses 200 liters of water per day). Because rainfall is not uniformly distributed throughout the year, the harvested rainwater is a very valuable resource during the wet season. However, it cannot be relied on to provide an adequate water supply during the dry season. Collected rainwater would be the primary water supply source during the rainy season, supplemented by public water when sufficient collected water is unavailable. This strategy reduces the cost of water to the customer. And, it reduces the total volume of water that must be treated by the community water system, reducing the cost of providing adequate, safe, and high-quality water to village residents.

Figure 5.1 illustrates the recommended water supply system for individual houses in Longju Village. Rainwater supplements water from a central supply source. A float valve in the cistern ensures a steady supply of water, even during the dry season. A pump in the cistern fills a water tank in each of the houses in the village.

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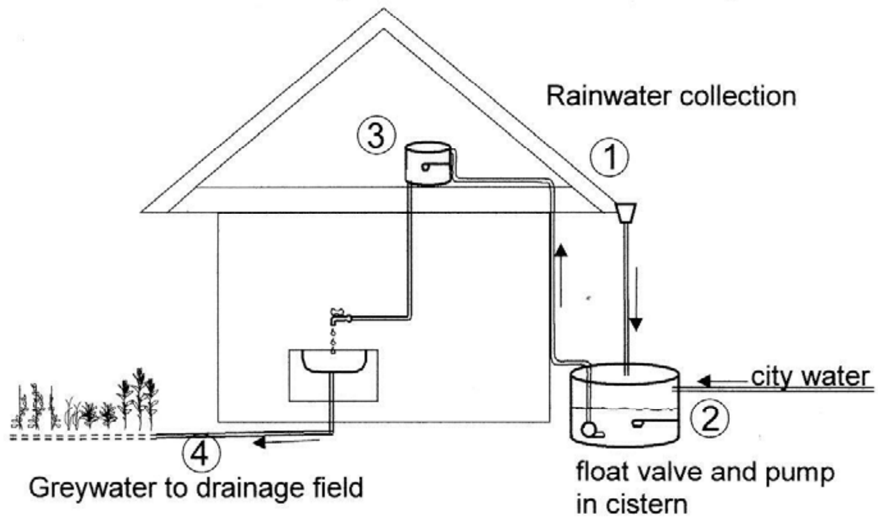
[15] There is adequate shallow groundwater for each house to have its own well. Individual wells currently supply water to each house in the village. The water is first encountered at a depth of approximately nine meters from the surface. Authorities report it to be moderately high in minerals such as iron.

Figure 5.1
Schematic Design of Water/ wastewater System



1. Gutters drain rainwater to cistern.
2. Float valve in cistern controls city water to maintain cistern at minimum of 1/3 full (if no rain). Top 2/3 of tank is for rainwater.
3. Attic tank filled by submersible pump in cistern and controlled by float valve in attic tank.
4. Sink drain water to drainfield under house garden.

5.2. Sanitation System

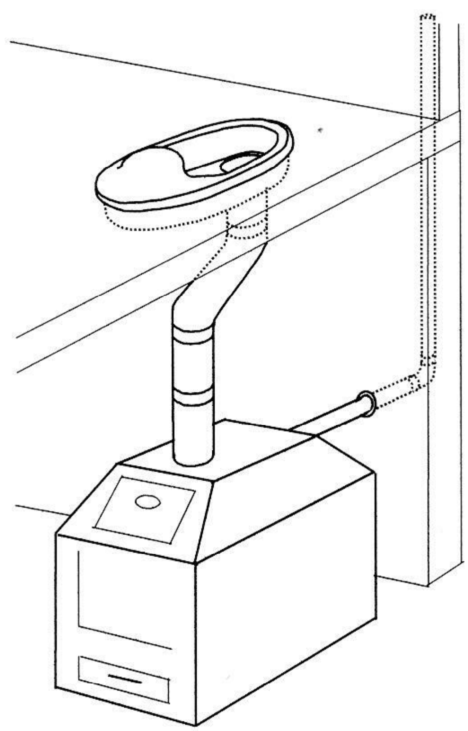
We recommend a decentralized waste treatment system for houses in the village. In this system, each house processes its own waste in a waterless composting toilet system and a grey water drain field. The toilets process the waste and convert it to compost that can be applied directly to non-food crops. (The compost could be applied to food crops after further processing in an outdoor compost pile.) Grey water is used to irrigate family gardens. Figure 5.2 illustrates the operation of the composting toilet.

The team considered two other options for wastewater treatment in the village.

The first option is a centralized one. Wastewater flows by gravity from a house into a digesting septic tank. Effluent from the digesting septic tank then flows by gravity to a pump station (if needed) or directly into a gravel filter. The horizontal gravel filter is approximately one meter in depth and filled with uniform gravel 2.5 to 3.0 cm. in size. Locally appropriate wetland plants are planted on the surface of the gravel filter. The purpose of the plants is to provide additional treatment of the waste on the surfaces of their roots.

The digesting septic tank removes solids from the wastewater and provides anaerobic digestion of the waste. The horizontal gravel filter further reduces suspended solids in the water and simultaneously reduces the potential of pathogens in the waste. Although wastewater is treated intensively in this process, remaining pathogens in the water more than likely make it unsuitable for direct human contact. The water also contains high levels of nutrients such as nitrogen and phosphorous which make it unsuitable for direct discharge to surface waters. However, the treated wastewater is ideally suited for growing non-food crops such as timber. The treated wastewater can also be used effectively in a landscaped area.

Figure 5.2
Schematic Design of a
Composting Toilet



- **Waste drops into composter below.**
- **Composted waste is removed from bottom drawer (once a year) — ready for use on garden.**
- **No odor—gases exhausted to roof.**

In the second centralized option, the human waste stream flows into the anaerobic digester. Individual household waste flows into a central piping system and then to the digester. Depending on the topography of the land, it could flow by gravity or with the aid of an electric pump.

Several factors led the team to conclude that a decentralized system is preferred in Longju Village:

- Because toilets in the decentralized system are waterless, water demand is significantly lower than with a flush-toilet central system.

- The cost of water infrastructure (pipes and pumps) is much higher in centralized systems.

- Because of increased processing costs for human waste, the anaerobic digester would be more expensive if required to process human waste.

6. Transport System

In large measure, existing construction commitments and Chinese regulations define the road network both in and around the village. A third-class road (11 meters wide with two-meter bike lanes on either side) will span the eastern side of the village on top of the levee (see Figure 2.1). It will be the primary thoroughfare, linking Longju Village with other villages in the region. A third-class road will also connect the agricultural processing center on the western part of the village with the main thoroughfare.

Fourth-class roads (5.5 meters wide) will form a grid within the village. Running roughly North-South, East-West, Chinese safety regulations require this road network. Roads are typically constructed using sand, stone, clay, and 18 cm of surface concrete.

Although this road network is in large measure dictated by national and local regulations, the design of the village still provides a significant opportunity for planners to demonstrate the importance of making sustainable transport choices. The model village will be designed to:

- reduce the number and length of trips needed by locating residences near services and employment;

- develop an efficient system of non-motorized transport for short trips and public transport for longer trips; and

- limit the unnecessary use of motorcycles and automobiles.

The number of motor vehicles in Guanghan has increased dramatically in the past decade. The use of motorcycles is increasing the most rapidly. Motorcycles (which include vehicles classified as scooters) now account for more than one half of the motor vehicles registered in the city.

The team recognizes that the rapid increase in ownership and use of motorcycles and automobiles in Guanghan—and Longju village—will likely continue. As the economy of Longju village grows, higher income of residents will lead to increased ownership of motorcycles first, and later automobiles. In this situation, the largest threat to Guanghan's sustainability arises from excess use of these new vehicles.

Despite the anticipated increase in the number of motorized vehicles, the village still can be designed to mitigate the adverse environmental effects of the local transport system. The village design will:

- Put major community needs close together. This furthers the village idea by locating residential, commercial and work areas as close as possible to each other. The object is to minimize the door-to-door distance between destinations

- Limit road speed. Roads in the model village will be designed so that the forward line-of-sight from a vehicle is limited, blocked by trees or other structures. This can be done with curves, shifting the road a road-width to the right or left. Tests show that visual limitation causes drivers to go more slowly. This reduces accidents and provides increased safety for bicycles, pedestrians and community activities. The visual limitation technique is more effective than traffic bumps. Bumps also can damage vehicles if the driver incorrectly estimates the severity of the bump.

- Create pedestrian priority areas. We will designate areas where pedestrians are given priority. Bicycles and tricycle-rickshaws would be allowed where appropriate, but the priority would be on pedestrian use. Motorized vehicles may be allowed at certain times for freight loading or local access where necessary.

- Give sustainable modes the shortest route. Roads in the village will be designed with physically separate areas for walking and bicycles. Motorized cycles will be prohibited from using bicycle lanes. Separated routes are most effective, with the shortest routes reserved for pedestrians and bicyclists, while motorized vehicles would take a longer route, farther from community gathering areas.

- Introduce electric vehicles. Electric tractors and motor bikes are the most promising options for introduction in the village. Electric tractors are manufactured in China. The fuel cell in the village will be the power source for these electric vehicles.

7. Agricultural System

Agriculture is the major source of income in rural Guanghan. It will continue to be an important source in the model sustainable village in Longju. However, devising a new agricultural strategy for existing farm land will make existing land more productive, spawn the creation of new agriculture enterprises, and increase income per unit of farmland. Further, integrating the agricultural waste stream with other economic activities in the village will increase total productivity of the village and promote sustainability. The proposed agricultural system promotes sustainability by integration of agricultural production (crop selection, irrigation, and fertilizer mix), distribution, and use of agricultural waste in other economic activities of the village.

The agricultural strategy allocates agricultural land in two areas (see Figure 2.1). In the major area, 280 mu (46.1 acres) are allocated for agricultural enterprises and infrastructure. The 280 mu of land will be allocated among 100 households with 355-400 residents. Using the latter number of residents, each household will be allocated 2.8 mu or 0.7 mu per person. Of the 280 mu, 125 is allocated for grains, oil crops, and other staples. This will be used to provide the basic subsistence level of 250 kg of rice per person and 90 kg/mu for the government. The remaining 155 mu will be used for fruits and vegetables, livestock (two “farm units”), poultry and eggs, aquaculture development (three mu), and agricultural infrastructure.

Creating a sustainable agricultural system includes the following activities:

- Selecting the most economically attractive crops and animals for growing, harvesting, and distributing.
- Creating the physical and institutional infrastructure to support the financial sustainability of crop enterprises.

- Developing an irrigation network.
- Creating a system for optimal disposal of agricultural waste.
- Strengthening the distribution channels for crop enterprises.
- Creating an outreach program to support the agricultural system.

Each of these activities will be discussed in turn.

7.1. Selection of Agricultural Enterprises

Guanghan government officials and local farmers were instrumental in selecting the agricultural enterprises that will be created in Guanghan. Working with government officials and local farmers, the following guidelines were used to select the enterprises:

- Individual families—not cooperatives—should control the leased land that the government allocates to individuals. Prior experiences dictate against developing a share/invested commercial farm corporation. Local farmers are not able to manage group enterprises well. In addition, they lack the business background and experience to conduct the exchange function of market-driven businesses.

- Although cooperative ownership is excluded, the land should be partitioned into crop areas as if there were cooperative ownership.

- Land should be allocated to crop production in a way that facilitates sustainability of the entire village.

- Soil conditions are important factors in selecting the crops. Those conditions are based on historical experiences of the villagers. Soil tests should be undertaken to determine precise soil conditions.

Based on these guidelines, agricultural enterprises will be created for seven crop/livestock types:

1. Livestock, poultry, and eggs, including:
   - Swine/Pigs
   - Chickens (broiler and eggs)
   - Rabbits
   - Ducks
   - Geese

2. Crops (Fruits, Vegetables, and Condiments), selected from among 40 possibilities:
   - Eggplants
   - Bitter melons
   - Sweet potatoes
   - Peanuts
   - White potatoes
   - Watermelon
   - Tomatoes
   - Squash (pumpkin)
   - Chinese cabbage

- Ginger root
- Garlic
- Onion
- Chive
- Carrot
- Cucumber
- Turnips
- Celery

3. Grains and Staples:
   - Rice
   - Wheat
   - Rapeseed
   - Corn

4. Aquaculture:
   - Carp/Perch
   - Catfish
   - Prawn/Shrimp
   - Mullet
   - Turtle/eel

5. Greenhouse production:
   - High-value vegetables
   - Flowers

6. Agricultural residue:
   - Rice straw and hulls
   - Rape seed straw and husks
   - Corn cobs

7. Agricultural animal waste for bio-gas production
   - Run-off from hog pens
   - Run-off from layers
   - Waste from broilers
   - Crop residues

Additionally, an agro-forestry enterprise may be created, depending on the availability of land. The most promising tree types for this industry are Italian poplar and black walnut.

