

Appendices: Sustainable Home Design and Technology Adoption in *Colonias*, Informal Homestead Subdivisions, and Innerburbs

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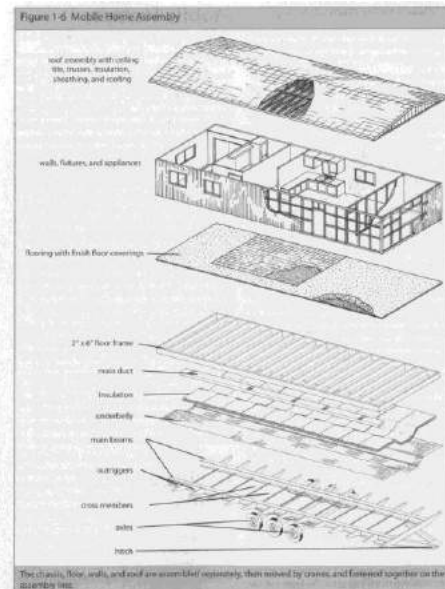
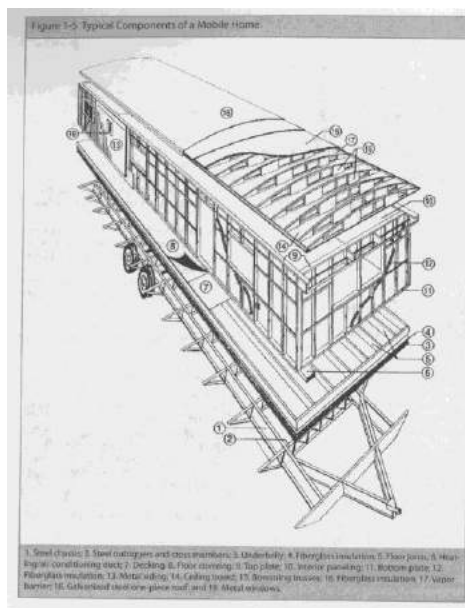
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APPENDIX A1: INFORMAL SETTLEMENT HOUSING TYPES & DEFINITIONS

There are few structural differences in current mobile, modular, and manufactured homes. Over time, the gap between these housing types and conventional, site-built homes has closed to a large extent, in construction technique and life expectancy. However, some differences still remain; many are implicit in what defines these home typologies. The greatest dissimilarities between a mobile home and a site built home are as follows:

1. *Its wooden frame is bolted to a steel chassis that remains with the home throughout its service life*
2. *It is constructed in long and narrow segments with shallow roof cavities to limit the home's height measured from the road, for clearance under bridges.*
3. *Its roofs, walls, and floors are assembled in large pre-built segments on a factory assembly line.*
4. *Its floors and exterior walls may only have one layer of sheeting, not two like many site-built homes.*
5. *It utilizes single framing, rather than double framing, around door and window openings.*
6. *Its interior wall paneling provides structural rigidity for keeping metal-sided mobile-home walls rectangular.*
7. *It incorporates sealed-combustion furnaces that get their combustion air from outdoors. These furnaces, an industry standard since the early 1970s, are safer than furnaces used in site-built homes.¹*



¹ John Krigger. (2006) *Your Mobile Home: Energy and Repair Guide for Manufactured Housing*, 5th ed. Helena, Montana: Saturn Resource Management, Inc, p.13.

Over time and likely due to marketing influences, mobile homes have since been called manufactured homes. Originally called house trailers in the 1950s and approximately 10 feet wide, the current homes are larger and often have nearly identical construction to standard, on-site home building. In fact, the double- and triple-wide homes currently being constructed are hard to distinguish from many site-built tract homes.² A recent study by the University of Georgia has found that the life expectancy of a manufactured home is 55.6 years.³ Since manufactured housing uses the same materials as site-built housing, life expectancy will be a function of owner maintenance.⁴ The primary difference from standard homes is the sectional nature or “component” quality of modular and manufactured home construction. Since they are larger siblings of mobile homes, it becomes necessary for purposes of road transportation to have pieces that are later assembled on-site.

The total cost of a mobile home (including land) is approximately \$50,000 compared to \$175,000 for a comparable site-built home.⁵ According to a study done by University of Michigan Professors Kate Warner and Robert Johnson speak directly to the bigger picture of manufactured home equity, value, quality, and construction methods:

1. Manufactured housing quality has become essentially equivalent to that of conventional housing
2. Manufactured housing compares favorably with site-built housing as an affordable housing option
3. Manufactured housing, like site-built housing, can be viewed as an investment with probabilities of appreciation and equity accumulation
4. Manufactured housing has no impact on the appreciation rates of surrounding properties, putting to lie the myths of negative property value impacts.⁶

The prevailing idea that mobile homes are viable investment properties means that sensible, sound upgrades can be sustained by stable or growing housing values. Consequently, this supports the idea of sustainable home improvement projects at a variety of scales.

² Ibid., 11.

³ “Manufactured Housing Institute (MHI), Modular homes, Mobile Home Communities Housing Industry Information, News, Surveys, Data Trade Association,” http://www.factorybuilthousing.com/lib/showtemp_detail01.asp?id=129&cat=.

⁴ “Home-Mart OK - FAQs,” <http://www.homemart.us/question.htm>.

⁵ John Krigger, (2006). *Your Mobile Home: Energy and Repair Guide for Manufactured Housing*, 5th ed. (Helena, Montana: Saturn Resource Management, Inc.

⁶ “Manufactured Housing Institute - MHI, Modular homes, Mobile home Communities Housing Industry Information, News, Surveys, Data Trade Association.”

APPENDIX A2: PRINCIPLES FOR SAFE AND HEALTHY HOMES

The Importance of Indoor Environmental Quality

A growing body of research links housing conditions to health outcomes such as asthma, lead poisoning, lung cancer, and unintentional injuries. The quality of indoor home environments is especially important when one considers that Americans tend to spend 90% of their time indoors, and children and the elderly spend a disproportionate amount of time inside their home environments. Unfortunately, as the Environmental Protection Agency advises, indoor air is often more polluted than outdoor air for a variety of reasons. First, enclosed indoor spaces with limited controlled ventilation tend to trap pollutants inside without dilution from outdoor air. Second, there are many emission sources for toxins, irritants, and allergens inside, including building materials, household chemicals, moisture and mold. Third, when all of these air pollutants spend time together inside a tight environment, they can react with each other to create even more toxic by-products. Considering that low-income children and the elderly are disproportionately at risk for asthma and respiratory disease and that these groups spend more time in substandard housing, it is important to consider the contribution of the home environment to health.

7 Principles of Healthy Housing

The National Center for Healthy Housing identifies 7 principles of healthy homes: dry, clean, pest-free, ventilated, safe, contaminant-free, and maintained.⁷

Dry: Moisture accumulation is a healthy and energy efficient home's worst nightmare. Water leaks and high moisture levels damage and erode building materials on their own, and breakdown of these materials often leads to release of toxic emissions. Even more problematic, where there is persistent moisture, there is almost always mold growth. Mold further erodes building materials and mold spores lead to allergic reactions and in some cases even respiratory infections. Humid air is also a problem for energy efficiency: humid air of the same temperature as dry air feels much hotter and requires more from air conditioning systems.

Clean: Clean homes help reduce pest infestations and exposure to contaminants.

Pest-Free: Recent studies have demonstrated a causal relationship between exposure to mice and cockroaches and asthma episodes in children; yet inappropriate pest management strategies can exacerbate health problems, since pesticide residues in homes pose risks for neurological damage and cancer. Healthy homes employ integrated pest management.

Ventilated: Dilution is a great way to confront pollution. Studies show that increasing the fresh air supply in a home improves respiratory health. Enabling natural cross ventilation through a home is an effective and energy-efficient strategy, especially when windows are aligned and oriented to take advantage of prevailing winds. Strategic ventilation for areas where there is a lot of moisture or pollutants is also critical. Bathrooms should always be vented outside to avoid moisture accumulation and mold growth. Similarly, dryers must be vented to the outside. Kitchen vents are essential to reduce exposure to products of incomplete combustion (PICs) such as carbon monoxide, nitrogen dioxide, nitrogen monoxide, and particulate matter.

⁷ <http://www.nchh.org/What-We-Do/Healthy-Homes-Principles.aspx>

Safe: Most injuries among children occur in the home. Falls cause the most frequent residential injuries to children, followed by injuries from objects in the home, burns, and poisonings.

Contaminant-Free: Chemical exposures include lead, radon, pesticides, volatile organic compounds, and environmental tobacco smoke (ETS). Exposures to asbestos particles, radon gas, carbon monoxide, and ETS are far higher indoors than outside. When building materials in homes get too hot, they are also likely to emit toxins such as formaldehyde. Formaldehyde is present in pressed, particleboard and many other inexpensive building materials. The Katrina trailers story is a good example of the risks from off-gassing from building materials. Space heaters are another common source of indoor emissions. Inefficient space heaters – especially gas or kerosene ones – produce PICs.

Maintained: Keeping homes well maintained reduces the risk of unnecessary moisture and pest problems. Additionally, maintaining the interiors of homes can prevent the deterioration of lead-based paint that is the primary cause of lead poisoning,

APPENDIX A3: MANUFACTURED HOME CODES AND STANDARDS

The U.S. Department of Housing and Urban Development (HUD) and the Department of Energy (DOE)⁸ have developed several programs, policies and codes aimed specifically toward rural and particularly, manufactured homes and their upkeep, maintenance, and weatherization. HUD has an entire division devoted to manufactured housing with a Construction and Safety Program, Dispute Resolution Program, and a Manufactured Home Installation Program.⁹ This appendix presents some of HUD's standards for mobile home construction and provides a basic understanding of what measures need to be accounted for, especially those necessary by region. Emphasis will be placed on those that deal with the humid, climate conditions along the border and most peri-urban Texan environments. Additional information on manufactured homes is available at the HUD Office of Manufactured Housing Programs website: <http://www.hud.gov/offices/hsg/ramh/mhs/mhshome.cfm>.

Manufactured Home Construction and Safety Standards

(All bolded text is of primary importance)

Subpart F - Thermal Protection

Sec. 3280.504 Condensation control and installation of vapor retarders.

Ceiling vapor retarders.

- (1) In U_o Value Zones 2 and 3, **ceilings must have a vapor retarder** with a permeance of not greater than 1 perm (as measured by ASTM E 96-95 Standard Test Methods for Water Vapor Transmission of Materials) installed on the living space side of the roof cavity.
- (2) **For manufactured homes designed for U_o Value Zone 1, the vapor retarder may be omitted¹⁰.**

Exterior walls.

- (1) **Exterior walls must have a vapor retarder** with a permeance no greater than 1 perm (dry cup method) installed on the living space side of the wall; or
- (2) **Unventilated wall cavities must have an external covering and/or sheathing that forms the pressure envelope.** The covering and/or sheathing must have a combined permeance of not less than 5.0 perms. In the absence of test data, combined permeance is permitted to be computed using the following formula: $P_{total} = (1/[(1/P1) + (1/P2)])$, where P1 and P2 are the permeance values of the exterior covering and sheathing in perms. **Formed exterior siding applied in sections with joints not caulked or sealed, are not considered to restrict water vapor transmission; or**
- (3) **Wall cavities must be constructed so that ventilation is provided to dissipate any condensation** occurring in these cavities; or
- (4) **Homes manufactured to be sited in "humid climates" or "fringe climates" as shown on the Humid and Fringe Climate Map in this paragraph are permitted to**

⁸ DOE training documents: <http://www.waptac.org/sp.asp?id=9629>

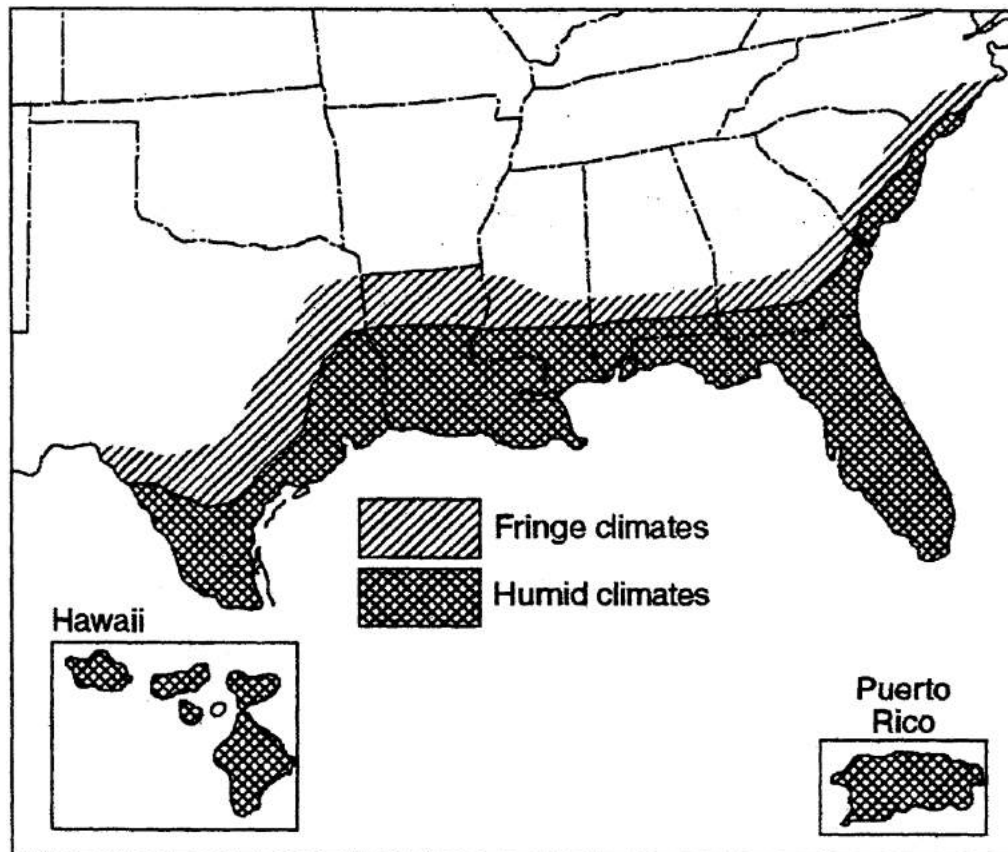
⁹ "HUD- Office of Manufactured Housing Programs," <http://www.hud.gov/offices/hsg/ramh/mhs/mhshome.cfm>.

¹⁰ Texas falls within U_o Value Zone 1. To better explain, how vapor barriers work, see Appendix A5.

have a vapor retarder specified in paragraph (b)(1) of this section installed on the exterior side of the wall insulation or be constructed with an external covering and sheathing¹¹ with a combined permeance of not greater than 1.0 perms, provided the interior finish and interior wall panel materials have a combined permeance of not less than 5.0 perms. The following need not meet the minimum combined permeance rating of not less than 5.0 perms for interior finish or wall panel materials:

- (i) Kitchen back splash materials, less than 50 square feet in area installed around countertops, sinks, and ranges;
- (ii) Bathroom tub areas, shower compartments;
- (iii) Cabinetry and built-in furniture;
- (iv) Trim materials;
- (v) Hardboard wall paneling of less than 50 square feet in area under chair rails.