7.2. Supporting Physical Infrastructure

Centralized agricultural infrastructure is important, especially those facilities that will provide benefits for more than one activity--i.e., positive externalities (for example, residue and waste that can be recycled into other products; crop residue for composting and fertilizer; and animal waste for the biogas generation unit).

Selection of appropriate buildings and agricultural infrastructure to support various agricultural enterprises in the village is a function of cost, availability of construction materials, and their contribution to sustainability. Table 7.1 shows the individual components of the infrastructure along with their financing and management. Appendix A contains detailed design specifications for all agricultural buildings.

Table 7.1
Supporting Agricultural Infrastructure with Ownership and Management Pattern

Infrastructure	Financing	Management
Centralized Flood/ Surface Irrigation System	Owned and financed by village residents	Village council
Modular Packinghouse, Post-Harvest and Storage Facility	Local government	Local government
Animal Rearing Facility	Owned by 10 households and financed as such	10 households
Aquaculture Facility	Owned by 1 or 2 households and financed as such	1 or 2 households
Compost Facility	Owned and financed by village residents	Village council
Greenhouse Facility	Owned by 1 or 2 households and financed as such.	1 or 2 households

7.3. Irrigation

Wells will be the major source of water for irrigation. Therefore, the system for irrigation is surface or flood irrigation. Because of the natural slope in the agricultural areas of the village, it is best to tap wells at the northern section of the agricultural areas and construct main canals from North to South.

7.4. Options for Agricultural Waste

The major agricultural and forest residues are rice straw and hulls, rapeseed straw and husks, corn stalks and cob, and wood chips (saw dust). Currently, the majority of the agricultural residues are burned by farmers or used as a fuel for cooking. In most cases, this poses a major environmental and health hazard. Reports indicate this method of disposal has caused major problems for the local community. Similarly, wood chips and sawdust are typically dumped in municipal landfills.

There are several possible uses for these wastes:

- Straw gasification where these products are used as primary feedstocks;
- Particleboard (PB), medium fiberboard (MFB), oriented strand board (OSB) for wood panels or walls, doors, and for general construction;
- Organic fertilizer;
- Growing medium or mulch for agricultural and nursery/horticultural sectors;
- Litter for poultry production;
- Fuel (ethanol) for domestic cooking; and
- Animal feed.

We recommend that a new construction enterprise be created and that the waste be used to construct wallboard to be sold to the construction industry. Using the waste in a new construction enterprise is the highest value use of the waste. The enterprise does not have to limit itself to agricultural waste from Longju village. It can also obtain waste from neighboring villages. Also, an agricultural waste-gathering enterprise will spring from the wallboard production enterprise.

7.5. Markets and Distribution Channels

Effective marketing and distribution channels are necessary for the efficient operation of agricultural markets. Currently, the food distribution system in Longju is fairly simple. Intermediate operators are not prevalent and the chain of distribution for agricultural products is not as complex as in other developing and developed countries. The existing distribution system is adequate to promote the efficient operation of agricultural markets.

7.5.1. Vegetables

There are two options for getting vegetables to market. In most cases, the average farmer markets products directly to consumers. In other cases, “middlemen” (Cai Fan Zi) purchase products at the farm gate and sell these products in local retail markets.

7.5.2. Livestock

Farmers take their pigs to a slaughterhouse to be processed. These slaughterhouses are created by the government but are operated by private groups. Once the animals are processed at the slaughterhouse, middlemen retail the products at the local market. In another system, middlemen purchase the animals at the farm, then slaughter the animals at their places of business and retail the products at the local market.

7.5.3. Grains and Staples

This market is dominated by rice. In the production and marketing system, a quota of 230 kg/year is required from each household. Based on yield data, the average household needs to plant less than one mu in rice, assuming the yield is 550 kg/mu. Once the rice is harvested, government trucks collect and transport it to the central depot for storage and processing.

7.6. Integrated Support Services and Technology Transfer

Within the village structure, agricultural enterprise managers and workers must be trained and supported in the new ways of creating and operating the new enterprises. Outreach and support activities providing assistance to local farmers will further promote efficient and sustainable agricultural enterprises in the village. In collaboration with Guanghan authorities and local farmers in Longju, the team identified three important areas of support.

7.6.1. Extension Service

In competitive agricultural markets, extension agents are employed. In the case of Longju Village, a similar system should be developed because of the move to commercial agriculture. The Longju Village Council (discussed in Section 10) should provide the necessary leadership by harnessing those agricultural agents that are currently providing assistance to farmers. At least one should be assigned to Longju Village for three (3) years to provide needed services. The person selected could be trained by participating in one of the short summer programs in the United States at one of the institutions engaged in Asian crop and livestock husbandry.

7.6.2. Inputs

Local farmers requested creation of a program to assist producers with technology transfer related to improved farm productivity. The main areas of need are:

- Seeds and Varieties. Growers are interested in using improved seeds and plant varieties. U.S. seed and agronomic suppliers could partner with registered Chinese distributors that are willing to work with farmers in Longju Village. However, there is a seed and germ plasm development company called Zhong Du located in Guanghan City that currently has a program to supply such seeds. In the short term, it is advisable for this firm to become involved in supplying the selected seeds and varieties.

- Fertilizers and Chemicals. There are several sustainable programs that are currently available in the United States designed to show farmers how to reduce the use of physical fertilizer and chemicals, as well as to produce more organically grown crops. Through the coordinating office of this project, material on these improved farming methods could be distributed to the farmers. If a training program is developed, the agronomist could work with a U.S. counterpart to evaluate appropriate systems for Longju Village.

- Growing Livestock. The technology, production systems, and management information are available to raise healthier, more productive animals. The Longju Village Council should designate farmers to be trained in this area.

7.6.3. Credit and Management

Various agribusiness credit and management systems are available that producers can use to improve farming in Longju Village. If there is no formal educational program to institutionalize this aspect of agriculture, authorities should identify individuals to be trained in exchange programs and to participate at in-country workshops and seminars.

8. The Local Economy

Agriculture is the cornerstone of Guanghan's rural economy. Unfortunately, agriculture alone is no longer able to provide a reliable livelihood for growing populations in rural areas. Alternative or additional income generating opportunities are needed to support poor families who can no longer support their livelihoods from the land alone.

8.1. Agriculture

A typical rural household in Guanghan currently earns only one half of its annual income from agriculture (crops and livestock), the "first primary industry." Of agricultural income, three-quarters is obtained from crop production and one quarter from livestock. The remaining one half of a typical rural household's income is obtained almost exclusively from family enterprises (second and third industries). The typical household obtains very little of its annual income from township-village enterprises (TVEs), the commercial business firms in China. The challenge in designing the model village is to create opportunities for new TVEs.

TVEs notwithstanding, agriculture will continue to be a major portion of the economy in the model village. In its Five-Year Plan, Guanghan officials emphasize wheat, rice, and rape seed production as a major part of its overall economic strategy for rural areas. This will not change in the model village. Rice will be a major export commodity of the village.

However, the team recommends that a new strategy be developed to increase the productivity of farms in Longju Village. That strategy, discussed in Chapter 7, includes:

- selecting the most financially attractive agricultural enterprises;
- developing the physical infrastructure for agriculture;
- creating an irrigation system;
- optimally using agricultural waste;
- refining distribution channels; and
- creating an extension service.

8.2. Tourism

Tourism will be an important economic activity in the model village. The village has four tourist attractions. Individually or packaged together, these sites can be a major source of income for villagers.

First, in the mid 1980s, the ruins of the San Xing Dui civilization were discovered on the outskirts of Guanghan. The civilization was destroyed 3,000 years ago, dating back to China's Qin Dynasty. Guanghan constructed a museum showcasing these ruins. The museum is five kilometers from the site of the model village.

Second, rural resorts attract urban residents to the countryside and increase the incomes of rural residents. These resorts are a type of "bed and breakfast" in which rural families supplement their incomes by providing lodging, restaurants, garden areas, recreational activities, and orchards for holidays in the countryside. One such resort exists across the road from the model village site and another will be constructed in the village.

Third, the Longju Temple is also across the road from the model village site. A Buddhist Temple constructed more than 300 years ago, it is a major tourist site, attracting more than 200,000 visitors in 2000.

Fourth, the model village itself will attract tourists. This "village of the future" will showcase housing, industry, sustainable systems, and technologies that contribute to a sustainable village.

The challenge for planners is to package the museum, temple, resort, and model village together in the most effective way to attract more tourists.

8.3. New Enterprises

8.3.1. Enhanced Service Industry

A vibrant tourist industry in the village and its environs will spawn a vibrant service industry. The promenade along the Eastern edge of the village will be a focal point of the service industry. Villagers with houses along the promenade can exploit the economic opportunities of tourism by establishing restaurants, souvenir shops, and other small enterprises in rooms adjacent to the promenade. Other villagers not living on the promenade can also exploit the tourist trade by setting up temporary shops on the promenade along the levee.

8.3.2. Construction Materials

Construction and habitation of the village can be a catalyst for creation of a vibrant construction industry in Longju village. Two enterprises are especially promising. A third must overcome some obstacles to thrive.

First, the residual straw from growing rice is a waste product that could serve as the basis for a commercial enterprise in the model village. The straw will be used to manufacture building panels for construction of walls and ceilings in Longju Village itself and surrounding villages and towns in Guanghan.

Second, production of compressed earth bricks used in the construction of houses and the community center will spawn a new enterprise in the village. As discussed in Section 3.2, an investment of $40,000 for a compressed earth brick machine will allow entrepreneurs to provide sustainable materials for the construction industry.

The third enterprise involves collection of fly ash and bottom ash from coal plants. Fly ash and bottom ash can be used for the column, beam, and floors of houses in the construction industry. Fly ash can also be used in road construction. Based on an inventory of coal plants in the region, there is enough ash to support an enterprise. Demand is not necessarily limited to activities associated with construction and habitation of the model village at Longju. This industry can also service demand in surrounding areas. However, consistent monitoring of radiation levels in the fly ash is an obstacle that must be overcome to develop this industry.

8.3.3. Solar Support Industry

The community center in the village will be fitted with solar arrays. One demonstration house in the village will also be fitted with solar modules and a solar water heater. All of the other houses in the village will be fitted with the infrastructure for installing solar arrays and the piping needed for a solar water heater. Households decide to use solar energy on the basis of preferences and income. The public lighting along the levee on the Eastern side of the village will also use solar cells. Finally, households and businesses outside of the model village may adopt solar energy after they see it deployed effectively in Longju Village.

The increased penetration of solar technologies is the catalyst for creation of another enterprise in Longju Village. Although assembly of solar cells is not ruled out, it is more likely that the enterprise will be involved with marketing and distribution of solar cells produced by other Chinese business enterprises that manufacture solar cells and assemble solar modules and arrays.

8.3.4. Agro Processing

Agro processing--turning primary agricultural products into other commodities for market—has the potential to provide new business opportunities in Longju Village. A model for developing the enterprises is the Value-Added (Commercial Kitchen) Operation**.** Here farmers and producers of specialty/gourmet food items can be trained in preparing their food products in a fully licensed and certified kitchen. The kitchens, often sponsored by an umbrella nonprofit organization or existing business incubator, provide start-up businesses the opportunity to explore food production without the high cost of buying their own equipment or constructing their own building.

8.3.5. Agro Forestry

The amount of available land in the village is a constraint on development of an agro-forestry industry. Land commitments for housing, agriculture, and energy infrastructure in the model village preclude a significant agro-forestry industry without taking land away from these three uses. If land outside the existing boundaries of the village is made available for other uses, however, villagers could create a potentially lucrative agro-forestry industry.

Agro-forestry could conceivably support a number of different types of commercial enterprises in this industry. Wood chips could be used for road construction. They can also be used in the housing/construction industry as fill for wallboards and panels. Wood can also be used as an input for electricity production. Finally, the tree plantation could support a lumber industry. The most promising species of trees are Italian poplar and black walnut.

8.3.6. Livestock Enterprises

Animal husbandry is currently an important source of income for many rural households. The raising of animals for resale accounts for one-quarter of the income of Guanghan households in the "first primary industry" (agriculture, livestock, fishing, etc.). Pigs, chickens (for eggs also), ducks (for eggs also), and rabbits are the major animal types. By tradition, animal husbandry occurs adjacent to the villagers' residences. Each household raises animals for both its own use and for re-sale. These activities will continue in the model village.

However, these activities at the household level will be expanded by introducing the bio-energy system in the village. Animal husbandry in the village will be centralized and converted to a larger-scale, commercial enterprise. This enterprise will complement the existing animal husbandry activities of individual households. Section 4.1.2 discussed these enterprises by introducing the concept of a “farm unit.” A farm unit is a livestock enterprise (geese, ducks, pigs, rabbits, and chickens) whose waste is of sufficient quantity to provide cooking gas to 100 households (size and scope defined in Table 4.1). An additional farm unit consisting entirely of pigs will provide gas for the fuel cell.

8.3.7. Commercial Laundry

An important byproduct of producing electricity with a fuel cell is hot water (see the discussion in Section 4.3). The hot water can be used to develop a laundry enterprise in the village. An ideal location for the laundry facilities is adjacent to the fuel cell in the Southwestern corner of the village (see Figure 2.1).

8.3.8. Internet Enterprises

Access to the internet in the village's community center offers an opportunity for villagers to develop enterprises exploiting the internet. An example is the adoption of the internet-based GreenStar program. GreenStar currently provides electricity, electronic commerce, water, education, and telemedicine to villages in many parts of the developing world. But GreenStar also brings local products--including art, music, photography, and storytelling--to world markets through the Internet. Local entrepreneurs in Longju Village could create an internet-based business enterprise in association with the GreenStar program.

8.3.9. An Electric Enterprise

A fuel cell will be installed in the village to provide the majority of the village's electric power needs: residential and commercial lighting, other household uses, some needs of the community center, and the energy source for electric vehicles. Users of electric energy will pay the capital and operating costs of supplying the electricity. Additionally, at 200 kW, the capacity of the fuel cell will likely be larger than the electric needs of the village itself. In this case, local authorities have two options: they can scale down the capacity of the fuel cell or sell excess power back to the provincial grid. This is a business decision by the operators of the electric system in Longju Village.

The activities of the fuel-cell operator suggest that an enterprise should be created to manage the operation of the fuel cell and administer the production and sale of electricity in the village.

8.3.10. Bio-Energy Enterprise

The waste stream from animals in the two "farm units" and, to a lesser extent, agricultural waste will be used in an anaerobic digester to produce gas for household cooking and an energy source for the fuel cell. The waste will be purchased from the farm unit enterprises at a negotiated price. In turn, the gas will be sold to households and the fuel-cell operator at the economic cost of production: capital and operating costs, plus an allowance for profit.

Here again, the activities of the digester operator suggest that an enterprise be created to manage the digester and administer the production and sale of gas in the village.

9. The Local Community

The design of the model village preserves the local culture and local traditions of Longju residents to the greatest extent possible. For example, the design of housing in the village accommodates the local traditions of raising farm animals and growing vegetable gardens adjacent to one's house. The village is also designed to promote a sense of "community" for its inhabitants.

Many of Guanghan's rural residents live in tightly knit communities or, in some cases, "natural villages." They consist of contiguous households engaged primarily in agriculture on farmland a distance away from the central village. The villagers typically walk to their livelihood: their farmland. The residents of the village form a tightly knit, cohesive group. The village leader posts work assignments for members of the village. Cultural and social activities revolve around the village itself.

Other households live in communities not as well knit. They do not have this central village focus. Households are dispersed intermittently in rural areas. The sense of community is nearly non-existent. Longju Village currently consists of more than 1,000 people dispersed over the countryside. Three natural villages dot this rural landscape. There is no formal community infrastructure.

The challenge for creating a lasting social infrastructure in the model village is to harness the 100 households (355 residents, a subset of the existing village) to identify as one community and create mechanisms for interaction with each other and the inhabitants of other communities. The focal point of this “community” will be the community center. Here, the social hall allows villagers to congregate for cultural activities. Television and internet access also provide opportunities for social interaction. Additionally, the promenade along the levee promotes both commercial and social interaction.

10. Capacity and Institution Building

This master plan of the model sustainable village in Longju introduces many new technologies, techniques, and institutions. Some of these are radically different from what the villagers in Longju have experienced in the past. The introduction of new technologies, techniques, and organizations suggests a need for new institutions and management approaches in the village both at the enterprise and individual household level to effectively implement the master plan. This, in turn, suggests the need for additional training of villagers in new technologies, techniques, and institutions. The remainder of this chapter addresses management and training.

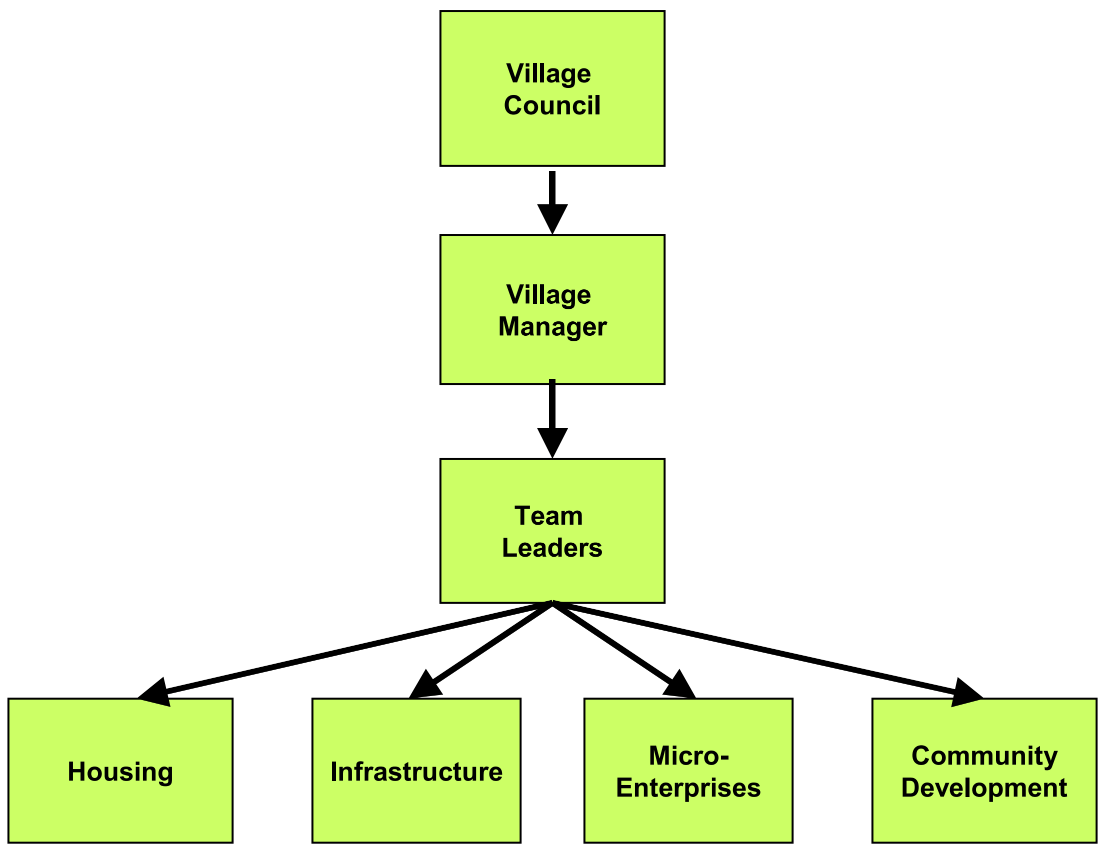
10.1. Organizational Structure and Governance

At the highest level, Longju village should create a community-based organization (Longju Village Council) somewhat like a community development corporation in the United States. This organization would be responsible for the economic and social development of the village by sponsoring and supporting training and development programs. The Village Council would be responsible for developing the village’s resources and managing the input/output mix to ensure a better quality of life for the villagers, while supporting the principles of sustainability.

Figure 10.1 suggests an organization and management structure for the Village Council. The Longju Village Council, consisting of five members, is the Board of Directors with over-all responsibility for social and economic development of the village. The village manager, who is chairperson of the council, runs the day-to-day activities of the village. Team leaders are responsible for activities in four areas: housing, infrastructure, micro-enterprises, and community development.

Sound governance and management is imperative for Longju Village to implement this master plan. Although this is especially true for management of the new enterprises (for example, electric and biogas enterprises, new agricultural enterprises), it is also true for management of the construction of Longju Village. The team suggests that Guanghan authorities develop a program of capacity and institution building in the four activity areas related to construction and habitation of the village (Figure 10.1). The next section outlines the training needs.

Figure 10.1
Organization and Management Structure of Longju Village



10.2. Training Requirements to Support the New Institutions

10.2.1. Housing

- Architect Training. The USDOE team will conduct a three- to five-day training workshop to instruct local architects on (1) the design principles and methods for optimizing energy efficiency in the buildings and (2) passive solar techniques for different types of buildings in the Sichuan climate.

- Compressed Earth Block Technology. To be successful in using the compressed earth brick technology, the company that manufacturers the TerraBuilt Block system will bring Chinese technicians to the United States for a one-week training period. A representative from the company will then travel to China to oversee and recommend best practices to successfully adapt the technology in the Chinese situation.

10.2.2. Infrastructure

- Integrated Bio-Energy Facility. The construction of the integrated bio-energy facility will be a joint effort between the United States and Chinese groups. The National Renewable Energy Laboratory will work jointly with the Chengdu Energy Institute to design and construct the facility.

- Other Renewable Energy Technologies. To ensure the proper installation and operation of other renewable energy technologies, the local authorities in Guanghan and Longju Village must ensure that appropriate staff are made available to become local experts in the installation and operation of the technologies. These include ground source (geothermal) heat pumps, photovoltaics, solar water heaters, and fuel cells. In the case of heat pumps and fuel cells, manufacturers' representatives will make site visits for installation and training.

10.2.3. Micro-Enterprises

- Crop Enterprises. They include Asian vegetables, flowers and ornamentals, and grains and staples. These training sessions should address:

  - Production Practices. Seed variety selection and quality, irrigation, organic fertilizers, no-till cultivation, cover crops, targeted yield, and erosion control.

  - Agribusiness Management. Farm management, record keeping, developing enterprise budgets, budgeting, pricing and costing, evaluating profitability and return on investments.

  - Post-harvest Handling. Sanitation, record keeping, liabilities, transportation, HACCP.

  - Marketing. Market research, packaging, customer preference (size, fresh, frozen, processed), import/export opportunities.

  - Value-Added. Processing, packaging, canning, salads, soup mixes, and medicinal uses.

  Land preparation plays a major part in sustainable production systems. Farmers must learn how to prepare the land and nurture the soil throughout the production season. They will develop marketing plans, and produce these products for the markets. They will also learn the importance of quality, consistency, market location, and adding value.

- Livestock and Poultry Enterprises. They include chickens, ducks, geese, rabbits, swine, aquaculture (farm-raised fish to include talapia , carp, catfish. and prawn). Training requirements for the livestock and poultry enterprises include:

  - Production Practices. Breed selection, weight, housing facilities, feed and soil conservation, irrigation.

- Agribusiness Management. Farm management, record keeping, developing enterprise budgets, budgeting, pricing and costing, evaluating profitability and return on investments.

- Hazard Analysis Critical Control Point (HACCP). Processing and handling, sanitation, record keeping, liabilities.

- Marketing. Packaging, customer preference (fresh, frozen, processed), import/export opportunities, insurance, consistency, freight.

- Value-Added. Processing (animal parts, soup mixes, roasted, sliced, drying).

The livestock and poultry training sessions would inform the farmers and outreach workers about the production and marketing systems for meat and meat by-products. In addition, the sessions would address procedures to regulate the system so that all of the producers will adhere to the same quality standards when raising animals, keep adequate records to verify their proper handling of the animals and meat products, and meet market demands.

- Agro-Forestry Enterprises. Training should address procedures for growing trees for the forestry industry. Other training sessions should address the potential uses of agriculture residues. The forest residues, agricultural crops and wastes, wood and wood wastes, animal wastes, livestock operation residue, aquatic plants, and municipal wastes can be processed into biomass fuel (ethanol, methanol, and biodiesel).

In the United States, several schools of agriculture, research, and extension (through their centers of excellence), state and federal agencies, and the private sector have the experience and capability to develop the training sessions in crop, livestock and poultry, and agro forestry enterprises. The training programs could be conducted through summer exchanges or in-country seminars and workshops for Training-the-Trainers.

10.2.4. Community Activities

A representative of the GreenStar program will visit Guanghan to discuss business opportunities on the internet.