Humid and Fringe Climate Map



¹¹ There is some debate about the appropriate location of vapor barriers, but refer to Appendix A5 to see issues discussed more clearly. Texas falls into humid climate region, so this is especially important.

(5) The following areas of local governments (counties or similar areas, unless otherwise specified), listed by state are **deemed to be within the humid and fringe climate areas shown on the Humid and Fringe Climate Map in paragraph (b)(4) of this section, and the vapor retarder or construction methods specified in paragraph (b)(4) of this section may be applied to homes built to be sited within these jurisdictions:**

Texas

Anderson, Angelina, Aransas, Atascosa, Austin, Bastrop, Bee, Bexar, Brazoria, Brazos, Brooks, Burleson, Caldwell, Calhoun, Cameron, Camp, Cass, Chambers, Cherokee, Colorado, Comal, De Witt, Dimmit, Duval, Falls, Fayette, Fort Bend, Franklin, Freestone, Frio, Galveston, Goliad, Gonzales, Gregg, Grimes, Guadalupe, Hardin, Harris, Harrison, Hays, Henderson, Hidalgo, Hopkins, Houston, Jackson, Jasper, Jefferson, Jim Hogg, Jim Wells, Karnes, Kaufman, Kennedy, Kinney, Kleberg, La Salle, Lavaca, Lee, Leon, Liberty, Limestone, Live Oak, Madison, Marion, Matagorda, Maverick, McMullen, Medina, Milam, Montgomery, Morris, Nacogdoches, Navarro, Newton, Nueces, Orange, Panola, Polk, Rains, Refugio, Robertson, Rusk, Sabine, San Augustine, San Jacinto, San Patricio, Shelby, Smith, Starr, Titus, Travis, Trinity, Tyler, Upshur, Uvalde, Val Verde, Van Zandt, Victoria, Walker, Waller, Washington, Webb, Wharton, Willacy, Williamson, Wilson, Wood, Zapata, Zavala.

Attic or roof ventilation.

(1) **Attic and roof cavities shall be vented** in accordance with one of the following:

(i) A minimum free ventilation area of not less than 1/300 of the attic or roof cavity floor area. At least 50 percent of the required free ventilation area shall be provided by ventilators located in the upper portion of the space to be ventilated. At least 40 percent shall be provided by eave, soffit or low gable vents. **The location and spacing of the vent openings and ventilators shall provide cross-ventilation to the entire attic or roof cavity space.** A clear air passage space having a minimum height of 1 inch shall be provided between the top of the insulation and the roof sheathing or roof covering. Baffles or other means shall be provided where needed to insure the 1 inch height of the clear air passage space is maintained.

(ii) **A mechanical attic or roof ventilation system may be installed instead of providing the free ventilation area** when the mechanical system provides a minimum air change rate of 0.02 cubic feet per minute (cfm) per sq. ft. of attic floor area. Intake and exhaust vents shall be located so as to provide air movement throughout space.

(2) **Single section manufactured homes constructed with metal roofs and having no sheathing or underlayment installed, are not required to be provided with attic or roof cavity ventilation provided that the air leakage paths from the living space to the roof cavity created by electrical outlets, electrical junctions, electrical cable penetrations, plumbing penetrations, flue pipe penetrations and exhaust vent penetrations are sealed.**

(3) Parallel membrane roof section of a closed cell type construction are not required to be ventilated.

(4) **The vents provided for ventilating attics and roof cavities shall be designed to resist entry of rain and insects.**

Sec. 3280.505 Air infiltration.

Envelope air infiltration.

The opaque envelope shall be designed and constructed to limit air infiltration to the living area of the home. Any design, material, method or combination thereof which accomplishes this goal may be used. The goal of the infiltration control criteria is to reduce heat loss/heat gain due to infiltration as much as possible without impinging on health and comfort and within the limits of reasonable economics.

(1) *Envelope penetrations. Plumbing, mechanical and electrical penetrations of the pressure envelope not exempted by this part, and installations of window and door frames shall be constructed or treated to limit air infiltration. Penetrations of the pressure envelope made by electrical equipment, other than distribution panel boards and cable and conduit penetrations, are exempt from this requirement. Cable penetrations through outlet boxes are considered exempt.*

(2) *Joints between major envelope elements. **Joints not designed to limit air infiltration between wall-to-wall, wall-to-ceiling and wall-to-floor connections shall be caulked or otherwise sealed.** When walls are constructed to form a pressure envelope on the outside of the wall cavity, they are deemed to meet this requirement.*

Sec. 3280.506 Heat loss/heat gain.

The manufactured home heat loss/heat gain shall be determined by methods outlined in Sec. Sec. 3280.508 and 3280.509. The U_o (Coefficient of heat transmission) value zone for which the manufactured home is acceptable and the lowest outdoor temperature to which the installed heating equipment will maintain a temperature of 70 F shall be certified as specified in Sec. 3280.510 of this subpart. The U_o value zone shall be determined from the map in figure 506.

Coefficient of heat transmission.

The overall coefficient of heat transmission (U_o) of the manufactured home for the respective zones and an indoor design temperature of 70 F, including internal and external ducts, and excluding infiltration, ventilation and condensation control, shall not exceed the Btu/(hr.) (sq. ft.) (F) of the manufactured home envelope as tabulated below:

U_o value zone	Maximum coefficient of heat transmission
1.....	0.116 Btu/(hr.) (sq. ft.) (F).
2.....	0.096 Btu/(hr.) (sq. ft.) (F).
3.....	0.079 Btu/(hr.) (sq. ft.) (F).

To assure uniform heat transmission in manufactured homes, cavities in exterior walls, floors, and ceilings shall be provided with thermal insulation.

(Manufactured homes designed for U_o Value Zone 3 shall be factory equipped with storm windows or insulating glass.

APPENDIX A4: AUDITS AND ASSESSMENTS FOR WEATHERIZATION

Current Required Energy Audit Processes

In Texas there are two general energy audit tests in use: Texas EASY audit and the Weatherization Assistant (supported by the Department of Energy), which includes two different audit packages:

- The National Energy Audit Tool (NEAT) and the
- Manufactured Home Energy Audit (MHEA).

The Texas EASY Audit

The State of Texas created the computerized EASY audit to recommend weatherization measures at the time the field study was performed. Auditors use the software to 1) draw a site and building plan of the home being audited, 2) place doors, windows, space-heaters, air conditioners, water heaters, etc, on the plan, 3) specify initial values for home components (operating efficiencies, shading, orientation, and other performance data), 4) enter target values for weatherization measures they wish to consider for objects that have been included in the drawing (e.g., attic R-value, final blower door reading, new furnace efficiency), and 5) enter annual heating and cooling costs based on the client's utility bills. EASY then performs calculations using heating and cooling degree days for the specific location of the house to estimate energy savings and cost-effectiveness for the measures requested.¹²

The Weatherization Assistant

The DOE's Weatherization Assistant operates similarly to the Texas EASY audit. It is a family of easy-to-use but advanced energy audit software programs that identify cost-effective energy-efficiency retrofit measures for a home after taking into account local weather conditions, retrofit measure costs, fuel costs, and specific construction details of the home. It is an umbrella program for NEAT (audit tool specifically for site-built single-family homes) and MHEA (audit tool for mobile and manufactured homes). Based on site-specific information provided and various scenarios in the software, NEAT and MHEA produce a prioritized list of cost-effective weatherization measures tailored to the dwelling being audited. The output is specific about the benefits to be gained, the rough costs of materials and installation, and other key information for project planning.

The key differences between the Texas and the DOE tools were identified by Oak Ridge National Laboratory as follows:

- NEAT and MHEA evaluate a greater number of weatherization measures than EASY (e.g., refrigerator replacement, lighting retrofits).
- NEAT and MHEA automatically check on the applicability and cost effectiveness of a library of weatherization measures on each house audited, while EASY only considers measures that the auditor specifies.

¹² All information from McCold et al. 2008, p. 5

- NEAT and MHEA automatically determine the optimum amount of insulation to install, while EASY only considers the level of insulation specified by the auditor.
- NEAT and MHEA account for the interaction between measures before developing its final list of recommended measures, while EASY does not.

Current Required Health Audits

Chapter 1, “Health and Safety” of The Texas Weatherization Field Guide, published this year by the Texas Department of Housing and Community Affairs, offers several health and safety guidelines for weatherization practitioners. Specifically, they review 1) when not to weatherize a dwelling, and 2) key client health and safety concerns related to weatherization and how to address them (carbon monoxide, moisture problems, and lead-paint dust).

Weatherization practitioners cannot weatherize a dwelling with serious structural problems that make weatherization impractical or impossible (e.g., seriously damaged roof with gaping holes), when the dwelling is condemned (or presumably would be condemned by local codes), or a mobile home is not adequately installed or supported. Practitioners can *choose* not to weatherize if there are pests, unsanitary conditions or other health and safety problems that present an immediate hazard to weatherization workers or if the dwelling unit is being remodeled and there is no coordination with the weatherization work.¹³

Weatherization auditors must also check several key health and safety areas that can be exacerbated by the weatherization work:

- Test heating systems and homes for carbon monoxide and solve problems causing CO
- Test combustion appliances and homes for carbon monoxide and other related hazards and solve problems related to these hazards
- Find moisture problems and discuss them with the client - and never make moisture problems worse, and
- Practice lead-safe weatherization according to new federal guidelines.

Based on federal requirements for WAP fund allocation, TDHCA notes that allowable “health and safety measures must be performed in conjunction with cost-effective weatherization and not as standalone measures. In other words, allowable health and safety measures are those that eliminate hazards that would be created or influenced by weatherization interventions. It is left to the assessor’s *discretion* whether to educate the client on other hazards in the home that can pose high statistical threat to occupants or to make referrals to other local service agencies.

Given that low-income homes are often in substandard conditions and may need home repair along with weatherization, some leadership is required to ensure that repair funds from other social services programs can be leveraged with weatherization money to create a safe, healthy, and energy efficient home environment for clients. City departments in other parts of the country and nonprofit organizations such as the National Center for Healthy Housing offer guidelines for more integrated, comprehensive yet efficient approaches to home audits for weatherization. There is a growing movement for a whole-house approach to retrofitting.

¹³ Field Guide, p. 10-11

APPENDIX A5: HOME WEATHERIZATION TECHNOLOGIES

Weatherization is one of the most easiest, cheapest, and most effective ways to increase the energy efficiency of a home. Here we outline the key areas in which weatherization retrofits take place.

Air Infiltration

Stopping air leakage not only helps with the performance of Heating, Ventilation, and Air Conditioning (HVAC) systems, but also lowers utility bills and enhances comfort against feelings of draftiness. This can be done by either prescriptive or guided methods, such as blower door testing.¹⁴ When dealing with limited resources, the prescriptive method may prove to be the most economical manner of addressing air leakage. A list of most common sources of lost air is assessed on a point-by-point basis and any problems are dealt with as they are discovered.

Most Common Sources of Air Leaks

1. Return air plenums in floor and ceiling
2. Joints and holes in forced air supply ducts and cracks in registers
3. Packaged air conditioners without proper backdraft dampers
4. Torn or missing underbelly
5. Plumbing areas under bathtubs, behind washing machines, under sinks, and interior walls adjoining water-heater closets
6. Joints between halves of double wide homes around entire perimeter
7. Joints between main building and additions
8. Gaps around light fixtures, electrical receptacles, flue pipes, and exhaust fans
9. Hidden openings in closets, cabinets, etc.
10. Loose siding, paneling, and trim
11. Electrical service panel boxes
12. Room air conditioners and evaporative coolers
13. Older window assemblies
14. Damaged, malfunctioning, or poorly fitting doors

Major leaks can be first addressed by caulking, sealing, weather-stripping, or insulating openings. This is one of the least expensive ways to lower energy use in a home, especially if windows or doors do not need to be replaced.

Insulation

Older mobile homes, particularly those manufactured before the mid-1970s are not well insulated. In many cases there are gaps in the insulation, creating a way for cold or hot air to move around and into the mobile home. This can create a loss in R-value anywhere from 15-50%.¹⁵ Additionally, if there is a moisture or vapor problem, any insulation loses most of its effectiveness and needs to be replaced once the wetness has been addressed. In warmer climates, the greatest financial return comes from insulating the ceiling/roof, to reduce the

¹⁴ Ibid, p.69.

¹⁵ Ibid., p.75.

intense heat gain coming through the roof.¹⁶ It is important to measure the space in the roof so that the householder can choose insulation that best fits and complies with HUD code.

There are several types of insulation that can be placed into cavities. The most commonly used are fiberglass batts, fiberglass blowing wool, mineral rock blowing wool, cellulose blowing insulation, polystyrene beads, polystyrene beadboard, and urethane foamboard. The following describes these and other insulation types, their installation technique, and best uses. We quote at length here (all italicized text) from a trade home rehabilitation site:¹⁷

Loose-fill Insulation: *Loose-fill insulation includes loose fibers or fiber pellets that are blown into building cavities or attics using special equipment. It generally costs more than batt insulation. However, it usually fills nooks and crannies easier, reduces air leakage better, and provides better sound insulation than batt-type insulation.*

Cellulose fiber, made from recycled newspapers, is chemically treated for fire and moisture resistance. (Check that the bags are clearly labeled to indicate that the material meets federal specifications for fire resistance). It can be installed in walls, floors or attics using a dry-pack process or a moist-spray technique.

Fiberglass and rock wool loose-fill insulation provide full coverage with a "Blow-in Blanket" System (BIBS) that involves blowing insulation into open stud cavities behind a net.

Loose-fill insulation typically has a value of approximately R-3 to R-4 per inch. Cellulose fiber has approximately 30% more insulating value than loose-fill rock wool for the same number of inches installed.

Batt and Blanket Insulation: *Batt and blanket insulation is made of mineral fiber -- either processed fiberglass or rock wool -- and is used to insulate below floors, above ceilings, and within walls. Generally, batt insulation is the least expensive wall insulation material but requires careful installation for effective performance.*

This type of insulation is best suited to a standard joist, rafter, or stud spacing of 16 or 24 inches. Batts and blankets come in widths to fit securely between the wood-framing members. Some come with a radiant barrier backing. Batts generally come in lengths of 4 or 8 feet. Blankets come in long rolls that are cut to the desired length for installation. Both batts and blankets typically have an R-value of approximately R-3 per inch of thickness.

Rigid Board Insulation: *Rigid board insulation is commonly made from fiberglass, polystyrene, or polyurethane and comes in a variety of thicknesses with a high insulating value (approximately R-4 to R-8 per inch). This type of insulation is used for reproofing work on flat roofs, on basement walls and as perimeter insulation at concrete slab edges, and in cathedral ceilings. For interior applications it must be covered with 1/2-inch gypsum board or other building-code approved material for fire safety. For exterior applications it must be covered with weather-proof facing. Check the applicable codes to determine local requirements for covering rigid board insulation to achieve fire resistance.*

¹⁶ Ibid.

¹⁷ <http://www.rehabadvisor.pathnet.org/sp.asp?id=10783>.

Spray Foam Insulation: Spray foam insulation is a two-part liquid containing a polymer (such as polyurethane or modified urethane) and a foaming agent. The liquid is sprayed through a nozzle into wall, ceiling, and floor cavities. As it is applied it expands into a solid cellular plastic with millions of tiny air-filled cells that fill every nook and cranny. Spray foam insulation should be applied by a professional using special equipment to meter, mix, and spray into place. Spray foam insulation is commonly used for retrofits; it is good for irregularly shaped areas and around obstructions

Spray foam materials cost more than traditional batt insulation. However, since spray foam forms both an insulation and an air barrier, it can be cost competitive with batt insulation because it eliminates the steps for air-tightness detailing (such as caulking, applying housewrap and vapor barrier, and taping joints).¹⁸

There are many considerations when determining which insulation to use. The most significant are area to be insulated and space available. Some other considerations are fire resistance, chemical reactions, and level of difficulty in installation.

Installing Vapor Diffusion Retarders for New Construction

Traditional building materials used in cooler climates usually impede moisture without the need for additional vapor retarders. In hotter climate such as those found in Texas, vapor retarders are recommended in all new construction. The following is quoted at length from the U.S. Department of Energy's guide to energy efficiency:¹⁹

Reasonable rules-of-thumb to follow when placing vapor retarders include the following:

- *In climates with 2,200 or more Heating Degree Days, locate the vapor diffusion retarder on the warm side of the exterior structural assembly. If possible, locate it on the inside of the assembly using the "one-third, two-thirds rule": the vapor diffusion retarder has one-third of the cavity insulation to its warm side, two-thirds to the cold side. This protects the retarder from physical damage through errant construction or remodeling activities.*
- *In climates with fewer than 2,200 Heating Degree Days (cooling-dominated climates) and where the building is near, but not quite in, the 2,200 Heating Degree Days zone (a.k.a. fringe zone), place the vapor diffusion retarder in the same location as climates farther north.*
- *Farther south (about 1,900 Heating Degree Days) it is unimportant where the vapor diffusion retarder goes. For climates even farther south and generally hotter and more humid, some professionals recommend omitting the vapor diffusion retarder completely. This is due to the winter heating loads and summer cooling loads being roughly equal. Any location ends up having the vapor diffusion retarder on the wrong side of the structure during part of the year. However, other building science research indicates that it should be*

¹⁸ "Types of Insulation," <http://www.rehabadvisor.pathnet.org/sp.asp?id=10783>.

¹⁹ U.S. Department of Energy, "Energy Savers: Vapor Barriers or Vapor Diffusion Retarders," http://www.energysavers.gov/your_home/insulation_airsealing/index.cfm/mytopic=11810.

*applied directly under the exterior finish and is sometimes itself the exterior finish.
A combination air barrier/vapor diffusion retarder may be a better choice for this situation.*

Knowledgeable builders typically use vapor diffusion retarders with ratings of 0.1 or less. However, if you carefully seal the warm-side vapor diffusion retarder and interior finish, you can also safely install a low-permeable material, such as rigid foam board insulation (a perm rating as high as 1.4), on the cold side of walls. A good rule-of-thumb: to prevent trapping any moisture in a cavity, the cold-side material's perm rating should be at least five times greater than the value of the warm-side. Use a vapor diffusion retarder with a perm value of less than 0.50 if you also have a high water table.

When installing a vapor diffusion retarder, it should be continuous and as close to perfect as possible. This is especially important in very cold climates and in hot and humid climates. Be sure to completely seal any tears, openings, or punctures that may occur during construction. Cover all appropriate surfaces; otherwise, you risk moist air condensing within the cavity, which would lead to dampened insulation. The thermal resistance of wet insulation is dramatically decreased, and prolonged wet conditions will induce mold and wood rot.

Except for extensive remodeling projects, it's difficult to add materials like sheet plastic as a vapor diffusion retarder to an existing home. However, many existing homes don't really need a more effective vapor diffusion retarder than the numerous layers of paint usually on their walls and ceilings. These multiple layers are quite effective as a vapor diffusion retarder in all but the most extreme northern climates.

APPENDIX A6: WEATHERIZATION TRAINING RESOURCES

The Department of Energy offers Weatherization Assistance Program Standardized Curricula for weatherization professionals serving low-income communities (see http://www.waptac.org/sp.asp?mc=training_resources).

This site includes a Core Competencies document, which provides a comprehensive outline of core competency requirements for weatherization workers in various job positions developed by the Weatherization Trainers Consortium.

The Weatherization Assistance Program Standardized Curricula are designed to be comprehensive, yet flexible tools that both new and experienced instructors can use to expand the Weatherization Workforce. There are five core curricula currently available:

Weatherization Installer/Technician Fundamentals²⁰

Weatherization Installer/Technician Intermediate²¹

Weatherization Installer/Technician - Mobile Homes²²

Energy Auditor - Single Family²³

Crew Chief²⁴

The Mobile Homes curriculum is particularly relevant for the context of informal settlements.²⁵ Each component of this curriculum is provided below. The materials are provided free of charge and users can modify documents as they see fit. Questions about the materials can be directed to info@waptac.org.

Sample Course Schedule: Installer Mobile Homes: This course schedule is an example of how the information could be presented.

Installer Mobile Homes Glossary: A list of useful terms.

Core Competencies: A listing of skills and positions for weatherization work.

The following is a list of topics that are included within these key areas:

²⁰ <http://www.waptac.org/sp.asp?id=9630>

²¹ <http://www.waptac.org/sp.asp?id=9702>

²² <http://www.waptac.org/sp.asp?id=10055>

²³ <http://www.waptac.org/sp.asp?id=10263>

²⁴ <http://www.waptac.org/sp.asp?id=10355>

²⁵ See: <http://www.waptac.org/sp.asp?id=10055>

1. Introduction to Mobile Homes

Presentation: Introduction to Mobile Homes

Speaker Notes: Introduction to Mobile Homes

Lesson Plan: Introduction to Mobile Homes

Worksheet: Savings to Investment Ratio Comparison

2. Duct Diagnostics and Repair

Presentation: Duct Diagnostics and Repair

Speaker Notes: Duct Diagnostics and Repair

Lesson Plan: Duct Diagnostics and Repair

3. Mobile Home Belly Retrofits

Presentation: Mobile Home Belly Retrofits

Speaker Notes: Mobile Home Belly Retrofits

Lesson Plan: Mobile Home Belly Retrofits

4. Mobile Home Sidewall Retrofit

Presentation: Mobile Home Sidewall Retrofit

Speaker Notes: Mobile Home Sidewall Retrofit

Lesson Plan: Mobile Home Sidewall Retrofit

Loose Fill Insulation Coverage Chart

5. Mobile Home Roof Retrofit

Presentation: Mobile Home Roof Retrofit

Speaker Notes: Mobile Home Roof Retrofit

Lesson Plan: Mobile Home Roof Retrofit

6. Mobile Home Heating Systems

Presentation: Mobile Home Heating Systems

Speaker Notes: Mobile Home Heating Systems

Lesson Plan: Mobile Home Heating Systems

DOE EERE Combustion Equipment Fact Sheet. Oct. 2000

Combustion Appliance Safety and Efficiency Testing

7. Other Measures

Presentation: Other Measures

Speaker Notes: Other Measures

Lesson Plan: Other Measures

Ventilation Strategies in Weatherization

NFPA Washer and Dryer Safety Tips

NFPA Dryer Fact Sheet

OSHA Carbon Monoxide Poisoning Fact Sheet

8. Additional Resources for Hands-On Training

Guidelines for Selection and Placement of a Mobile Home for Hands-On Training

Mobile Home Duct Sealing Prop

Mobile Home Hands-On Training Strategies

Mobile Home Installer Supplement for Hands-On Training

Mobile Home Tool and Material Lists
Scratch Building a Model Mobile Home

APPENDIX A7: PASSIVE SOLAR DESIGN

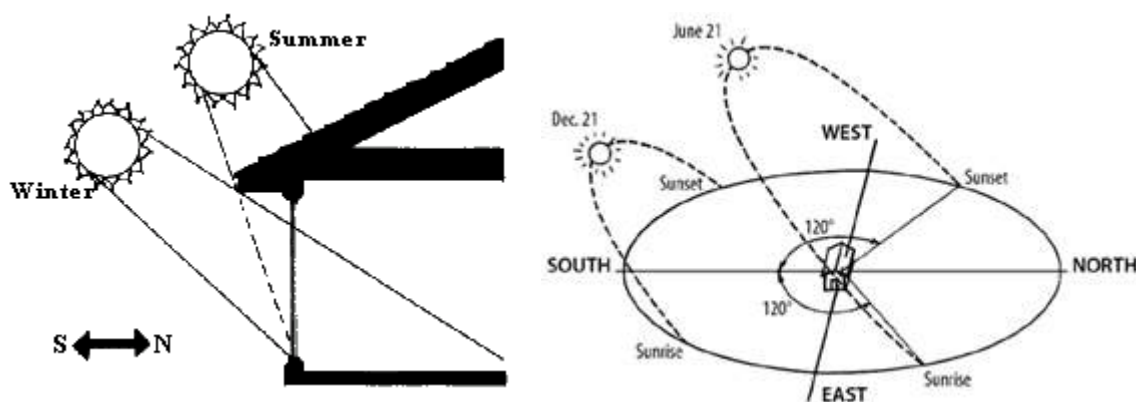
Strategies for Reducing Solar Heat Gain

We could save money and fuel resources while living much more comfortably if we designed *with* the sun instead of against it. With passive solar design, a home's windows, walls, and floors can be "designed to collect, store, and distribute solar energy in the form of heat in the winter and reject solar heat in the summer."²⁶ Passive solar home design offers many valuable tips on site design and architectural design for creating these comfortable, healthy and efficient homes in hot, humid climates.

Sun-smart homes in hot and humid climates generally have a long, narrow shape aligned along the east-west direction, maximizing northern and southern exposure of the thermal building envelope (the exterior walls and roof) to the sun, and minimizing east and west exposure. In this sense, a trailer oriented east-west would be perfectly oriented: there would be minimal wall exposure in the east and west, and maximum exposure along the north and south walls. Strategic shading with porches and overhangs prevents much of the solar gain costs of south facing walls and windows.

Overview of Implications of the Sun's Path for Heat Gain

In order to design a home or its landscape features to work with the sun instead of against it, it's first important to understand the path of the sun through the year and each day relative to homes. This section provides a basic overview of the most important concepts for homes in Central Texas. The reference for all of the information below is "Green By Design: 7 steps to Green Building Classroom Manual" from the Austin Energy Green Building Program.



Sources: Bright Power Energy Efficiency and Renewable Energy, and National Sustainable Agriculture Information Service²⁷

²⁶ http://www.energysavers.gov/your_home/designing_remodeling/index.cfm/mytopic=10250

²⁷ <http://attra.ncat.org/images/renewables/sun-path.jpg>

North

The north sides of buildings receive very little direct sun. Northern walls will experience solar gain only during the summer early morning hours and the latest hours of summer afternoons. At these times of day, the sun's vertical position in the sky (the solar altitude) is at its lowest, so northern walls are typically shaded by other buildings and trees.

South

The sun's position for most of the day is in the southern sky, making the south side the sunniest side of a home. This is a great thing for allowing sunshine to naturally light the inside of the home and to warm the home in the winter. Although it might appear to pose a major problem for heat gain in the summer, the worst heat gain can be avoided simply by having small awnings, overhangs, or porches on south and southwestern walls. Shading of windows is especially important. These awnings limit summer heat gain in the summer and make it possible in the winter. This is made possible because our knowledge of the seasonal and diurnal path of the sun relative to the earth. In Central Texas (and other places at 30 degrees N latitude) in the summer, the sun is almost directly overhead at solar noon (usually 1pm daylight time). This means that it's possible to use small awnings (18-24 inches deep) to shade the home. More specific information about roof hang sizing and typical solar angles for Central Texas is provided in Table 1, provided by Austin Energy's Green Building Program.

East

In the morning, the east walls of a home will be exposed to solar heat gain. Overhangs generally do not work very well on east facing walls because the sun angle in the morning is so low on the horizon that it can easily pass under the awnings. Thus, minimal windows are recommended on this side. Another option is to plant both canopy trees and more shrub like trees on the east and west sides of the home to block direct sun rays even at low angles.

West

The west sides receive the most sun. Since the sun sets in the west, the sun is low on the horizon for much of the afternoon and can pass under most awnings. In Central Texas, most air-conditioning occurs between 2 p.m. and 5 p.m: the air conditioner has to address the heat gain that is gradually built up throughout the day, plus the intense afternoon light from the west. Windows are generally not recommended on the west side of windows unless they are very small and well-shaded.

Summary of Key Recommendations for Passive Solar Design

- Use overhangs and porches on south and southwestern walls to minimize solar gain in the summer when the sun is mostly overhead, especially around solar noon (see images from Austin Energy's Green By Design Workshop at the end of this appendix for specifications).
- Minimize windows on east and west sides, but allow them in the north and south as long as they are properly shaded with emphasis on the south facade.
- Strategically plant trees to manage the sun – a tall mature tree in good health and good position can offer the equivalent of 2 to 3 tons of air conditioning capacity because of the shade it provides and the ambient cooling it offers from evapotranspiration.
 - Deciduous trees work especially well for east and west sides of the home: in the summer leaves provide shade and in the winter sun can pass through the windows.

- Planting shrubs with canopy trees helps block out direct sunrays even when the sun is very low on the horizon.
- It is important to place trees far enough away from the home to prevent insect and rain damage to the home.

ROOF OVERHANG SIZING

Shading windows from summer solar gain can considerably lower your annual cooling costs. Properly sized roof overhangs and other devices such as awnings can easily shade south facing windows. This FACTSHEET provides information about three different methods of sizing south facing window overhangs:

- 1) summer solar angles for Austin for geometric sectional drawings,
- 2) a table for roof overhang and awning sizing for south facing windows ranging in height from 24" to 84", and
- 3) an overhang equation for window sizes not included in the table.

SUMMER SOLAR ANGLES FOR AUSTIN (30°N LATITUDE)

Altitude (ALT) is the sun's angle in degrees above the horizon (how high)

Azimuth (AZM) is the sun's angle in degrees from south (how far east/ west)

MONTH \ TIME OF DAY	SOLAR 8 AM		SOLAR NOON		SOLAR 4 PM	
	ALT	AZM	ALT	AZM	ALT	AZM
June 21/ Summer Solstice	37	99	83	0	37	99
July 21	35	95	80	0	35	95
August 21	32	86	72	0	32	86
Sept 21/Fall Equinox	26	74	60	0	26	74

ROOF OVERHANG TABLE FOR SOUTH-FACING WINDOWS

Determine window height in inches and direction the window faces. Horizontal width of roof overhang to completely shade the window at noon on July 21st (the warmest and sunniest month of the year) is given in inches. All cases assume that the top of the window is 12" below the underside of the roof overhang. (See Roof Overhang Schematic on reverse side.)