11. Implementation Plan

The design and construction of the Longju model village is proceeding in seven phases. Table 11.1 lists the lead and subordinate responsibilities for the seven phases of the project.

The needs assessment and conceptual design were completed in the aftermath of a site visit to Longju village in August 2000. The conceptual design gave authorities in Guanghan a series of options for building design and materials, infrastructure, agriculture, and community development.[16] Those options were evaluated by Guanghan authorities and discussed with a team on another site visit to Guanghan in June 2001. As a result of those discussions, the team developed a master plan. This report documents the master plan, including discussions of:

[16] U.S. Department of Energy, *op.cit*.

- Building design and construction;
- Energy system;
- Water and sanitation system;
- Transport system; and
- Agricultural system.

Table 11.1
Phases and Responsibilities for the
Design and Construction of Longju Sustainable Village

Phase	Lead Role	Subordinate Role
1. Needs assessment	ESCP	Local Experts, Villagers
2. Conceptual design	ESCP	Local Experts, Villagers
3. Master plan	ESCP	Local Experts, Villagers
4. Design development	Local Experts	ESCP
5. Construction documents	Local Experts	ESCP
6. Actual construction	Local Experts	ESCP
7. Monitoring and evaluation	Local Experts	ESCP

ESCP—APEC Energy for Sustainable Communities Program
Local Experts—Guanghan government officials, architects, urban planners, etc.
Villagers—Residents of Longju Village expected to live in the model village

The next step in the process of designing the village is the review of the master plan by Guanghan authorities. After this review, the USDOE team will make another site visit to Guanghan. During this visit, the team will make a detailed presentation on the master plan, reconciling differences between the team's vision of the village and the viewpoint of Guanghan authorities.

The site visit will also initiate the fourth, design development phase of the process. In this phase, Guanghan experts will do detailed drawings of the village's physical systems, including buildings (houses, the community center, and agricultural/livestock facilities) and infrastructure (energy, water, and transport systems), working closely with the USDOE team. The detailed drawings of the fourth phase will be the basis for constructing the village.

Before the fourth or design development phase begins, however, capacity and institution building (Chapter 10) must be initiated because some aspects of the design phase cannot begin without it. For example, before Guanghan architects design houses and the community center, they should be exposed to sustainable design principles and construction materials.

The last three phases of the project deal with constructing the village.

Appendix A
Design Specifications for Agricultural Buildings

Selection of appropriate buildings and agricultural infrastructure to support various agricultural enterprises in a sustainable village is a function of cost, availability of construction materials, and their uses based on sustainable principles. The following descriptions and schematics of structures are based on technology used in the Southern United States with microclimate similar to that of Longju.

A.1. Packing and Post-Harvest Facilities

- Steel framed structure.
- Pole and beam construction at 15' intervals.
- Open sides.
- Building dimensions 60'x40' with 15' center and 10' clearance for roof.
- Floor raised to facilitate loading or portable loading platform.
- Concrete platform foundation and floor.
- Two-modular size walk-in cooler 10'x12'10' .
- Small office and bath room.
- Produce Packing line with capacity of 2 metric ton per hour for packing fruits and vegetables.
- Plumbing for water to packing line and bathroom.

Figure A.1
Packing and Post-Harvest Facilities, Floor Layout

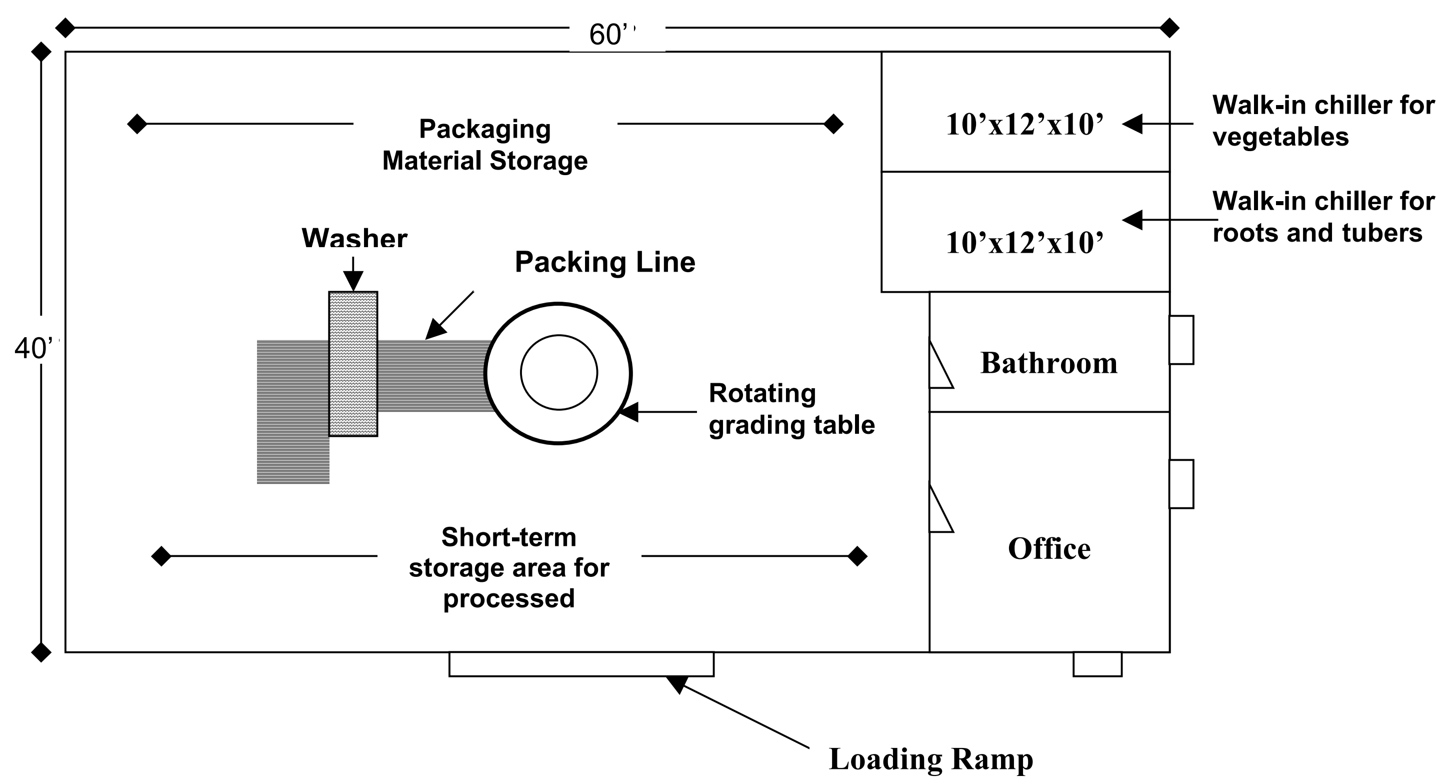


Figure A.2
Packing and Post-Harvest Facilities, Front Elevation

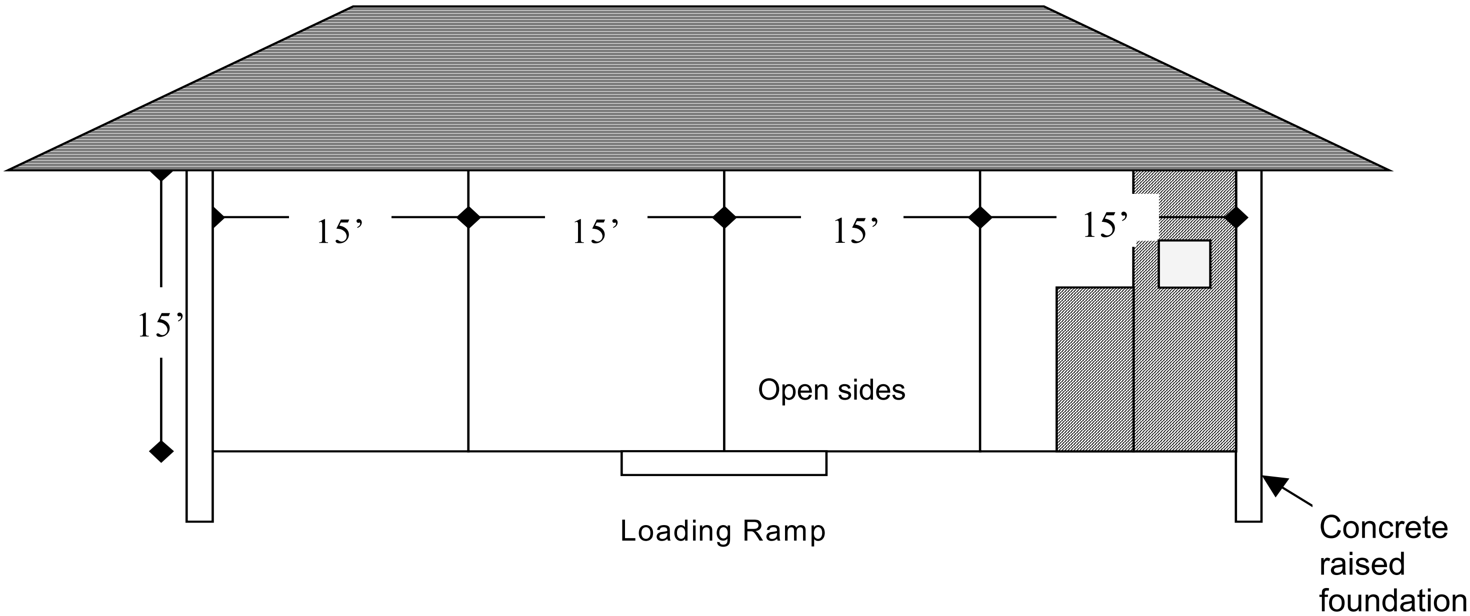
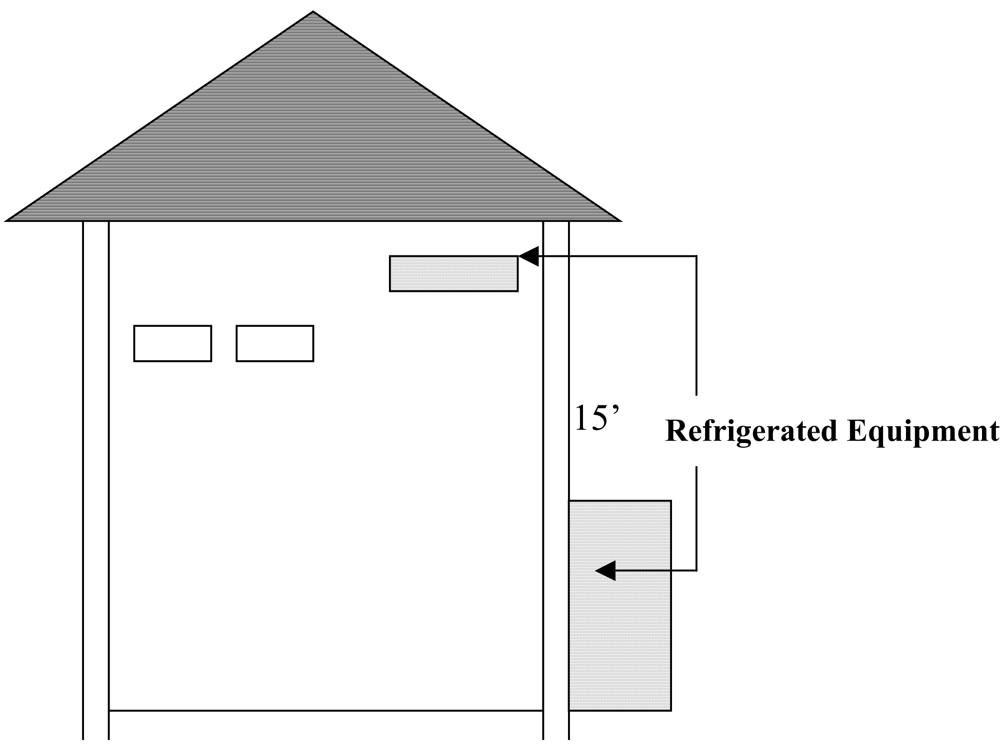