DIRECTION \ HGT. of WINDOW	Southwest SW 45° W of S	South, Southwest SSW 22.5° W of S	South S	South, Southeast SSE 22.5° E of S	Southeast SE 45° E of S
24"	9"	7"	7"	7"	9"
36"	12"	10"	9"	10"	12"
48"	15"	12"	11"	12"	15"
60"	18"	14"	13"	14"	18"
72"	21"	17"	15"	17"	21"
84"	24"	19"	17"	19"	24"

As indicated in the table above, a 24" wide roof overhang provides total shading for all window sizes from 24"-84" that face southwest to southeast and are in the exterior wall that is directly under the roof overhang (i.e., the first floor of a one story house and the second floor of a two story house). A second story roof will not provide shading for windows in a first story wall.

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The same table can be used to size awnings and other shading devices for any window not shaded by a roof overhang (e.g., first story windows in a two-story house). If there is a header space, then use the table as is. If no header space exists between the top of the window and the bottom or underside of the shading device, then add 12" to the height of the window to find the size of the overhang. For example, for a window facing southwest with no header space, a 72" window (60" + 12") will be totally shaded by an 18" overhang.

ROOF OVERHANG EQUATION FOR SOUTH-FACING WINDOWS

The size of roof overhangs, awnings, and other shading devices can also be calculated by using the following equation:

$$W = H + T_{alt}$$

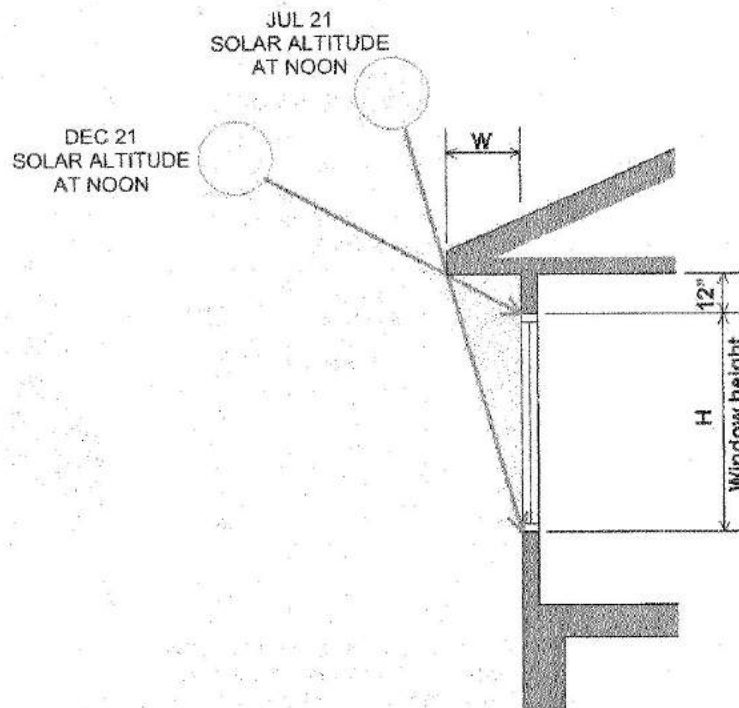
W = the horizontal width of the overhang in inches

$H +$ = the height of the window plus the header in inches
(or bottom of window to bottom of overhang)

T_{alt} = a conversion factor equal to the tangent of the altitude

For Austin, the conversion factors for each direction are:

DIRECTION	Southwest SW	South, Southwest SSW	South S	South, Southeast SSE	Southeast SE
CONVERSION FACTOR	4.0	5.1	5.6	5.1	4.0



ROOF OVERHANG SIZING FOR SUMMER SHADING

W = the horizontal width of the roof overhang in inches

H = the height of the window in inches

APPENDIX A8: FORMS OF ENERGY, PRICING, AND USAGE

When discussing renewable energy, it is important to take a look at more traditional forms of energy that are currently being used. This comparison will help us to assess the pros and cons of switching to renewable energy.

Natural Gas

Explanation: Natural gas is a fossil fuel consisting mainly of methane (CH₄). It is produced by microorganisms in many locations including swamps and landfills. Most commercially used natural gas comes from underground reservoirs (often associated with petroleum).

Cost: Natural gas gained popularity in the 1990s due to relatively low capital costs, its perceived minimal environmental impact compared to other traditional forms of energy, and its low costs per kWh. In fact, 90 percent of new power generation capacity came from natural gas during the 1990s. However, natural gas prices have been rising (despite a recent decline). Prices are also extremely volatile and have become increasingly difficult to predict since 2000.²⁸ The following table, taken directly from the Sustainable Options for Austin Energy Policy Research Project Report, is an analysis of two natural gas technologies:

Table A-2: Costs and Characteristics of Natural Gas Technologies

	Combustion Gas Turbines (CGT) (Advanced)	Combined Cycle Gas Turbines (CCGT)
Availability factor	0.96	0.96
Capacity factor	0.05-0.17	0.63
Technology maturity	Mature	Mature
CO ₂ or equivalent emissions (metric tons/MWh)	0.52-0.73	0.36
Load service function	Baseload, intermediate, peak (mainly intermediate)	Baseload, intermediate, peak (mainly peak)
Operational life (years)	25- 30	25- 30
Overnight capital costs (\$/kW)	426-568 (473)	1,067-1,423 (1,186)
Fixed operation & maintenance costs (\$/kW)	10.74	11.94
Variable operation & maintenance costs (\$/kW)	3.23	2.05
Fuel costs (\$/MWh)	60.48 -113.40 (75.60)	40.30 -75.56 (50.37)
Levelized cost of electricity (cents/kWh)	22.1-33.4 (24.9)	73-100 (82)
Current Austin Energy capacity (MW)	382 (CGTs)	312 (CCGT), 741 (steam turbines)

²⁸ Eaton, D. (2009). Sustainable Energy Options for Austin Energy. A Report by the Policy Research Project on Electrical Utility Systems and Sustainability. Lyndon B. Johnson School of Policy Research Report Number [XXX].

Propane

Explanation: Propane, a liquefied petroleum that comes from both oil and gas wells, does not occur naturally. Although propane does emit some greenhouse gases, it is relatively environmentally friendly. It generates fewer GHG emissions per Btu than 70 percent of today's fuel mix and has a lower carbon footprint than gasoline, diesel, heavy fuel oil, and ethanol for on-site emissions alone.²⁹

Cost: Propane like natural gas can fluctuate greatly depending on unforeseen factors such as economic, political, climatic variables. In addition to these factors, propane prices are largely shaped by demand. There are also stringent requirements imposed on propane companies by local, state, and federal government. Consequently, one of the largest expenses that propane incurs is insurance.

According to Texas Propane Energy, propane can actually be a very economical energy source. Propane gas water heaters, for example, cost approximately \$10 less per month than comparable electric heaters. Texas Propane Energy is currently selling propane at \$2.45 per gallon. Depending on the area and time, natural gas can be cheaper. However, this is not always the case.

Solar

Explanation: Solar energy can be used to generate light, heat, and electricity. Two technologies that utilize this energy are concentrated solar (CSP) technologies, which use direct radiation, and photovoltaic (PV) systems, which use diffuse solar radiation.³⁰ Both technologies can have great impacts. For example, for each KW of solar array installed, Austin Energy reduces the amount of energy they need to generate and distribute by an annual average of 1,363 KWH.³¹

CSP technologies collect and concentrate sunlight and transform it into thermal energy, which then drives a heat engine and generates electricity. This technology is much more viable at the utility rather than the individual level. Therefore, it will not be discussed here in further detail.³²

PV Systems consist of photovoltaic cells, which convert light energy directly into electricity without creating any air or water pollution.³³ There are both on and off grid PV systems. Those homeowners who are already on the grid and receive electricity from utilities can use this energy from the utility to supplement their energy needs when the PV system is not supplying

²⁹ Propane Education and Research Council. (n.d.). Retrieved March 2010, from www.propanecouncil.org/features.aspx?id=1044

³⁰ Eaton, D. (2009). Sustainable Energy Options for Austin Energy. A Report by the Policy Research Project on Electrical Utility Systems and Sustainability. Lyndon B. Johnson School of Policy Research Report Number [XXX].

³¹ Moore, S. (2008). Topics in Sustainable Development. The University of Texas Center for Sustainable Development. Pp. 135.

³² Eaton, D. (2009). Sustainable Energy Options for Austin Energy. A Report by the Policy Research Project on Electrical Utility Systems and Sustainability. Lyndon B. Johnson School of Policy Research Report Number [XXX].

³³ Introduction to Photovoltaic Systems: SECO Fact Sheet No. 11.

enough energy. They can also export excess electricity back to their local utility when their PV system is generating more than they need.³⁴

Cost: Although PV systems often remain more expensive than other electricity providers, they can be the least expensive, most viable option when applications are located away from existing power lines and require larger amounts of electricity. In Texas, it can cost a consumer anywhere from \$5,000 to \$30,000 per mile to extend power lines.

A PV systems connected to the grid will require a utility interactive DC to AC inverter, which will convert the direct current (DC) electricity produced by the PV array into alternating current (AC) electricity, which is often used by radios, televisions, and refrigerators.³⁵

PV systems are designed with and without battery backup. As mentioned earlier, solar energy is intermittent. Without battery backup, PV systems only provide electricity while the sun is shining on the solar array. At night or when it is cloudy, it will no longer provide electricity. If a household is not connected to the grid or wants to continually use solar energy, it may be necessary to purchase this battery. However, if a household is using the PV system to pump water, a battery backup may not be necessary since water can be pumped and stored when there is sun.

The exact cost of a PV system will vary based on various factors. A PV system often requires the purchase of much more than just the PV modules. Some factors that can determine the cost of a PV system include load size, available sunlight, PV array size, battery bank size, and whether or not an inverter is needed. An additional 20% should be added onto this cost in order to account for wires, switched, fuses, connectors, and other miscellaneous parts. Most small PV array systems (150-8,000 watts) cost about \$5 per watt. If a battery bank is needed, it can be purchased for under \$1 per amp-hour. Inverters should provide for 125% of the maximum load that will be run simultaneously. Inverters for residences and other small systems cost around \$1 per rated watt.³⁶

The cost of solar panels also seems to be decreasing with technological advances in plastic solar cells, nanotechnologies, and dye-sensitive solar cells. Nanosolar and Heliovolt are two leaders in solar technology development who are working on PV panels that would be lower in cost and higher in performance. Innovations include thin-film and higher current panels.³⁷

Externalities: In terms of environmental effects, PV systems do not produce significant greenhouse gases during operation. However, greenhouse gases are used in their production. Decommissioned PV systems also have highly toxic e-waste components.³⁸

³⁴ Introduction to Photovoltaic Systems: SECO Fact Sheet No. 11.

³⁵ Ibid.

³⁶ Estimating PV Size and Cost: SECO Fact Sheet No. 24.

³⁷ Moore, S. (2008). Topics in Sustainable Development. The University of Texas Center for Sustainable Development. Pp. 134.

³⁸ Eaton, D. (2009). Sustainable Energy Options for Austin Energy. A Report by the Policy Research Project on Electrical Utility Systems and Sustainability. Lyndon B. Johnson School of Policy Research Report Number [XXX].

Feasibility: In implementing these technologies, several rules and guidelines may restrict possible applications. For example, those residents served by Austin Energy and several other utilities are not allowed to have electrical facilities that cross property lines.³⁹ This regulation is particularly problematic for low-income residents because solar panels are usually fairly expensive and out of their price-range. Sharing the electricity produced by them could make them more affordable.

Solar Water Heating

Explanation: There are two types of solar water heating systems, passive and active systems. Passive systems do not require any external energy sources other than the sun itself. Passive solar water heaters are often more appropriate for places that rarely have freezing temperatures. The four types of thermal collectors are swimming pool absorbers, flat plate collectors, and parabolic concentrating collectors.⁴⁰

More common are active systems, which are more efficient but which rely on other equipment such as collectors, sensors, pumps, and controllers. Active solar thermal heaters are also the only ones recognized by Austin Energy for their rebate program.⁴¹ There are two types of active systems, direct- and indirect-circulation systems. Direct systems heat the household water in the collector.⁴² These systems use pumps to circulate pressurized water directly through the collectors and are appropriate for places that do not freeze for long periods.⁴³ Indirect-circulation systems do not directly heat the water. The household water in indirect systems is instead heated by pumping heat-transfer fluids through collectors. Fluids such as antifreeze, drainback systems, Freon, distilled water or propylene glycol are used. Direct systems are more efficient but require more maintenance and could develop problems such as scaling.⁴⁴

The EIA categorized solar thermal energy collectors as low-, medium, and high-temperature. In the U.S., low temperature collectors are mainly used to heat swimming pools or to heat and cool homes. Medium temperature collectors are mainly used for cooking.

Cost: According to NREL, the average capital costs of domestic hot water heating systems in 2000 were \$1,900 to \$2,500 per system. The yearly operating and maintenance cost of domestic hot-water heaters ranged from \$25 to \$30 per system.⁴⁵

Solar water heaters range in price from \$800-\$3500+ and can reduce water-heating bills by 50-80%. Conventional water heaters cost approximately \$1,000 when installed. Most solar water heating systems are composed of a solar collector and storage tank. Both solar collectors and

³⁹ Moore, S. (2008). Topics in Sustainable Development. The University of Texas Center for Sustainable Development. Pp. 130.

⁴⁰ Eaton, D. (2009). Sustainable Energy Options for Austin Energy. A Report by the Policy Research Project on Electrical Utility Systems and Sustainability. Lyndon B. Johnson School of Policy Research Report Number [XXX].

⁴¹ Moore, S. (2008). Topics in Sustainable Development. The University of Texas Center for Sustainable Development. Pp. 129.

⁴² Solar Water Heaters Fact Sheet: SECO Fact Sheet No. 10.

⁴³ Eaton, D. (2009). Sustainable Energy Options for Austin Energy. A Report by the Policy Research Project on Electrical Utility Systems and Sustainability. Lyndon B. Johnson School of Policy Research Report Number [XXX].

⁴⁴ Solar Water Heaters Fact Sheet: SECO Fact Sheet No. 10..

⁴⁵ Eaton, D. (2009). Sustainable Energy Options for Austin Energy. A Report by the Policy Research Project on Electrical Utility Systems and Sustainability. Lyndon B. Johnson School of Policy Research Report Number [XXX].

water storage tanks will need to be purchased.⁴⁶ An 80-gallon storage tank, which is the most common, is usually sufficient for three to four people.

Low-income residents may not initially have the money to purchase a water heater. Therefore it may be advisable to pre-pipe homes to allow for later installation. Homes that have not been pre-piped may face additional charges when installing solar water heaters at later times.

Feasibility: Of all renewable energy technologies, solar water heating is the most accessible to low-income households. However, some type of financial assistance (loans, programs, etc) may still be needed.

ENERGY USAGE

Costs and environmental effects are closely related to the amount of energy consumed. Therefore, this section aims to give some background on average usage.