Figure A.3
Packing and Post-Harvest Facilities, Side Elevation

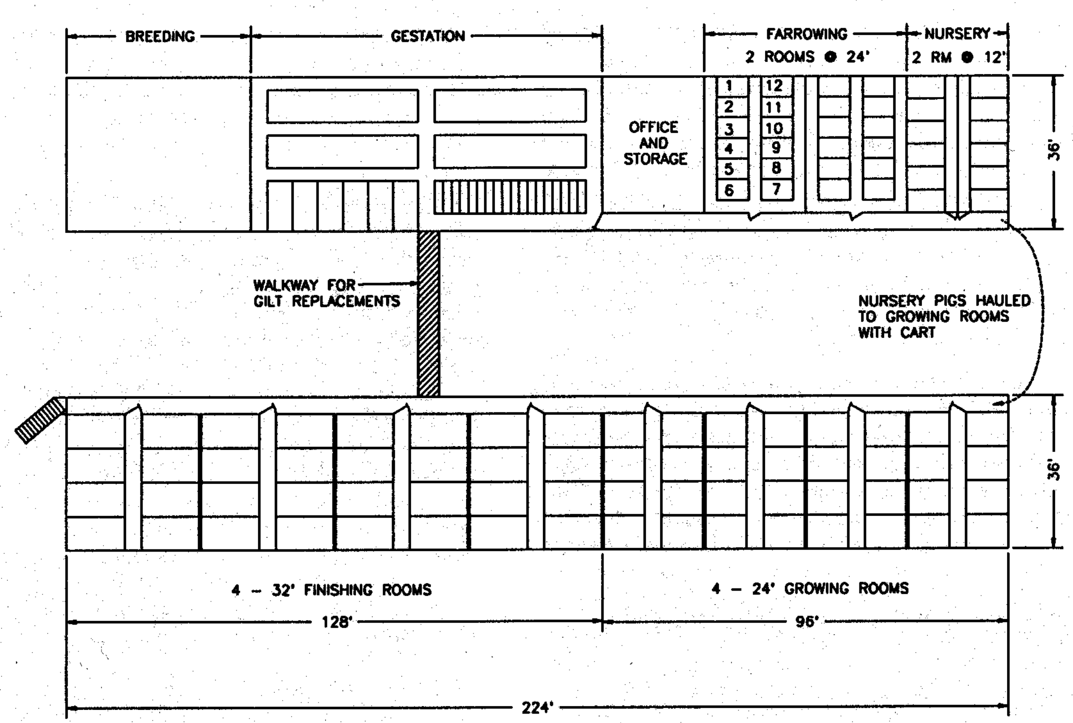


A.2. Animal-Rearing Facilities

A.2.1. Swine

- Building dimensions: 36'x224'.
- Check local zoning laws and regulations.
- Locate downwind from your residence and neighboring residences to minimize potential odor problems.
- Choose location that protects facilities from severe weather conditions.
- Determine the total daily water requirements. As a rule of thumb, the water intake will be about 2.5 times the amount of feed intake.
- Plan for reserves for peak demands.
- Make allowances for washing floors and flushing gutters if fresh water is used.
- Floors should drain to the biogas mixing pit.
- Choose a high location with good drainage to the biogas mixing pit.
- Determine the number of pigs to be bred.
- Consider the choice of building materials, electric wiring, heaters, and fire walls.

Figure A.4
Two-Building Swine Barn, 150-Sow, All-in/All-out Production



The following are some of the recommended drawings for designing roofs, floors, pens and gutters.

Figure A.5
Swine Barn, Insulated Roof Option for Single Row of Pens, Partial Slats

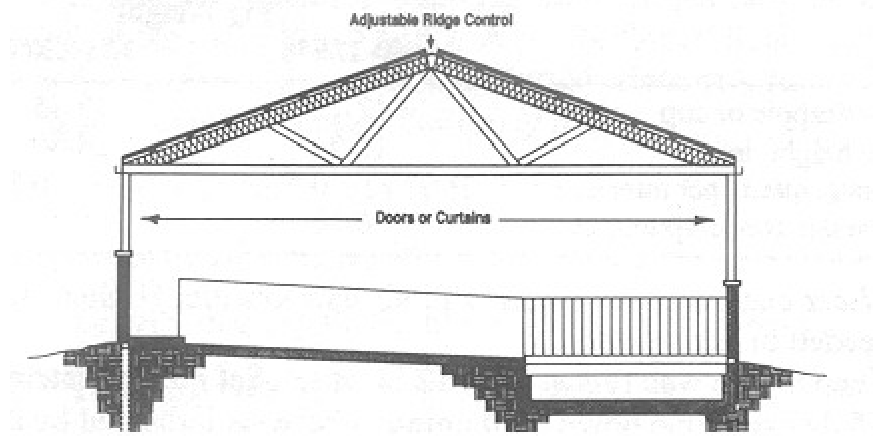


Figure A.6
Swine Barn, Partially Slotted Floor Building with a Single Row of Pens

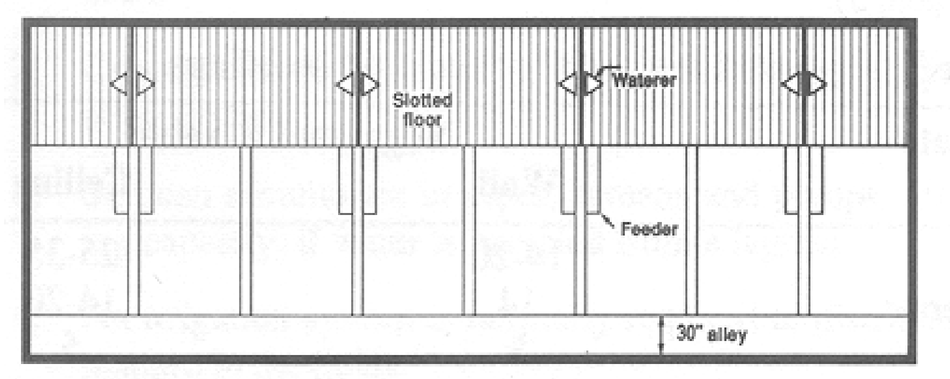


Figure A.7
Swine Barn, Floor layout for open gutter unit (either flushed or scraped)

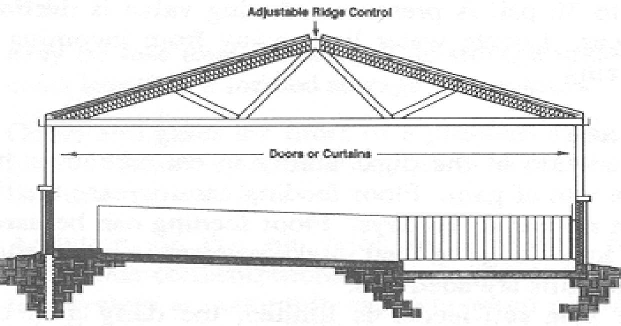


Figure A.8
Swine Barn, Single Slope Roof, Partial Slats

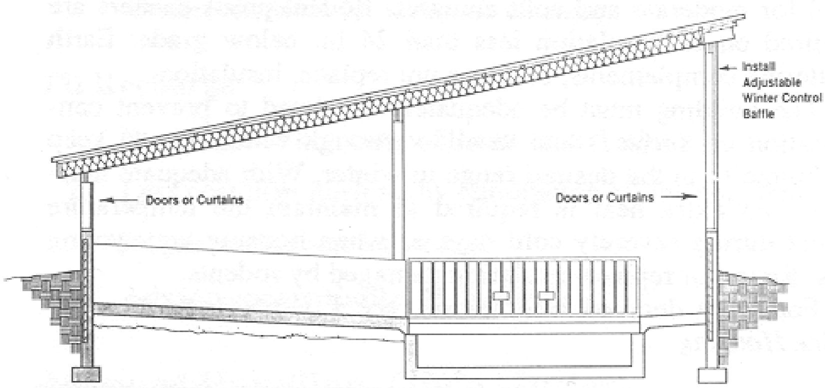


Figure A.9
Swine Barn, Totally Slotted, Center Alley

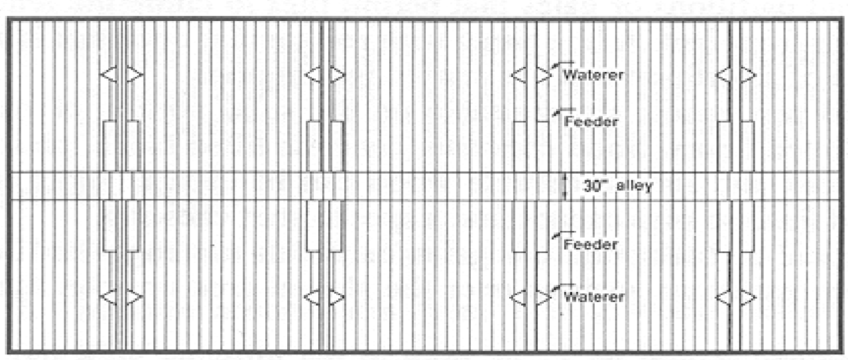


Figure A.10
Swine Barn, Insulated Roof for Two Rows of Pens, Partial Slats

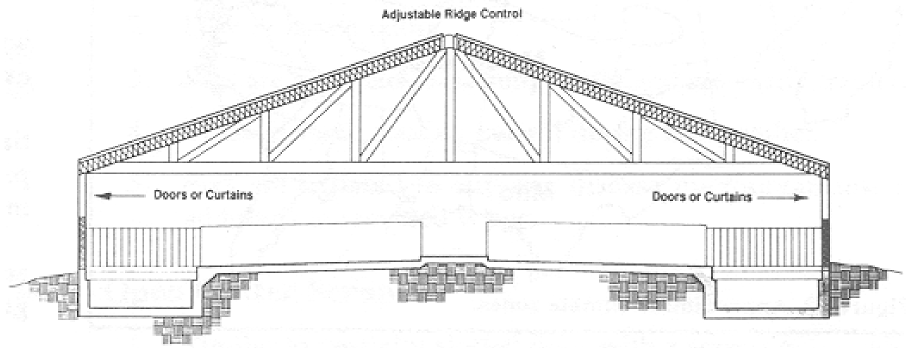


Figure A.11
Swine Barn, Continuous, Sloped Center Chimney

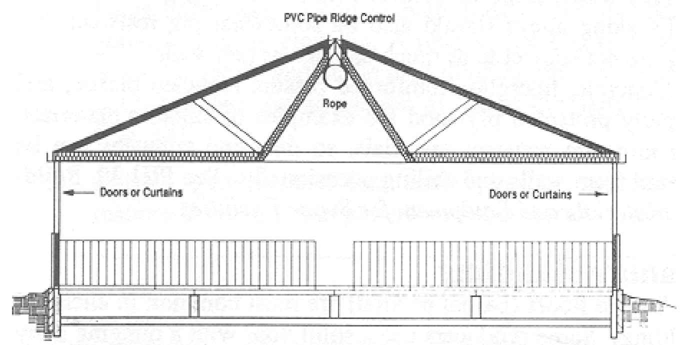


Figure A.12
Swine Barn, Intermittent Square Chimney

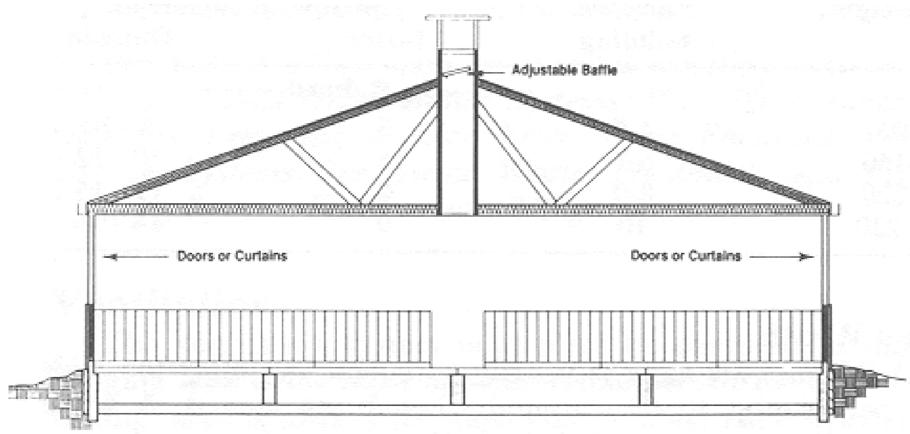
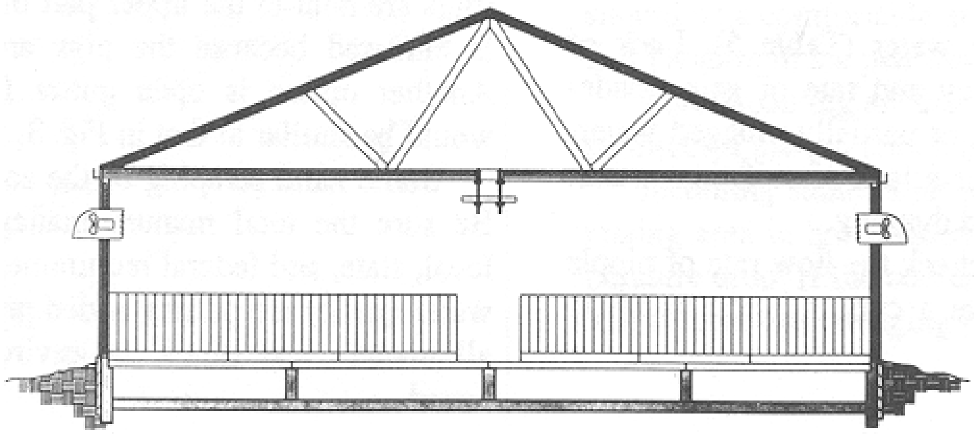


Figure A.13
Swine Barn, Year-Round Fan Ventilated, Minimum Insulation under Roof



A.2.2. Rabbits

- Building dimensions: 32’x310’.
- Be sure that spacing for cages is adequate. One thousand rabbits require housing at least 32’x310’.
- Select or install cages using leg supports.
- Provide a good drainage system under the cages to drain to the biogas collection pit.
- Install a good solid waste removal system.
- Provide adequate mechanical ventilation (fans).
- Insulate the building properly.
- Make the building without roof pole supports.

Figure A.14
Rabbit House, Floor Plan, Six Rows, Caged

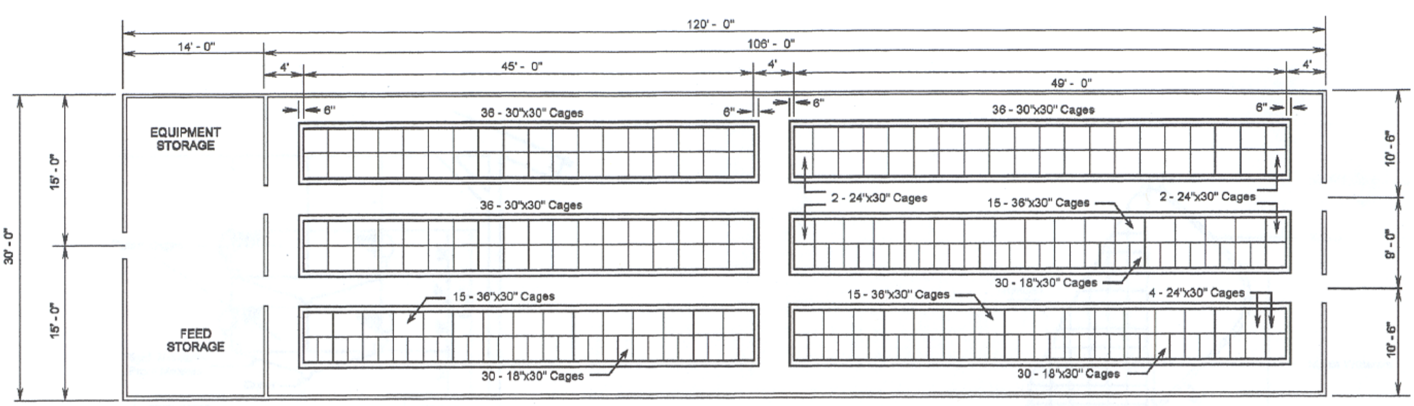


Figure A.15
Rabbit House, Cross Section, Six Rows, Caged

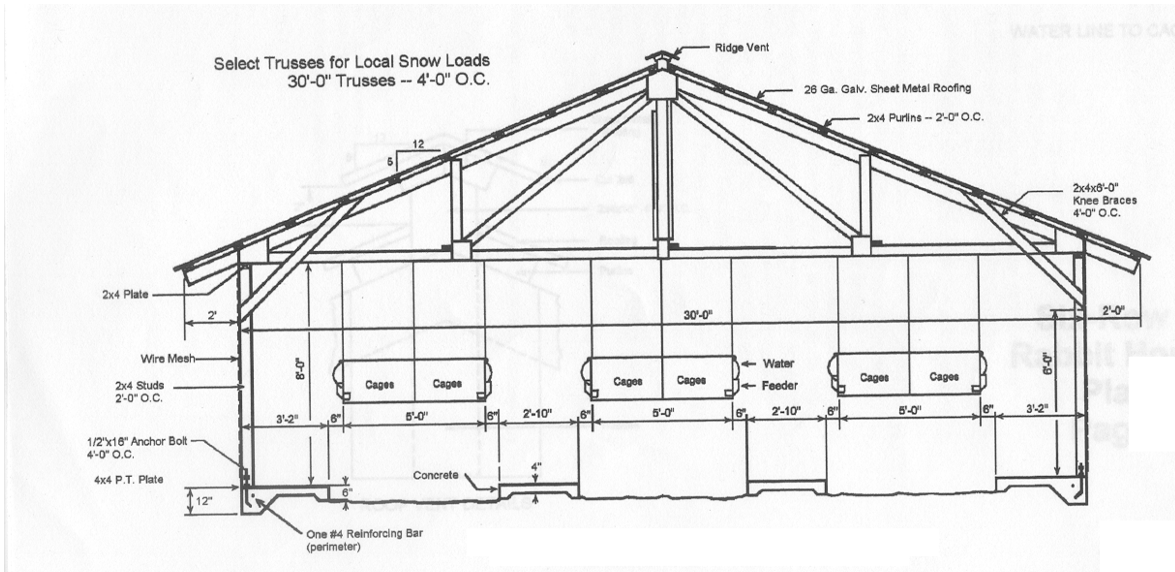


Figure A.16
Rabbit House, Double-Decked Cages

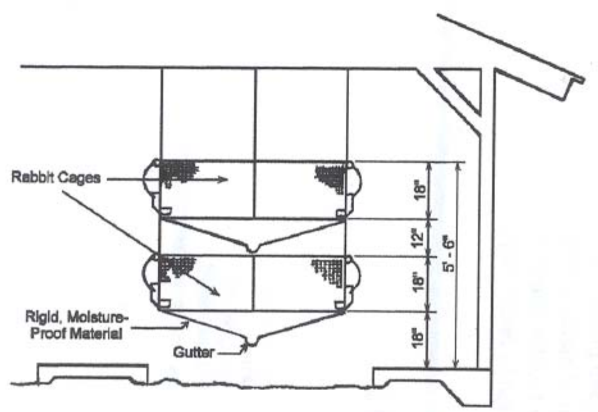


Figure A.17
Rabbit House, Water Line to Cages

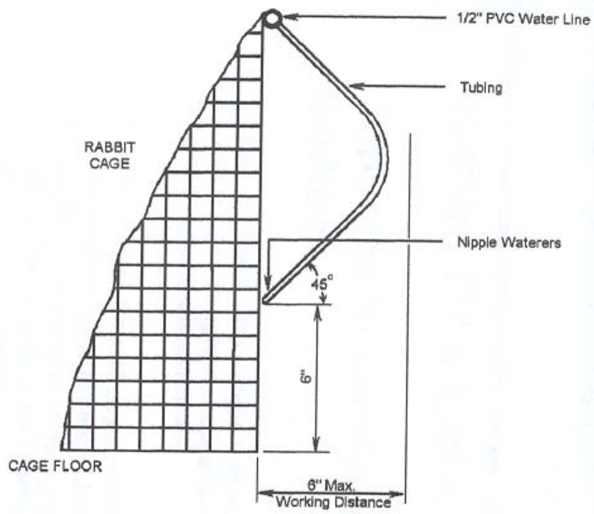
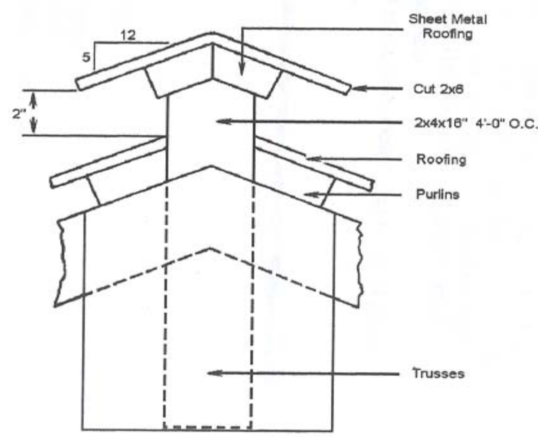


Figure A.18
Rabbit House, Roof Vent



A.2.3. Ducks and Geese

- Building dimensions: 30’ x 200’.
- Building dimensions: 30’ x 200’.
- Building housing that is dry and draft-free
- Make sure adequate spacing is provided for movement and exercise.
- Provide 3 square feet for ducks and 6 square feet for geese.
- Place feeders and water conveniently throughout the building.
- Have a source of electric light.
- Allow proper ventilation. Fresh air brings in oxygen and allows excess moisture, ammonia, or carbon dioxide to be removed.

Figure A.19
Duck and Geese Barn, Front Elevation

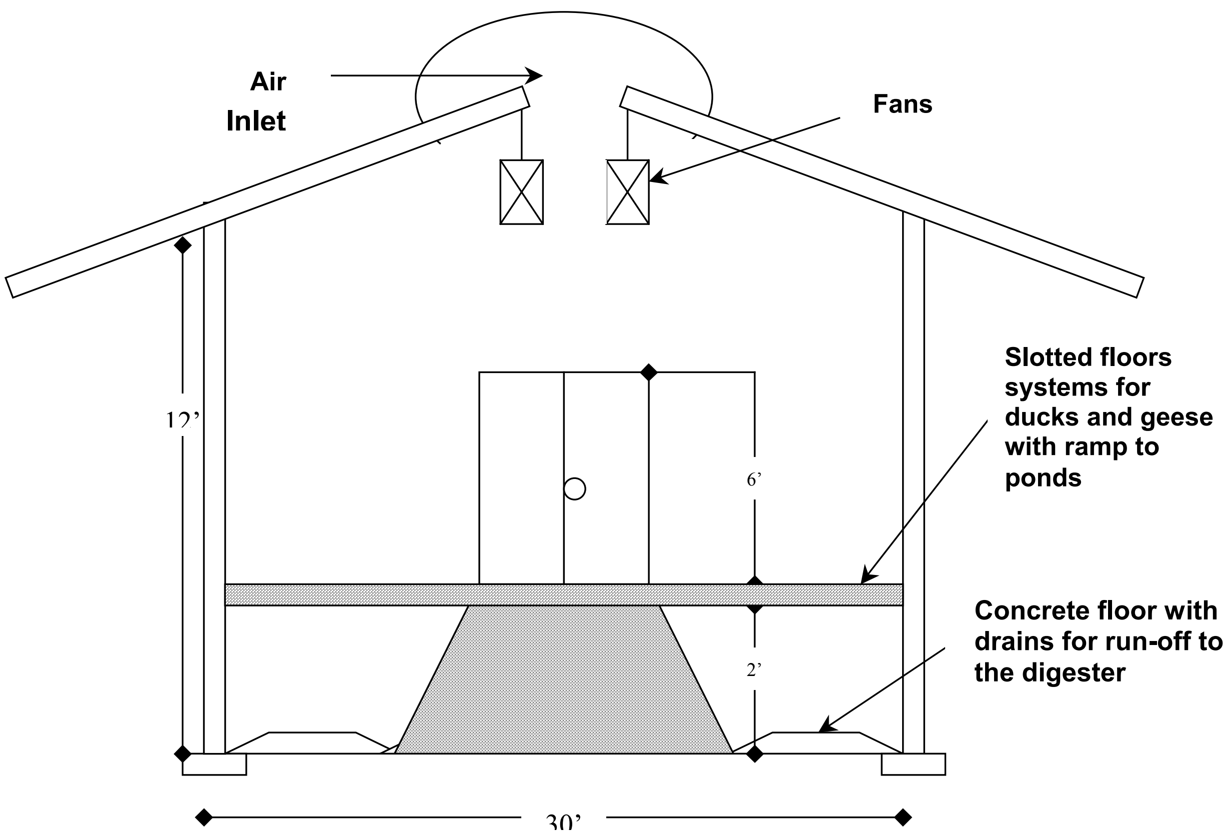
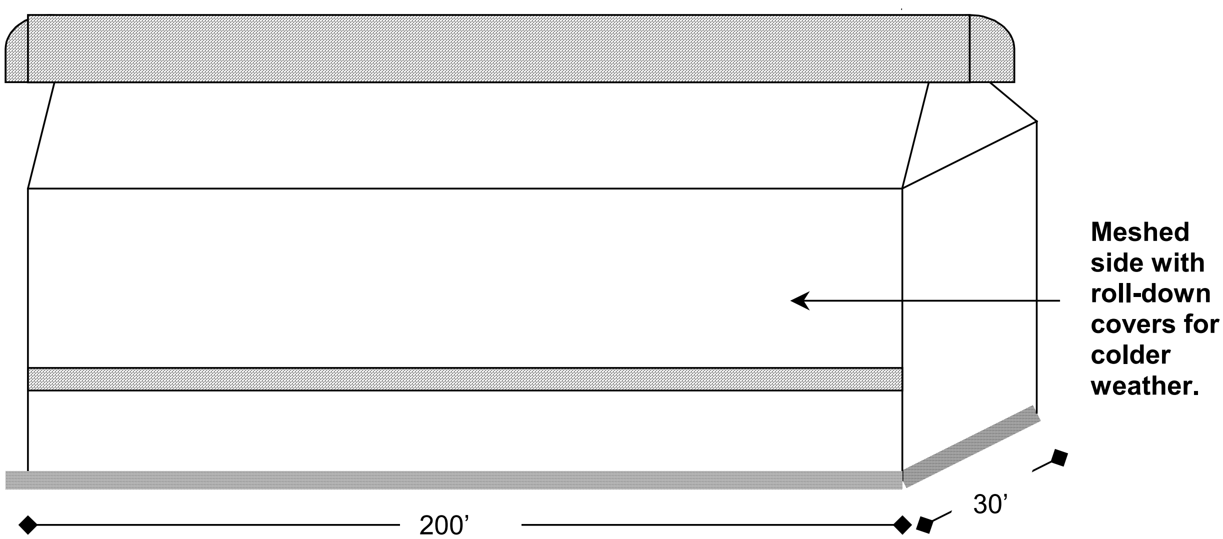