On average, Texan households use approximately 1,100 kilowatt-hours (kWh) of electricity per month. This is equal to approximately 36,000 Wh of electricity per day. Designing homes to be energy efficient can lower this usage to as little as 6,000-10,000 Wh per day. The following table shows the amount of energy used by various appliances:

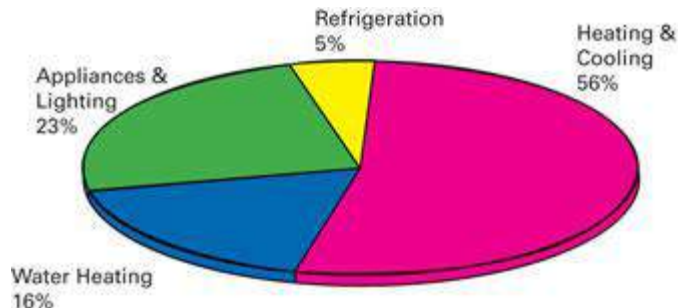
Appliance	AC or DC Watts		Hours Used/Day		Watt Hours/Day
Ceiling Fan	100	x	8.0	=	800
Coffee Maker	600	x	0.3	=	180
Clothes Dryer	4,856	x	0.8	=	3,885
Computer	75	x	2.0	=	150
Computer Monitor	150	x	2.0	=	300
Dishwasher	1,200	x	0.5	=	600
Lights, 4 Compact Fluorescents	4x15	x	5.0	=	300
Microwave Oven	1,300	x	0.5	=	650
Radio	80	x	4.0	=	320
Refrigerator	600	x	9.0	=	5,400
Television	300	x	8.0	=	2,400
Vacuum Cleaner	600	x	0.2	=	120
VCR	25	x	8.0	=	200
Washing Machine	375	x	0.5	=	188
Total					15,493

Table 1 *Typical household electrical appliances and run times*

(Estimating PV Size and Cost: SECO Fact Sheet No. 24)

⁴⁶ Solar Water Heaters Fact Sheet: SECO Fact Sheet No. 10..

The following pie chart also depicts the national average energy consumption patterns:



(Bluebonnet Electric Cooperative)

UTILITIES IN CENTRAL TEXAS

The price that homeowners pay for energy is largely determined by the prices that utility providers in the area charge. Whether or not renewable energy is available and the price of that renewable energy is also determined by the utility provider. Costs of two utility providers in Central Texas are discussed below:

Austin Energy Prices

Through its Green Choice Program, Austin Energy has offered customers a rate that is somewhat higher than traditional energy rates. However, customers have been able to lock into these rates for several years. Customers essentially choose to sign a contract and get their energy from a particular wind farm for 10 years. They receive 100% renewable energy.

This program has been highly successful and popular. Austin Energy currently sells more renewable energy through its Green Choice program than any other utility in the United States. The renewable energy has often been sold out. The fixed cost has been used to hedge against rising natural gas prices. From 2000, the natural gas prices had in fact risen. They have, however, declined somewhat recently. The rate of this wind energy has also recently spiked to more than 50 percent higher than that of standard electricity generated by fossil fuels. According to the Statesman, the monthly summer bill of an average Austin homeowner would increase from \$93.35 to \$151.85 with a new subscription to GreenChoice .⁴⁷

Because Austin Energy has recently seen dramatic cost increases in this renewable energy, it is consequently having trouble selling this energy. The latest batch of green power is selling at rates almost 80% higher than the previous batch. Prices of several types of energy seem to be

⁴⁷ Toohey, M. (2009, July 17). "All Austinites may soon shoulder extra green energy costs to meet ambitious renewable energy goals, city must find a way to pay for them." *The Austin American Statesman*.

increasing, and the base rate of energy provided by Austin Energy will increase in 2012 for the first time in 15 years.⁴⁸

Electricity is sold by Austin Energy based on two charges, one to cover distribution costs and the other to cover fuel costs. The charge to cover distribution costs is applied to all customers but varies for residential, commercial, and industrial customers. Residential customers during the summer are charged a base charge of 3.55 cents per kWh for the first 500 kWh consumed in a month and then 7.82 cents per kWh for each kWh over 500.

Bluebonnet

Bluebonnet Electric Cooperative provides energy to 14 southeastern Texas counties from Travis County to Washington County and from Milam County down to Gonzales County. Guadalupe County is included within this service area.

For General Services (including residential uses), Bluebonnet had the following rates as of February 2010: \$ 0.072674 per kWh for a wholesale charge, \$ 0.023948 per kWh for a distribution charge, \$22.50 per month for a membership charge.

Additionally, Bluebonnet has a renewable energy program. For every member who signs up for the Green Energy Rate, Bluebonnet will purchase the amount of energy those members use from a renewable energy source. Bluebonnet charges these customers an additional \$0.005 per kWh than the regular rate. This means that a member who uses 1,000 kWh of electricity per month would pay an additional \$5. The source for this renewable energy is wind power produced at the Indian Mesa and Delaware Mountain wind farms outside of Fort Stockton, Texas.

⁴⁸ Meehan, C. (2009, November 12). "Austin Energy Contemplates Costs, Considers Customers" *The Austin American Statesman*.

APPENDIX A9: HOUSEHOLD WATER CONSERVATION PRACTICES

The following household water conservation practices are based on suggestions from:

EarthEasy.com, "25 Ways to Conserve Water in the Home or Yard,"⁴⁹

Squidoo.com, "Home energy savings tips,"⁵⁰ and

Wateruseitwisely.com, "100 Ways to Conserve Water."⁵¹

General

- Insulate water using pre-slit foam pipe insulation. This will help you get hot water faster and avoid wasting water while it heats up.
- Monitor your water bill for unusually high use in order to discover leaks promptly.
- Install low flow sink aerators. They are inexpensive (as little as \$5) and can save up to 75% of the water that comes out of your sink. They are one of the most effective ways to save water in the home.

Toilet

- Use plastic bottles or a float booster to turn your toilet into a low flush toilet. Place two inches of sand or stones inside a plastic water bottle and close them securely. Put them inside the toilet tank away from the operating mechanisms and make sure 3 gallons of water remain in the tank.
- Install an adjustable toilet flapper and adjust it to get the lowest yet still effective flush.
- Put food coloring in your toilet tank, if it enters into the toilet bowl this indicates a leak. Fixing the leak could save up to 1,000 gallons a month.
- Use a garbage bin rather than the toilet as a receptacle for tissues, saving unnecessary flushes.

Bathroom Sink

- Do not let the water run while washing your hands, shaving, washing your face, or brushing your teeth. Instead, fill the sink with warm water to rinse your razor and turn the water off while you lather your hands, etc.

Shower

- Keeping showers under 5 minutes can save up 1000 gallons of water a month.
- Use water-efficient showerheads and turn the water off while you lather or shave. If your shower can fill a one-gallon bucket in less than 20 seconds, you do not have a water-efficient showerhead.
- Keep a bucket in the shower to catch water as it warms up or runs. (Use this water to flush toilets or water plants.)

Laundry

- Reuse towels to save a load of laundry

⁴⁹ http://www.eartheasy.com/live_water_saving.htm

⁵⁰ <http://www.squidoo.com/SavingEnergyTips>

⁵¹ <http://www.wateruseitwisely.com/100-ways-to- conserve/index.php>

Kitchen Sink

- Install an instant water heater on your kitchen sink so you don't have to let the water run while it heats up. (This will also reduce heating costs for your household.)
- Use sink garbage disposal units sparingly. They require large amounts of water to operate properly and add to the volume of solids in a septic tank. Instead, compost organic waste in a compost pile.
- Wash vegetables in a bowl of water rather than keeping the sink running. Then use the water to water plants.
- Don't use running water to thaw food.

Fridge

- Store drinking water in fridge rather than running the tap.

Dishwasher

- Run your washing machine and dishwasher only when they are full and save up to 1000 gallons a month.

Lawn

- Increase absorption by layering organic mulch around plants and watering for shorter periods of time. Decrease evaporation by watering small patches by hand and by watering in the morning or evening with the temperature is cooler and there is less wind. Adjusting watering frequency to the season can also save a great deal of money. (Water your summer lawns once every three days and your winter lawn once every five days.)
- Don't overwater - Use a screwdriver as a soil probe to test soil moisture. If it goes in easily, don't water.
- Adjust your lawn mower to a higher setting. Taller grass maintains moisture and protects roots from excess sun exposure.
- Use porous materials for walkways and patios to keep water in your yard and prevent wasteful runoff.

Other

- Use commercial car washes, which recycle water. If you wash your car at home fill up several buckets of water rather than leaving the hose running and wash your car on the grass. This will water your lawn at the same time.
- Bathe your pets outdoors in an area in need of water.
- When cleaning out fish tanks, give the nutrient-rich water to your plants.
- Designate one glass for your drinking water each day or refill a water bottle, cutting down the number of dishes to wash.
- Know where your master water shut-off valve is located. Quickly stopping leaks saves water and prevents damage to your home.

APPENDIX A10: HARVESTING RAINWATER

Rainwater can be stored and harvested in numerous ways. Here in the United States, harvested rainwater is not advisable for drinking, but it can be disinfected or filtered for other uses. In developing countries harvested water is used for drinking.

Gutters: The most basic and commonly used method of harvesting is a gutter on the roof to direct rainwater to a specific location. Roofs do not have to be treated or cleaned when water is collected for irrigation of land. Installing a gutter can cost between \$4-\$20 per foot.⁵²

First-flush Devices: First-flush devices increase the quality of harvested rainwater by disposing of the first several gallons of water, which often contain debris and impurities.

A first-flush device prevents this initial flow from draining into the storage tank. Many first-flush devices have a simple design. Such devices include tipping buckets that dump when water reaches a certain level. In addition, there are containers with a ball that floats with the rising water to close off an opening after an inflow of 5 gallons.⁵³

Rain harvesting and hot water heater: One technology company implemented a rain harvesting initiative in an Arizona Colonia. The project used harvested roof rainwater and routed it into a storage container. The water was then heated by solar panels to provide the community with accessible hot water.⁵⁴ A website with more case examples of rain harvesting in low-income communities can be found at:

<http://www.eng.warwick.ac.uk/ircsa/factsheets/lowincome.htm>.



⁵² <http://www.ext.colostate.edu/pubs/natres/06702.htm>, http://www.essortment.com/home/installinggutte_sbzu.htm

⁵³ <http://www.ext.colostate.edu/pubs/natres/06702.html>

⁵⁴ <http://tfssolar.com/2112/colonia-allegre-residence/>

Table 6-1. Storage Tank

	Cost	Size	Comments
Fiberglass	\$0.50–2.00/gallon	500–20,000 gallons	Can last for decades w/out deterioration; easily repaired; can be painted
Concrete	\$0.30–1.25/gallon	Usually 10,000 gallons or more	Risks of cracks and leaks but these are easily repaired; immobile; smell and taste of water sometimes affected but the tank can be retrofitted with a plastic liner
Metal	\$0.50–1.50/gallon	150–2,500 gallons	Lightweight and easily transported; rusting and leaching of zinc can pose a problem but this can be mitigated with a potable-approved liner
Polypropylene	\$0.35–1.00/gallon	300–10,000 gallons	Durable and lightweight; black tanks result in warmer water if tank is exposed to sunlight; clear/translucent tanks foster algae growth
Wood	\$2.00/gallon	700–50,000 gallons	Esthetically pleasing, sometimes preferable in public areas and residential neighborhoods
Polyethylene	\$0.74–1.67/gallon	300–5,000 gallons	
Welded Steel	\$0.80–\$4.00/gallon	30,000–1 million gallons	
Rain Barrel	\$100	55–100 gallons	Avoid barrels that contain toxic materials; add screens for mosquitoes

⁵⁵ http://www.twdb.state.tx.us/publications/reports/RainwaterHarvestingManual_3rdedition.pdf

Table 6-2. Gutters

	Cost	Comments
Vinyl	\$.30/foot	Easy to install and attach to PVC trunk lines
Plastic	\$.30/foot	Leaking, warping and breaking are common problems
Aluminum	\$3.50-6.25/foot	Must be professionally installed
Galvalume	\$9-12/foot	Mixture of aluminum and galvanized steel; must be professionally installed

Table 6-4. Pumps and Pressure Tanks

	Cost	Comments
Grundfos MQ Water Supply System	\$385-600	Does not require a separate pressure tank
Shallow Well Jet Pump or Multi-Stage Centrifugal Pump	\$300-600	These require a separate pressure tank
Pressure Tank	\$200-500	Galvanized tanks are cheaper than bladder tanks but often become waterlogged, and this will wear out the pump more rapidly

Table 6-5. Filtering/Disinfection

	Cost	Maintenance	Effectiveness	Comments
Cartridge Filter	\$20-60	Filter must be changed regularly	Removes particles >3 microns	A disinfection treatment is also recommended
Reverse Osmosis Filter	\$400-1500	Change filter when clogged (depends on the turbidity)	Removes particles >0.001 microns	A disinfection treatment is also recommended
UV Light Disinfection	\$350-1000; \$80 to replace UV bulb	Change UV bulb every 10,000 hours or 14 months; the protective cover must be cleaned regularly	Disinfects filtered water provided there are <1,000 coliforms per 100 milliliter	Water must be filtered prior to exposure for maximum effectiveness
Ozone Disinfection	\$700-2600	Effectiveness must be monitored with frequent testing or an in-line monitor (\$1,200 or more)	Less effective in high turbidity, can be improved with pre-filtering	Requires a pump to circulate the ozone molecules
Chlorine Disinfection	\$1/month manual dose or a \$600-\$3000 automatic self-dosing system	Monthly dose applied manually	High turbidity requires a higher concentration or prolonged exposure but this can be mitigated by pre-filtering	Excessive chlorination may be linked to negative health impacts.

APPENDIX A11: GREYWATER SYSTEMS

Definition

Greywater is the wastewater produced from baths and showers, and washing machines. The wastewater from toilets, kitchen sinks, and dishwashers is called blackwater.⁵⁶ A brief overview is provided here:

Greywater is of lesser quality than tap water, but generally of higher quality than blackwater. The most obvious advantage of domestic greywater use is that it may potentially replace other water used for landscape irrigation, although many interests are now advocating the use of gray water for toilet flushing. Greywater systems vary from simple, low-cost systems to highly complex and costly systems. A common (but illegal in Colorado and most other states) method for reusing greywater is to drain the washing machine directly onto outside vegetation. Sophisticated systems treat greywater prior to disposal using settling tanks and sand filters in order to remove solids and pathogens.⁵⁷

Reuse of Greywater

Greywater can be reused in various ways depending on the level of treatment. Low-tech, low-cost treatments allow greywater to be used for agricultural purposes only. Higher-tech, higher cost treatments allow water to be reused for toilets, laundry machines, and cooling systems. Greywater cannot be used for drinking.⁵⁸

Internal Household Reuse: Toilet flushing, laundry machines, cooling systems

In individual households grey water usually accounts for 50 – 80% of the water used, by reusing greywater you can considerably adjust the amount of water you consume monthly.

Toilet Flushing: To use greywater to flush toilets the system has to have separate piping so that black and greywater do not mix. Furthermore greywater can only be used for flushing toilets; using it in the bowl can cause the grey/black water to mix and could cause the entire sewer system to malfunction.⁵⁹ Something to consider is that when building a new house, installing toilets with separate blackwater and greywater draining is cheap. Yet, to replace systems can be very expensive, and an efficient flushing handle can be effective way of limiting the amount of water used.⁶⁰

Laundry Machines: Reusing greywater for washing laundry could be as simple as rerunning a load with *gently* used water. More complex filtering systems can allow greywater to be filtered and then rerouted to the laundry machines. In general when you are reusing greywater you should not use laundry softener and should not wash diapers.⁶¹

Cooling systems: Through low-costing systems greywater can be rerouted back into the house and used in cooling and heating systems. Cheap, purple, tubing can be used to filter back into

⁵⁶ <http://greywater.sustainablesources.com/#Define>

⁵⁷ <http://www.ext.colostate.edu/pubs/natres/06702.html>

⁵⁸ <http://www.howstuffworks.com/gray-water-reclamation.htm/printable>

⁵⁹ http://aces.nmsu.edu/pubs/_m/m-106.html

⁶⁰ <http://www.greeniacs.com/GreeniacsGuides/Reuse-Your-Grey-Water.html>

⁶¹ http://aces.nmsu.edu/pubs/_m/m-106.html

cooling systems. Purple tubing is used to distinguish that water is grey and being rerouted.⁶²

External Household Reuse: Irrigation systems

The main use for greywater outside of your house is for irrigation systems for lawns, trees, and gardens. Implementing greywater systems for external use can be little to no cost. Technology ranges from putting a filter, or cloth, over a drain running directly into the lawn to advanced underground filtering systems.

Types of plants on which greywater can be used: Online there are lists of plants that can and cannot adapt to greywater. Greywater is alkaline, a base, and thus cannot be used on plants that thrive in acidic soil. In general, greywater should not be used in a sprinkling system but rather routed to an underground system. It is advisable that new plants are not treated with greywater. There are mixed sources on whether or not greywater can be used on crops. If in fact a family was to eat root crops or any crops that grew with greywater they should always cook the food first. Also, certain chemicals, such as fabric softener, should be avoided; it is important to use eco-friendly brands of shampoos and soaps to make greywater less toxic. Overall, greywater encourages plant growth and allows residents to afford landscaping, lawns, gardens, and large shady trees.⁶³

Fire protection: communities susceptible to dry grass and brush fires, greywater can be used to accelerate the growth of a “greenbelt” around homes to break fires. Greywater is “ideal” for supplying nutrients to plants that retain high levels of water.⁶⁴

Community reuse: Most greywater is reused at an individual level for outside irrigation. Some communities have tried community-wide reuse systems. These systems overall take more maintenance and are more expensive to install.

Lagoons or ponds: With the proper expertise and construction, communities can drain greywater into a holding pond. The pond/lagoon will begin to rapidly grow algae, which can be collected to feed fish held in a separate pond or provide food for waterfowl. The of the algae is imperative to keep the pond odor-free.⁶⁵

Benefits of Reusing Grey Water

Cost Effective: Individual households will reap the benefits of savings by lowering the amount of water they use monthly. Grey water accounts for at least half of water used by a household; thus families should be able to cut their water bill in at least half. Furthermore, many states, counties, and cities offer tax benefits, subsidies, and grants for installing greywater systems. This aid can both offset the cost of installing a system and also allow residents to pay substantially subsidized water bills. Greywater also “greatly extends the useful life and capacity of septic systems. For municipal treatment systems, decreased wastewater flow means higher treatment effectiveness and lower costs.”⁶⁶

⁶² <http://www.ebuild.com/articles/989781.hwx>

http://aces.nmsu.edu/pubs/_m/m-106.html

⁶³ <http://www.greeniacs.com/GreeniacsGuides/Reuse-Your-Grey-Water.html>

⁶⁴ http://aces.nmsu.edu/pubs/_m/m-106.html

⁶⁵ *Ibid.*

⁶⁶ <http://greywater.sustainablesources.com/#Define> <http://www.greeniacs.com/GreeniacsGuides/Reuse-Your-Grey-Water.html>

<http://www.greywater.net>

Increased water access - Obviously, using greywater saves water, but it also allows an increase of supply to communities. Low-income communities that could not afford access to water for irrigation may be able to through the reuse of greywater.⁶⁷

Benefits to plants and land: Additional benefits to the land include the following:

Grey water may contain detergents with nitrogen and phosphate and can be beneficial to your plants. In addition, if you use a subsurface irrigation system (required in California), it forces plant roots to reach downward to obtain water making them stronger. For those of you in areas prone to droughts, the availability of grey water can be a lifesaver for your plants.⁶⁸

Loss of nutrients through wastewater disposal in rivers or oceans is a subtle, but highly significant form of erosion. Reclaiming nutrients in greywater helps to maintain the fertility of the land.⁶⁹

Factors in Installing a Greywater System

Cost: The cost of implementing greywater systems greatly ranges from small budget do-it-yourself projects, to more than \$1000. Lower technology and individual home solutions are cheaper than community-wide projects.⁷⁰

Untreated greywater systems: Publications from New Mexico State University suggest the following: "Untreated greywater should not be kept for longer than one day, but adding two tablespoons of chlorine bleach per gallon of water will extend storage time somewhat. Try to use greywater the day it is collected or the high bacteria count will cause objectionable odors." Greywater from dishwashing machines or with fats/ oils is not acceptable for use.⁷¹

Policy

Individuals and communities should check local laws before they implement a water conservation system. Austin's Health Department makes the decisions on the use of greywater, and has set a standard that it can be used for root zone irrigation but not above ground spraying. Policies like this range depending on city and state.⁷²

Texas Gray Water Law: Rule 285.81-Texas Administrative Code, 2001- Summary: permits are not required for domestic greywater systems that use less than 400 gallons per day, and follow the requirements listed in the rule.⁷³

⁶⁷ <http://www.greywater.net/>

⁶⁸ <http://www.greeniacs.com/GreeniacsGuides/Reuse-Your-Grey-Water.html>

⁶⁹ <http://www.greywater.net>

⁷⁰ http://aces.nmsu.edu/pubs/_m/m-106.html

⁷¹ *Ibid.*

⁷² <http://greywater.sustainablesources.com/#Define>

⁷³ <http://info.sos.state.tx.us/>

APPENDIX A12: INNOVATIVE TOILET TECHNOLOGIES

There are countless options for conservation and filtration of water. Low-tech and inexpensive alternatives are out there and include using buckets to heat up bath water, hand pumps to tap into ground water, and countless other low-cost individual solutions. Some of the more interesting, innovative, and sustainable methods are found below. It is important to note though, that the following are considered more technologically complex, costlier, or may need to be implemented at a community level.

Toilets

Toilets use more water than any other appliance in a household. Families can conserve water and save money by switching to more efficient options. We list some of these options here along with their cost, advantages and disadvantages.

High Efficiency Toilets (HETs)

U.S. laws make sure that all new toilets do not use more than 1.6 gallons per flush. HETs only use anywhere from 1.1 - 1.28 gallons per flush. Due to new technology HETs usually are more efficient and even flush better than normal toilets, thus installing one is beneficial on many levels.

Cost: The savings in water usage from installing an HET can be upward of \$2,000 for the toilet's lifespan. The cost of an HET is often less than \$130. In addition WaterSense, an EPA program, offers subsidies and grants to offset the costs, especially for low-income families. The City of Austin, Texas, maintains a list of 1.28-gallon high efficiency toilets that are approved for rebate at <http://www.ci.austin.tx.us/watercon/toiletrebate.htm>.⁷⁴

Dual Flush Toilets

Like HETs, dual flush toilets are an easy, fairly low-cost, long-term investment for lowering the amount of water a family uses. A dual flush toilet has two separate buttons, or a handle that can be pushed either up or down. The resident chooses the amount of water needed to flush the toilet depending on the type of waste. A short flush only uses 0.8 gallons per flush, and a long flush uses 1.6 gallons per flush. Dual Toilets are installed just as easily as a regular toilet and on average save a family 67% of its normal water usage. These can be found at Sam's club for \$99 or at Walmart for around \$110.⁷⁵

⁷⁴ <http://high efficiencytoilets.org/>

⁷⁵ <http://www.dualflushtoilets.net/>



Example of a dual flush toilet

Source: <http://www.furniturehomedesign.com/eco-design/what-is-a-dual-flush-toilet/>

Composting Toilets General

Composting toilets use microorganisms to break down waste. They greatly reduce the water consumption of the toilet. Here we quote liberally from the National Environmental Services Center (NESC) quarterly report on composting toilets:

Advantages of composting toilets: “Reduced water consumption, Reduced quantity and strength of wastewater to be disposed of on- site, Well suited for new construction at remote sites, Low power consumption, Elimination of need to transport wastes for treatment/disposal, Nutrient-rich end product, Potential reduction in size of septic system to handle other wastes”⁷⁶

Disadvantages of composting toilets include: “Maintenance requires commitment from owner/user, Improperly installed or maintained systems may produce odors or an unprocessed end product that may have possible health consequences, Too much liquid (leachate) in the reactor can disrupt the composting process if not drained or maintained properly, Removal of end product may be unpleasant if unit is not functioning properly, Does not eliminate the need for a septic system in many cases to treat other wastes, Some units require a power source for heat and/or ventilation, Aesthetics may be a concern since the excrement in some units may be in sight of the user”⁷⁷

How they work: “The main components of a composting toilet include: a composting reactor connected to a dry or micro flush toilet, a screened air inlet and exhaust system, a means to drain/manage excess liquid, a mechanism to provide necessary ventilation to support the aerobic organisms in the reactor, a heating system to warm the temperature within the reactor if necessary, and access to remove the end product periodically. In cold climates, composting toilets should be well insulated and heated to levels specified by the manufacturer or

⁷⁶ http://www.nesc.wvu.edu/nsfc/Articles/SFQ/SFQ_su04_PDF/QA_su04.pdf

⁷⁷ Ibid.

designer.”⁷⁸

Factors: “Several factors affect the rate of composting and the overall performance of a composting toilet. They include: temperature, moisture, pH, carbon to nitrogen ration (C/N), aeration, microorganism population, time, and maintenance.”⁷⁹

Maintenance: “Composting toilets require regular operation and maintenance; thus a serious commitment on the owner and/or user of the composting system is necessary. Once the liquid or leachate has been removed from the system, either by draining or evaporation, the aerobic organisms decompose the solids. Bulking agents such as grass clippings, leaves, sawdust, or finely chopped straw can be added to provide spaces for aeration and an adequate carbon food source for microbial growth. Periodic turning or mixing of the compost is required, and for some units, this is automated so that the owner or user does not have to perform this task. For other units, it will be the responsibility of the owner or user. The finished end product, the humus, must be removed periodically. Time frames for removal will vary with each unit. The humus should be inoffensive and safe to handle. Handling and disposal or reuse of the humus should follow in accordance with local and state regulations.”⁸⁰

Operation: “Handling raw waste has historically been a problem from a management standpoint. Removing vault or pit type waste has led to accidental spills and is always a difficult task. This is why managers appreciate the concept of composting human waste ... Management considerations for composting toilets include gathering information on how much maintenance is needed annually, administration and operation, quality control and assurance, record-keeping, and training. Waste, aeration, and other features of the system. The main factors that determine costs are the cost of the equipment, the building foundation, electrical work, and installation labor.”⁸¹

Cost: “For a year-round home of two adults and two children, the cost for a composting toilet system could range anywhere between \$1,200 and \$6,000, depending on the system. Cottage systems designed for seasonal use range from \$700 to \$1,500. Large-capacity systems for public facility use can cost as much as \$20,000 or more. However, site-built systems, such as cinder-block double-vault systems are as expensive as their materials and construction labor costs. A septic tank and soil absorption or subsurface irrigation system to manage greywater will usually be required.”⁸²

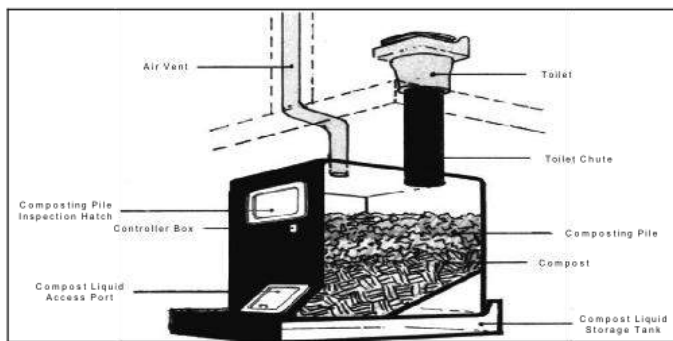
⁷⁸ Ibid.

⁷⁹ Ibid.

⁸⁰ Ibid.

⁸¹ Ibid.

⁸² Ibid.



Source: Adapted from Clivus Multrum, Inc., 1994.

FIGURE 1 COMPOSTING TOILET

Example of a composting toilet

Source: <http://www.epa.gov/OW-OWM.html/mtb/comp.pdf>

Solar Assisted Composting Toilet (SIRDO - Sistema Integral de Reciclamiento de Desechos Orgánicos)

This is a dry-composting toilet, which has been used in Naucalpan, Mexico and Ciudad Juarez, Mexico. The toilet is a “single-vault, self-contained, fiberglass and plastic structure[s] that stand separate or connected to the home and serve usually a single family [sized 4 to 5 members]”. This toilet requires no water and very little space (unlike septic fields) and is intended for areas, which are not connected to sewer lines, and may currently be running on septic tanks. It works by using a two pile system, an additive and a passive solar heating to process waste.

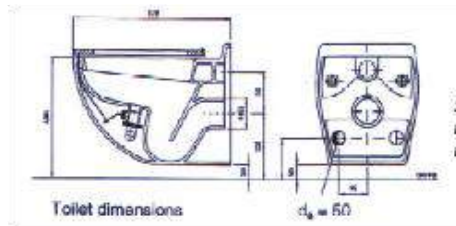
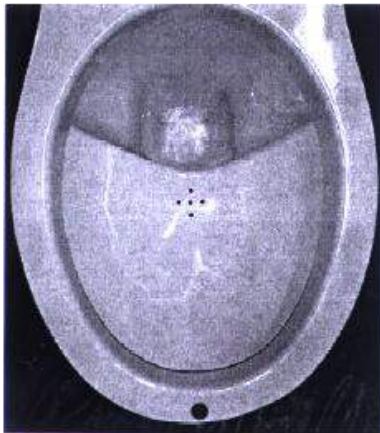
Cost: This technology is low-cost, around \$300 when implemented in Mexican communities. It also uses no water thus saving money. It has been highly accepted by communities and has left users very satisfied: “The main variables that users considered important were the absence of flies and odor. Compared to their previous system (pit latrines), the new systems had no odor and only a few flies.”⁸³

Composting Toilets: “No-Mix Toilets”

This toilet uses separate bowls for urine and feces by diverting the urine into a separate holding tank. The urine that is separated from no-mix toilets can be recycled into agricultural watering, but requires maintenance. This has been a widely accepted use in Europe and this system can “remove 30-50% of phosphorus from waste stream.”⁸⁴

⁸³ http://www.seco.cpa.state.tx.us/zzz_re/re_colonias-report.pdf

⁸⁴ <http://www.hudsonwatershed.org/sustainablewatershed/pdfs/etnier.pdf>



Example of a “no-mix” toilet

Source: <http://www.ccb.se/documents/Marketsurveylow-flushtoilets.pdf>

Microflush Toilets

This toilet uses very small amounts of water coupled with air. It usually hooks up to a holding tank, requires maintenance and can “divert up to 75% of phosphorus from waste stream.”⁸⁵

Water consumption: The toilet consumes $\frac{1}{2}$ gallon of water in a flush. The water volume for a standard flush can be set to less than this, or the volume can be increased by pressing the push button longer. The daily water flush volume per person with this toilet would be approximately 3 gallons.