Figure A.20
Duck and Geese Barn, Side Elevation



A.2.4. Broilers

- Building dimensions: 30' x 200'.
- Building housing must be dry and draft-free.
- Make sure adequate spacing is provided for movement and exercise.
- Provide 1' to 2 ' of space per bird.
- Place feeders and water conveniently throughout the building.
- Have a source of electric light.
- Allow proper ventilation. Fresh air brings in oxygen and allows excess moisture, ammonia, or carbon dioxide to be removed.

Figure A.21
Chicken (Broiler) Barn, Front Elevation

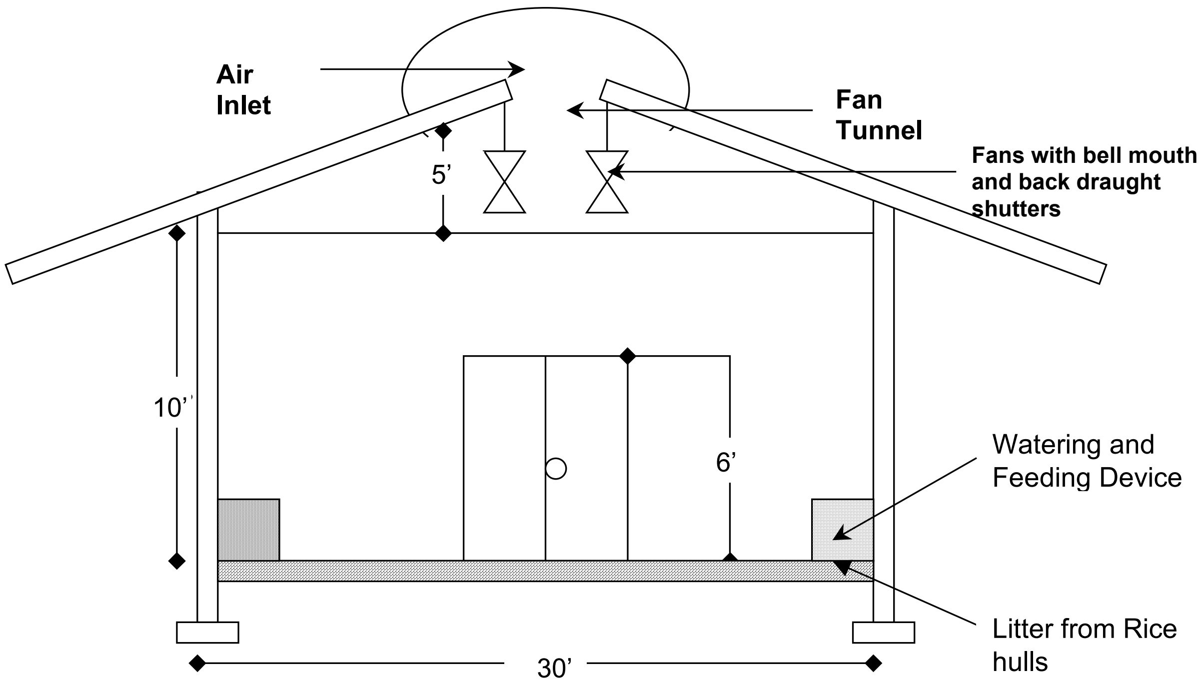
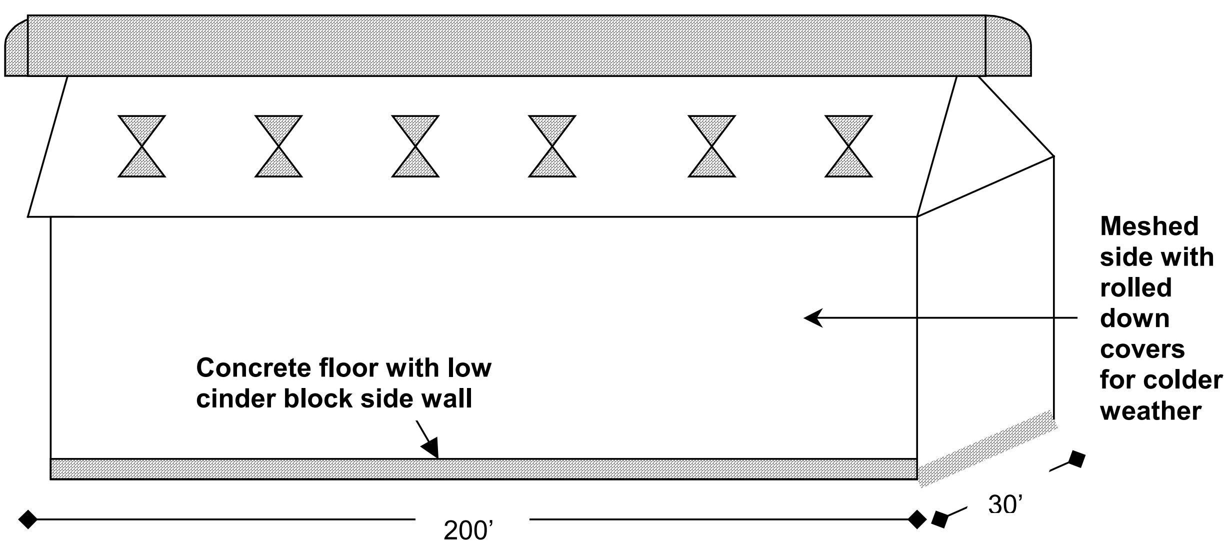


Figure A.22
Chicken (Broiler) Barn, Side Elevation



A.2.5. Layers

- Building dimensions: 30’ x 200’.
- Building housing must be dry and draft-free.
- Make sure adequate spacing is provided for the movement and exercise.
- Provide 6 to 10 inches of perch space per bird.
- Place feeders and water conveniently throughout the building.
- Have a source of electric light.
- Allow proper ventilation. Fresh air brings in oxygen and allows excess moisture, ammonia, or carbon dioxide to be removed.

Figure A.23
Chicken (Layer) Barn, Front Elevation

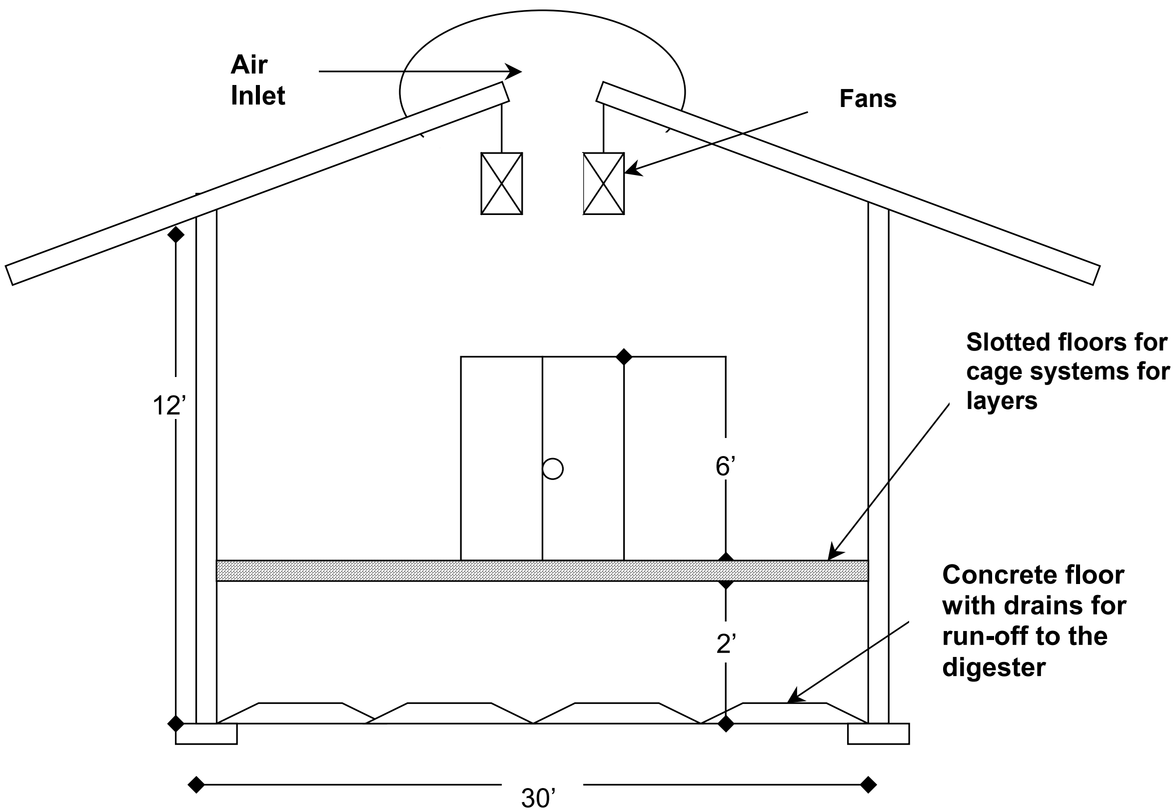


Table A.1
Recommendations for Poultry Enterprises
Using the Open Pasture or Range System

Types of Birds	Sq ft/bird inside	Sq ft/bird outside runs
Laying hens	1.5 – 3	4
Ducks	3	15
Geese	6	18
Broiler	1.2	10

A.3. Greenhouses

- Building dimensions: 100’x 21’ with 12’ – 15’ centers.
- Sidewall heights: 6’ to 8’.
- Frame made of strong 2” O.D., 14 Ga. Galvanized steel tubing.
- Simple construction.
- Ideal for new growers.
- Additional gutters connected bays can be added.
- Natural or mechanical ventilation.
- Free standing or gutter connected.
- 6’ hoop spacing and 6’ straight sidewalls allow for ample headroom.
- Thermostatically controlled.

Figure A.24
Greenhouse, Six Units

A.4. Aquaculture

Facilities can be used for prawn, catfish, talapia/perch and crawfish. The design is based on the six mu allocated for aquaculture in the village. The descriptions are based on commercial operations in the United States.