Other consumption: “As with all vacuum operated sewage systems, electricity is consumed by the vacuum compressor. However, the energy consumption is small. The toilet’s flush pressure is created by means of a compressor as small as or smaller than the one in a refrigerator.”

Maintenance: “The toilet should be serviced every 3 years by installing an air and water valve rebuild kit. This can be accomplished by the owner if he/she is handy, otherwise a plumber is suggested.”

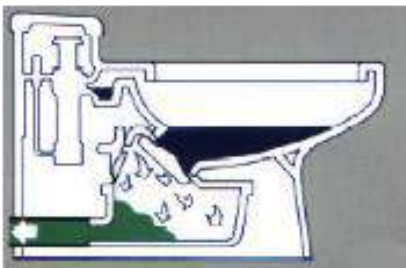
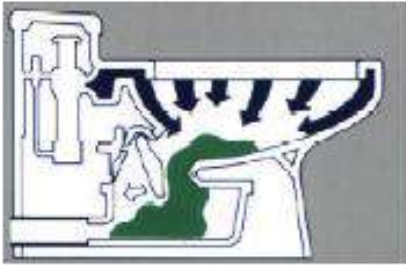
Price: “The toilets have primarily been sold to large installations, and no price to individual customers is available.”

Miscellaneous: “The toilet is mainly sold in a system suited for ships or trains, the “Microphor-system”, which is based on a compost tank where the toilet waste is composted before being let over board.”

Comments: “The water consumption of the Microflush- toilets is rather high, considering that

⁸⁵ <http://www.hudsonwatershed.org/sustainablewatershed/pdfs/etnier.pdf>

they are vacuum flushed. We have no information about the degree of treatment in the compost tank that the toilet often is sold together with. Price information for single toilets is not available as they are mainly sold in systems or to wholesalers.”⁸⁶



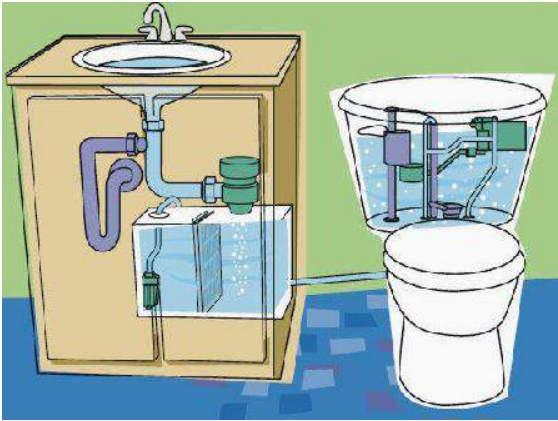
When the push button is pressed, the hatch is opened and the waste is flushed down. When the hatch is closed water continues filling up the bowl. The waste and water is then flushed away with vacuum.

Sinks

The Aquas: This filtering and holding tank uses water from the sink to flush the toilet. The system, which holds water from the sink and then diverts it into the tank of the toilet, cost \$200, but will pay itself off in savings in an average of 4 years, and will last 10-12 years. ⁸⁷

⁸⁶ <http://www.ccb.se/documents/Marketsurveylow-flushtoilets.pdf>

⁸⁷ http://www.treehugger.com/files/2006/10/watersaver_tech.php



Example of The Aqus

Source: http://www.treehugger.com/files/2006/10/watersaver_tech.php

Toilet Lid Sink: This easy installation piece allows sink water to be used to flush the toilet without any complicated filtering or altering. The toilet lid sink runs as low as \$89 and installs without tools or a plumber in just 10 minutes. Some benefits include: conserving water, auto on/off faucet, daily savings of up to 2 gallons per person, and savings to bills.⁸⁸



Example of a toilet lid sink

Source: <http://www.apartmenttherapy.com/ny/tubs-toilets-showers-sinks/toilet-lid-sink-007768>

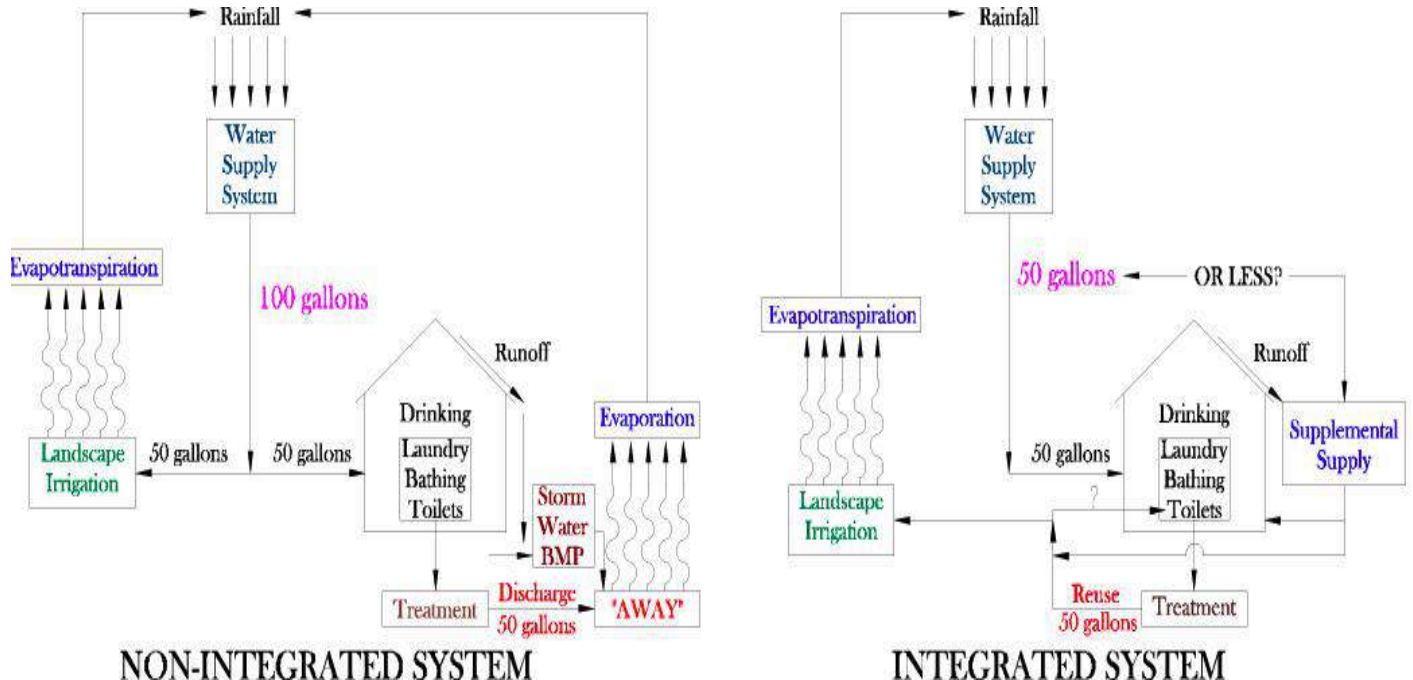
Note: *Do it yourself model can be found at [http://www.instructables.com/id/Hack-a-Toilet-for-free-water./](http://www.instructables.com/id/Hack-a-Toilet-for-free-water/)*

⁸⁸ <http://www.realgoods.com/product/home-outdoor/water-quality-conservation/shower-bath/toilet+lid+sink.do>

APPENDIX A13: WASTEWATER MANAGEMENT TECHNOLOGIES

Conventional decentralized wastewater systems consist of a septic tank and a drainage field. In addition to conventional methods this document examines information about alternative treatment and disposal. Where possible, technologies are examined as follow: operation, advantages, disadvantages, costs, alternatives, availability, and known laws and regulations. Before beginning it is worthwhile to note the following comments on sustainable wastewater management from Engineer/Planner David Venhuizen:

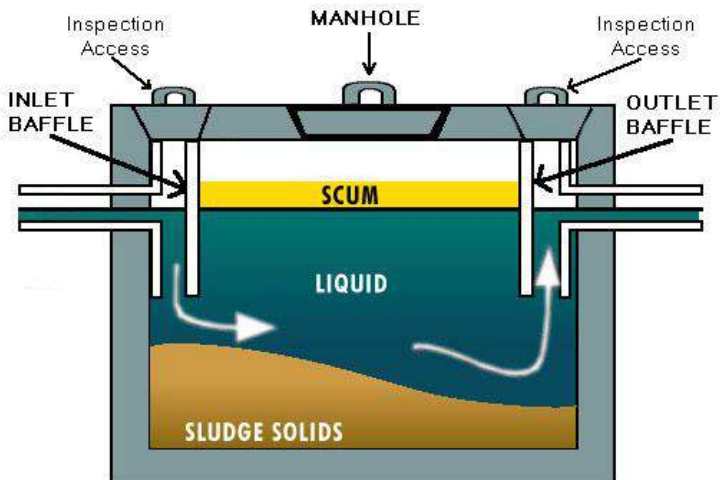
Sustainable water management strategies center on integrating the water supply, stormwater management and ‘waste’ water management functions. Our water resource exists within a closed system – called the hydrologic cycle – but traditional approaches used in residential and commercial developments “silo” the management of each of those functions into totally separate systems – water supply, stormwater, and wastewater. If we are to maximize the efficient and effective use of water, and so maximize sustainability of water resources, our management strategies must recognize that all water exists in the context of this closed system. We must therefore design our management approaches in accord with that understanding – as integrated systems, with the infrastructure that addresses each function being designed as an integrated component of an overall system. The simple schematic below compares a non-integrated – or ‘silo’d’ – system with an integrated management system, illustrating how husbanding of the water resource may be enhanced by “tightening” the water loops.⁸⁹



⁸⁹ Venhuizen, D. Small Diameter Effluent Sewerage Systems” <http://www.venhuizen-ww.com/>

Conventional Septic Tanks

How they work: Septic tanks remove solids they do not treat water: "Waste water flows from the house to the septic tank. The tank is designed to retain wastewater and allow heavy solids to settle to the bottom. These solids are partially decomposed by bacteria to form sludge. Grease and light particles float, forming a layer of scum on top of the wastewater. Baffles installed at the inlet and outlet of the tank to help prevent scum and solids from escaping."⁹⁰



Source: http://bandbpumping.com/photos/septic_tank.jpg

Advantages: Conventional septic systems are flexible; they can be made to various sizes. Minimum maintenance and minimum skills required for operation.⁹¹ There are many funding opportunities for conventional septic systems, some of which can be found through the EPA at the following link: http://cfpub.epa.gov/owm/septic/septic.cfm?page_id=272

Disadvantages: Conventional septic systems have low treatment efficiency, i.e. treating waste takes time. They must be pumped occasionally and require a landfill for the disposal of the sludge and septage they produce.⁹² They also require adequate space for the septic field and are thus not suitable for small lots.

⁹⁰ Miller, T. (2007) "Septic Systems and Their Maintenance" Maryland Cooperative Extension, University of Maryland <http://extension.umd.edu/environment/Water/files/septic.html>

⁹¹ Anderson, J., Axler, R., Christopherson, S., and Gustafson, D. (2001) "Constructed Wetlands" *Innovative Onsite Sewage Treatment Systems*. University of Minnesota, <http://septic.umn.edu/professionals/systemoptions/index.htm>
<http://www.extension.umn.edu/distribution/naturalresources/DD7671.html>

⁹² Wastewater Treatment Technology, International Environmental Technology Centre. (1997) *Source Book of Alternative Technologies for Freshwater Augmentation in Latin America and the Caribbean*. United Nations Environment Programme, <http://www.oas.org/OSDE/publications/Unit/oea59e/begin.htm#Contents>

Cost: Total: \$2,000 – \$12,000 (Tank \$500-\$1,800, depending on size; Piping etc. \$100-\$200; Permit \$250-\$1000; Replacement turf and plantings - \$100-\$1000⁹³

Variations: Most variation occurs in the second stage of treatment i.e. additions to or alterations of the drainfield system (more information in the coming sections).

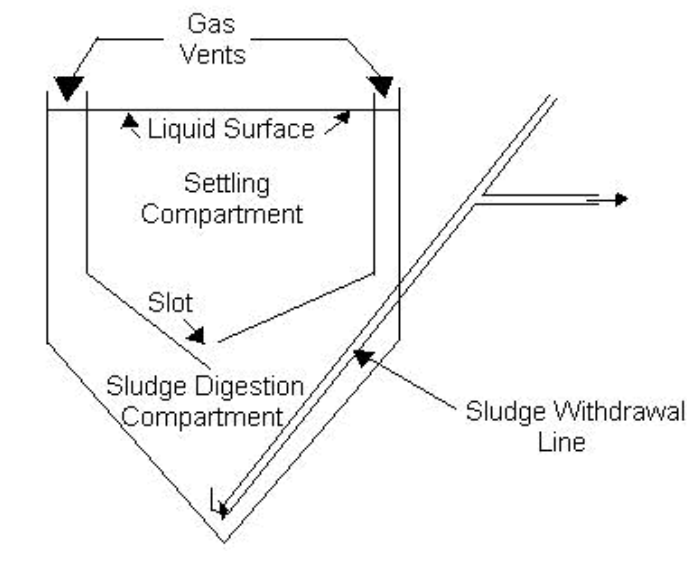
Availability: Septic tanks are widely available.

Known Laws and Regulations: Varies locally..

Imhoff Tanks

How they work: Imhoff tanks are not a treatment in themselves:

*Imhoff tanks are anaerobic sewage settling tanks. They are actually modification of the septic tank. Though it is differing from, septic tank in physical design and larger size, it functions in a similar way to that of septic tank. The tank is divided into two sections. The upper section acts as a settling tank. Digestion occurs in the lower section where conditions are more anaerobic. Gaseous products are removed by a gas pipe at the top. The settling compartment is separated from the digestion compartment. Solids move down into the digestion compartment but are prevented from being carried back up into the settling compartment. Stabilized solids are removed from the bottom of the tank.*⁹⁴



⁹³ Costhelper.com (2008) "Septic System Cost" Costhelper.com, <http://www.costhelper.com/cost/home-garden/septic-system.html>

⁹⁴ Microbiologyprocedure.com. "Imhoff Tank" <http://www.microbiologyprocedure.com/waste-water-microbiology/imhoff-tanks.htm>

Source: <http://water.me.vccs.edu/courses/ENV149/imageGQQ.gif>

Advantages:

- The Imhoff tank was developed to correct the two main defects of the septic tank:
- It prevents the solids once removed from the sewage from again being mixed with it, but still provides for the decomposition of these solids in the same unit.
- It provides an effluent amenable to further treatment. Best suited to small municipalities and large institutions where the tributary population is 5,000 or less, and a greater degree of treatment is not needed.
- No mechanical parts and is relatively easy and economical to operate⁹⁵
- Combine the advantages of both the septic and sedimentation tanks and, as such find use in case of small treatment plants requiring only preliminary treatment. They have better economy and give good results without skilled attention with minimum problems of sludge disposal⁹⁶

Disadvantages: Refer also to septic tank information above. In addition:

Greater depth means greater costs and especially where excavation is to be done in quick sands or solids rock, they become uneconomical. (ii) Unsuitable to acidic wastewater exists. (iii) There's no adequate control over their operation. This makes them unsuitable for use in large treatment plants where separate sludge digestion tanks are preferred.⁹⁷

Costs: Requires further research

Variations: Most variation occurs in the second stage of treatment i.e. additions to or alterations of the drainfield system. (More information in the coming sections.)