Figure A.25
Aquaculture Pond Layout

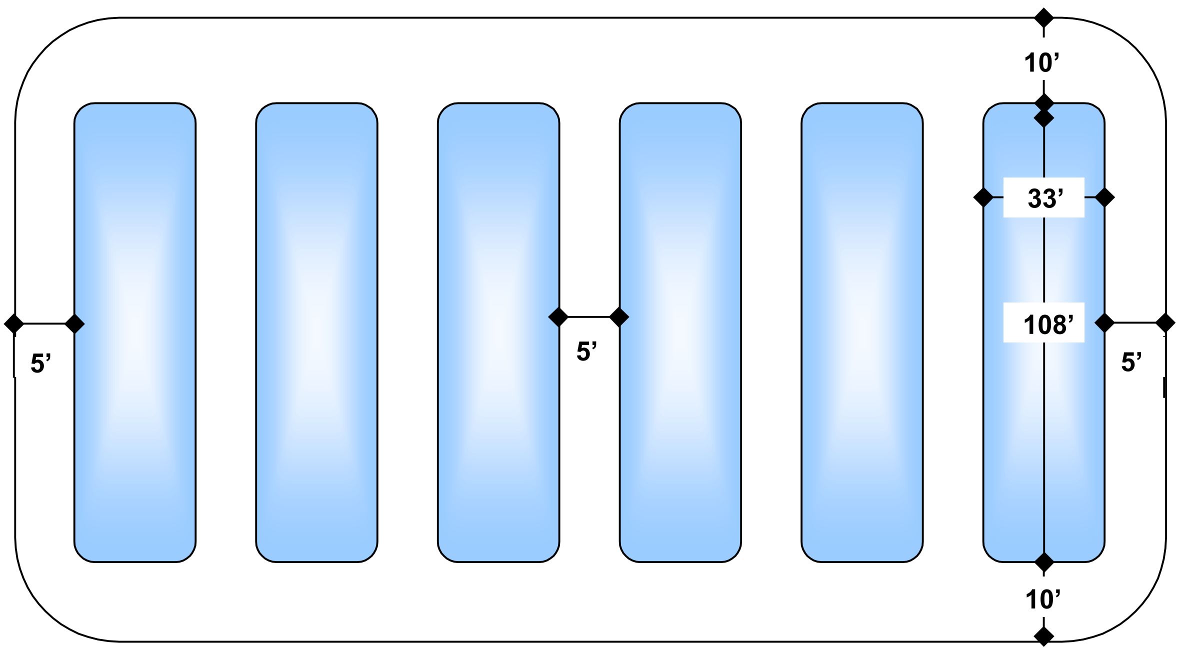
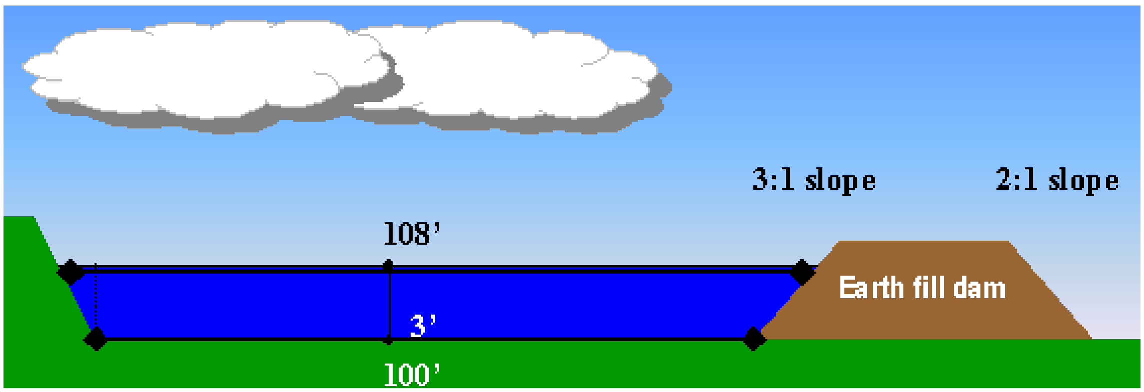


Figure A.26
Aquaculture Pond Layout, Side View



A.4.1. Prawn

- Have a good supply of fresh water. Water should be at least 68°F (20°C).
- Do not use water with a hardness of 300-plus ppm.
- Soil surrounding pond must have water-retention qualities.
- Build pond in areas that are not subject to flooding.
- Check soil for presence of pesticides.
- Bottom of pond should be smooth and free of any potential obstruction of seining.
- Surface area of pond should range from 1 to 5 acres; however, larger ponds have been successfully used.
- Depth of pond should be at least 2 feet at the shallow end and a maximum depth of 3.5 to 5 feet at the deep end.
- Allow for rapid draining at the slope of the bottom of pond.
- Collect a soil sample from the pond bottom to determine whether lime is needed. If pH level of soil is less than 6.5, lime is needed to increase the pH to a minimum level of 6.5; however a pH level of 6.8 is preferable.
- Apply ½ to 1 gallon of 10-34-0 or 13-38-0 liquid fertilizer per surface area to the pond at least 1 to 2 weeks before stocking juvenile prawn. Fertilizer should be diluted with water 10:1 before application. It can be sprayed from the banks or a boat equipped for chemical application.
- If phytoplankton bloom has not developed within a week, make a second application of the liquid fertilizer.
- Check the pond for aquatic insects (adults and larvae) that may eat prawn one to two days before stocking the prawns.
- Remove all fish from pond.
- Stock juvenile prawn at a density of 12,000 or 16,000 per acre.

A.4.2. Catfish

- Stock fish during the spring at the rate of 5000 fingerlings per acre.
- Harvest fish in one year at weight of 1 – 1.25 lb/fish.
- Ponds must be built with drainage structure at a sloping end.
- Ponds must be aerated at lease once per week to increase the oxygen levels.
- Consider topography first because it directly affects construction costs and management.
- Locate the pond where an adequate volume of water can be impounded with the least amount of earth fill. A good site is usually one in which a dam can be constructed across a narrow section of a steep valley, and where the slope of the valley floor permits a large area to be flooded. Such sites are ideal and minimize areas of shallow water.
- Avoid large areas of shallow water because they become too shallow for use during late summer and fall dry periods, and they encourage the growth of undesirable aquatic plants. If possible, avoid locations with constantly flowing creeks or streams.
- Water should be adequate, but not excessive, and may be provided by springs, wells, or surface runoff. For ponds where surface runoff is the main source of water, the contributing drainage area should be large enough to maintain a suitable water level during dry periods.
- The drainage area should not be so large that expensive overflow structures are needed and water exchange occurs too frequently. As a rule, a pond should have 5 to10 acres of drainage area for each acre of impounded water. The amount of runoff that can be expected from a watershed depends on several factors: topography, soil type, and plant cover.

- Suitable soil is one of the primary factors in selecting a pond site.
- The soil should contain a layer of material so water will not seep through. Clays and silty clays are excellent for this purpose. Sandy clays are also usually satisfactory.
- To determine suitability, take soil borings at frequent intervals and have them analyzed. Failure to evaluate hidden soil strata properly could result in a pond that will not hold water.
- Establish suitable vegetation, such as Bermuda grass, fescue grass, Bahia grass, or other perennial cover on the dam as soon as possible to prevent erosion, muddy water, and maintenance problems.
- Do not allow trees to grow on dam.
- A combination drain and overflow pipe, as well as an emergency spillway, are necessary for good management. The emergency spillway is designed to carry excessive runoff from heavy rainfall.
- The overflow pipe is the outlet for normal water flow through the pond.
- The bottom drain allows the water level to be lowered, which is often necessary for weed control and fishery management. A drain gives the pond owner a necessary tool to manage his pond efficiently. Overflow and drain pipes may be corrugated metal, aluminum, steel, or polyvinyl chloride (PVC). Some materials are more durable than others, and thus may be preferred. For example, PVC pipe, although inexpensive, is prone to breakage and vandalism. Be sure the pipe meets the standards for use in a pond dam. Drains can be added to existing ponds, but you will need professional assistance.
- Banks should be sloped with a water depth of 3 feet near the shoreline to eliminate shallow water areas around the pond edge where aquatic weeds often start. Cattle may cause bank erosion and muddy water; fencing the pond may be necessary to limit or prevent damage.
- Seepage in new ponds sometimes develops. Draining the pond and compacting the bottom can often correct seepage. If the bottom soils have marginal water-holding capacity, a blanket of clay or other soil sealant packed with a sheepsfoot roller may reduce the seepage.

A.4.3. Tilapia

- Growth of tilapia will take 2 years. In the first year, stock newly spawned tilapia in the spring to early summer and grow into the fall up to about ¼ lb. In the second year, tilapia grows out to market size. When the temperature drops below 50°F, move tilapia to warmer water.
- To maximize growth, obtain optimum water temperature between 82°F and 86°F. Also, utilizing superior strains of fish selected for rapid growth can increase production.
- Tilapia can be cultured in cage, pond, or tank.

Cage culture of Tilapia

- Constructed cage should be made of materials that are durable, lightweight and inexpensive, such as galvanized and plastic coated welded wire mesh, plastic netting and nylon netting.
- Size of cage should vary from 1 to 1,000 cubic meters. As cage size increases, cost per unit of volume decreases. However, production per unit of volume also decreases, resulting from a reduction in the rate of water exchange.
- Equip cage with covers to prevent fish losses caused by jumping or bird predation. Covers are usually eliminated on large nylon cages if the top edges of the cage walls are supported 1 to 2 feet above the water surface.

- Use feeding rings in smaller cages to retain floating feed and prevent wastage. Rings consist of small –mesh (1/8 inch or less) screens suspended to a depth of 18 inches or more.
- Place cages in a large body of water and in places where water currents are greatest. Exceptions are eutropic waters that are rich in nutrients and organic matter.
- Small ponds (1 to 5 acres) can be used, but provisions for water exchange or emergency aeration may be required.

Pond culture of Tilapia

- There is no restriction on the size of the pond, but the ease of management and economical operation should be considered. Shallow (3 to 6 feet), small (1 to 10 acres) ponds with drains are recommended.
- Drain the pond. This is necessary to harvest all the fish.
- A harvesting pump is needed to concentrate the fish in the final stage of drainage.
- Dry the pond bottom to eradicate any fry or fingerlings that may interfere with the next production cycle.

A.4.4. Crawfish

- Ponds can be single-crop or rotational. However, ponds constructed for the sole purpose of producing crawfish are more productive.
- Ponds should be located in flat, open areas where soils have sufficient amounts of clay. Clay soils hold water and maintain the integrity of crawfish burrows.
- Surface water is less costly. However, this kind of water may contain predatory fish that must be removed.
- The bases of the perimeter levees should be at least 9 feet wide to prevent leakage caused by burrowing.
- A levee system of 3 feet high will contain the 12 to 18 inches of water necessary to cultivate crawfish.
- Make sure land has no more than 6-inch fall between perimeter levees.
- Ponds should be designed to thoroughly drain. Drains should be appropriate for the pond size, pumping capacity and projected rainfall. Two 10-inch drains are sufficient for a 20-acre pond.
- Position ditches outside the perimeter levees.
- Recirculate the water.
- Dissolved oxygen should be maintained above 3 ppm. To correct oxygen deficiencies, replace pond water with fresh oxygenated water or by recirculating water with pumps or mechanical aerators.
- The pH level of water should range from 6.5 to 8.5 at dawn.
- If the production is intensive, pumping capacity of 70 to 100 gallons per minute per surface acre is required. This rate is needed to exchange all the water in the pond over a 4- to 5-day period. Adding 4 to 6 inches of water at flood-up rather than the full, harvesting depth of 12 to 18 inches will reduce the amount of water needed for oxygen management.

A.5. Composting

- Structure dimensions should be 30’x15’ with floor sloped to allow for drainage.
- The structure should be open-ended to allow for first-in, first-out removal of compost.

- The center should be 6’ high to allow for good compaction.
- Plastic covers should be used to allow for regulation of the amount of water the composting material is exposed to during the rainy season.
- Compost must be handled properly to satisfy HACCP standards and food safety.
- Loading should be done in an orderly basis, with crop residue first, layered with night soil, regular soil, then animal waste.
- The composting material must be allowed to decompose for at least three months.
- Mix and apply compost to the soil; not on the leaf area of the crop.
- Each batch should be tested for organic content, microbes, micro-nutrients and heavy metals.
- While the same type of composition can be used for feed silage, DO NOT ALTERNATE USE BETWEEN COMPOSTING AND ANIMAL FEED SILAGE.

Figure A.27
Composting Unit

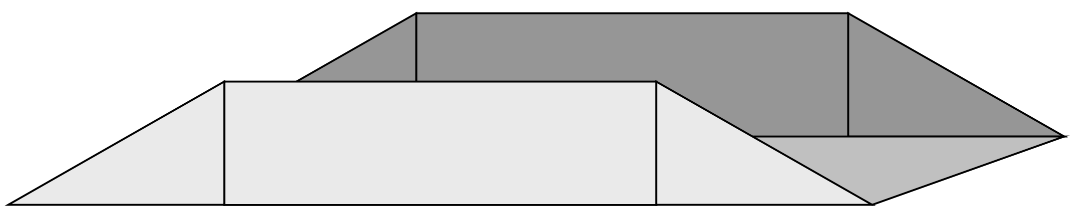


Figure A.28
Composting Unit, Side Elevation