Availability: Requires further research

Known Laws and Regulations: Requires further research

Conventional Drainage Fields

How they work:

Drainfield (Trench): A solid pipe leads from the septic tank to a distribution box where the waste water is channeled into one or more perforated pipes set in trenches of gravel. Here the water slowly infiltrates (seeps) into the underlying soil. Dissolved wastes and bacteria in the water are trapped or adsorbed to soil particles or decomposed by microorganisms. This process removes disease-causing organisms, organic matter, and most nutrients

⁹⁵ Water/Wastewater Distance Learning Center. "Imhoff Tank" Water/Wastewater Distance Learning Center, <http://water.me.vccs.edu/courses/ENV149/Imhoffb.htm>

⁹⁶ Runion, R. "All You Need to Know About Removing Solids From Wastewater Using Imhoff Tanks." Ezinaarticles.com, <http://ezinaarticles.com/?All-You-Need-To-Know-About-Removing-Solids-From-Wastewater-Using-Imhoff-Tanks&id=691816>

⁹⁷ Water/Wastewater Distance Learning Center. "Imhoff Tank" Water/Wastewater Distance Learning Center, <http://water.me.vccs.edu/courses/ENV149/Imhoffb.htm>

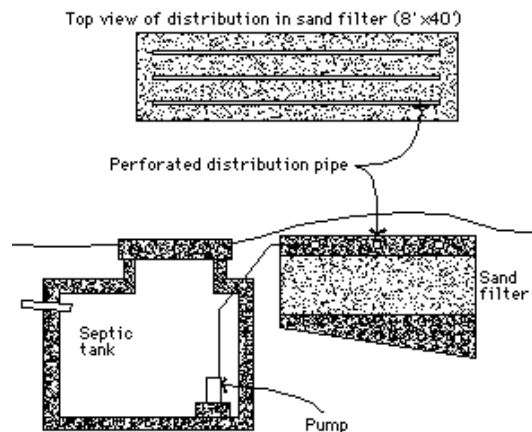
(except nitrogen and some salts). The purified wastewater then either moves to the ground water or evaporates from the soil.⁹⁸

Known laws and regulations: Requires further research

Sand Filters

How they work:

Pretreats septic tank effluent by filtering it through sand before sending it to a soil treatment system. Various sand filter types and designs have been extensively tested and used in the United States. Sewage flows from the house into one or several septic tanks, depending upon the size of the house and local requirements. Effluent from the septic tank(s) flows into a pump or lift tank. A pump introduces the effluent at the top of the watertight sand filter, using pressure distribution to apply the wastewater evenly to the filter surface to maximize treatment. A timer is used to dose the entire surface of the filter intermittently with wastewater. This draws oxygen from the atmosphere through the sand medium and its attached microbial community. The effluent is treated by physical, chemical, and biological processes. Suspended solids are removed by mechanical straining due to enhanced contact and sedimentation. Treatment occurs through the bacteria that colonize in the sand grains. Microorganisms use the organic matter and nutrients in the effluent for growth and reproduction.⁹⁹



⁹⁸ Anderson, J., Axler, R., Christopherson, S., and Gustafson, D. (2001) "Constructed Wetlands" *Innovative Onsite Sewage Treatment Systems*. University of Minnesota, <http://septic.umn.edu/professionals/systemoptions/index.htm>
<http://www.extension.umn.edu/distribution/naturalresources/DD7671.html>

⁹⁹ -- (2001) "Single Pass Sand Filters" *Innovative Onsite Sewage Treatment Systems*. University of Minnesota, <http://septic.umn.edu/professionals/systemoptions/index.htm>

Source: Anderson and Gustafson, 2001.

Advantages:

*Site flexibility is probably the biggest advantage of a sand filter system. Because the filter is watertight and uses media for treatment, the soil where it is constructed is not as important as the ability of the media in the filter to transfer oxygen. Without enough oxygen, bacterial action will be compromised. The system should be constructed to keep surface water from entering the filter ... Other wastewater treatment filters use peat, pea gravel, crushed glass, or other experimental media, but sand is the best understood and the most predictable.*¹⁰⁰

Disadvantages: Sand filters require more area than other filters and thus are not suited to small lots. Additionally:

*In addition to the problem with “fines,” sand of the best quality is not readily available in many parts of the country. The availability of appropriate filter medium has the greatest impact on the construction cost of sand filter systems.*¹⁰¹

Costs: The average operations cost (with a small submersible pump) is less than a dollar per month for an individual home: “Overall operational costs of \$200–\$500 per year includes cleaning tanks, repairs, maintenance, and electricity.”¹⁰²

Variations: Buried, Open, See also recirculating media filters

Availability: Requires further research

Known Laws and Regulations: Requires further research

Peat Filters

How they work:

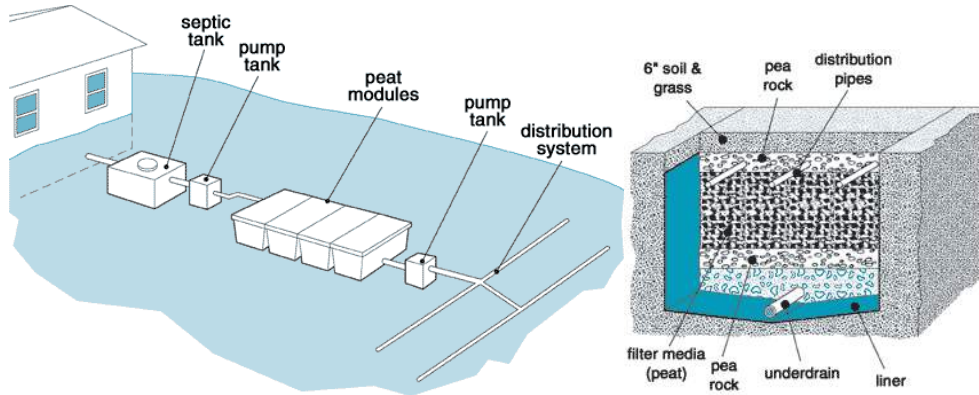
*A peat filter has three components: the peat, a pressure distribution system, and a drain. Filters using pressure distribution are longlasting and provide good treatment of wastewater. The drain is a liner or module that holds the effluent inside the filter. The drain collects the effluent and delivers it to the soil treatment system.*¹⁰³

¹⁰⁰ Ibid.

¹⁰¹ -- (Spring 2005) “Alternatives to Gravel Drainfields” in *Pipeline Magazine*. Vol. 16, No. 2 <http://www.nesc.wvu.edu/pipeline.cfm>

¹⁰² -- (2001) “Single Pass Sand Filters” *Innovative Onsite Sewage Treatment Systems*. University of Minnesota, <http://septic.umn.edu/professionals/systemoptions/index.htm>

¹⁰³ -- (2001) “Peat Filters” *Innovative Onsite Sewage Treatment Systems*. University of Minnesota, <http://septic.umn.edu/professionals/systemoptions/index.htm>



Module and Lined

Source: www.extension.umn.edu/.../DD7669.html

Advantages: Peat filters create a high effluent quality. Because of their modular design, installation is simple and their treatment capacity can be expanded. They work well for intermittent use. They often have low energy and land requirements. They do not require much skill for their proper maintenance.¹⁰⁴

Disadvantages: Peat filters require more maintenance than conventional septic tank drain field systems and may require a service contract.¹⁰⁵

Costs: Operational costs of about \$200–\$500 per year include pumping, repairs, maintenance, and electricity.¹⁰⁶

Variations: See also recirculating media filter. Additionally: “The two main types of peat filters are modules and lined filters. Modules are manufactured plastic peat treatment cells. Lined peat filters are built on site and usually lined with 30 mil polyvinyl chloride (PVC).”¹⁰⁷

Availability: Requires further research

Known Laws and Regulations: Requires further research

Soil Treatment Mounds

How they work:

Mounds were developed to overcome three natural conditions: (1) slow or fast permeable soils, (2) shallow soil cover over creviced or porous bedrock, or (3) a high water table. A

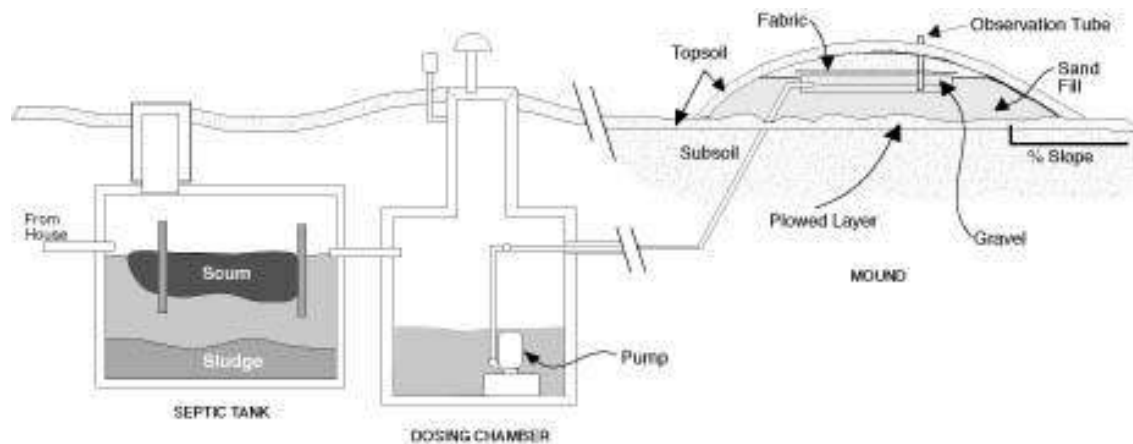
¹⁰⁴ -- “Peat BioFilters” College of Engineering,, Forestry and Natural Sciences, Northern Arizona University, <http://www.cefns.nau.edu/Projects/WDP/resources/treatmentsyst/Peat.htm>

¹⁰⁵ -- (2001) “Peat Filters” *Innovative Onsite Sewage Treatment Systems*. University of Minnesota, <http://septic.umn.edu/professionals/systemoptions/index.htm>

¹⁰⁶ Ibid.

¹⁰⁷ Ibid.

site that has any one of these three conditions (or a combination of them) is not suited for a conventional septic system. There are three main components to a mound system: (1) a septic tank or pretreatment unit, (2) a dosing or pump chamber, and (3) the elevated mound. The dosing chamber - Also made of concrete, fiberglass, or polyethylene, the dosing chamber is a container that collects the septic tank effluent. The chamber—also called a pump chamber—contains a pump control floats, and a high-water alarm float. The Mound - The mound is a drainfield that is raised above the natural soil surface. The mound is composed of a sand fill that has a gravel-filled bed and a network of small diameter pipes known as the distribution system. From the pump chamber, effluent is pumped through the pipes in controlled, low pressure doses so that uniform distribution is achieved throughout the bed. The effluent comes out of the pipes through small holes and trickles downward through the gravel bed and into the sand. Treatment occurs as the effluent moves through the sand and returns to the natural soil.¹⁰⁸



Source: <http://ohioline.osu.edu/aex-fact/0744.html>

Advantages: Mounds are appropriate in most climates. They can be used on land that is deemed unsuitable for in-ground or at-grade systems. They do not emit waste into a ditch or body of water. They require little excavation and preserve existing topography.¹⁰⁹

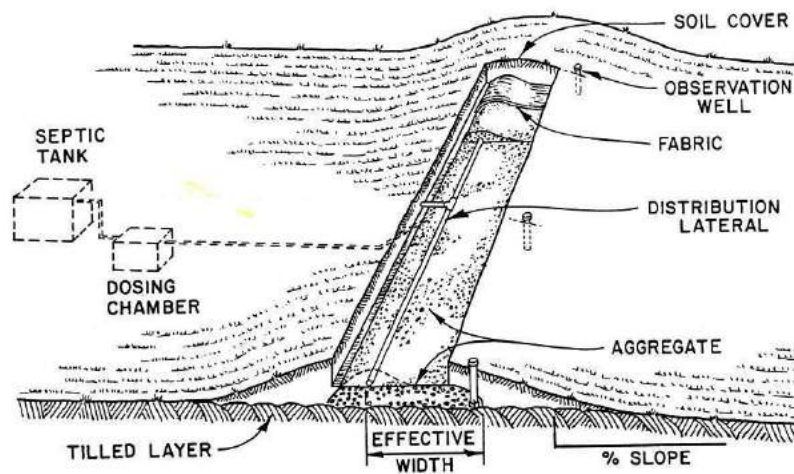
Disadvantages: Mound systems cost more than conventional systems. They require pumps or siphons. The top layer of the mound is permeable and must be carefully protected from construction equipment, etc. The location of the mound affects its function. Seepage or leakage may cause the mound to need reconstruction. Mounds may not be aesthetically pleasing.¹¹⁰

¹⁰⁸ -- (Summer 1999) "Mounds" in *Pipeline Magazine*. Vol 10, No. 3, <http://www.nesc.wvu.edu/pipeline.cfm>

¹⁰⁹ (Summer 1999) "Mounds" in *Pipeline Magazine*. Vol 10, No. 3, <http://www.nesc.wvu.edu/pipeline.cfm>

¹¹⁰ Ibid.

Costs: The average total for 3 bedroom house is \$9,000 and the average operational and maintenance costs are less than \$100. The mound construction is usually the largest expenditure.¹¹¹



Source: <http://www.hudsonwatershed.org/sustainablewatershed/pdfs/etnier.pdf>

Availability: Requires further research

Known Laws and Regulations: Requires further research

Alternative Filters

How they work: There are several alternatives to gravel when constructing the septic filters. Alternative filters such as shredded tires, recycled crushed concrete and crushed glass not only make use of preexisting materials but also have their own benefits. When considering an alternative filter it is important to remember the following:

There are certain physical characteristics that an aggregate should have in order to be an effective media in a wastewater distribution system. An aggregate used with onsite wastewater treatment systems must be able to be crushed or chipped to meet certain size specifications, yet not contain too many “fines”—tiny particles that can block flow between the larger pieces. The aggregate should be reasonably priced and handy to the location. (The shipping cost for hauling gravel over long distances is one of the detriments to using that media in some parts of the country.) Another required characteristic of a good media is that the chips or pieces must remain separate from each other (in other words, not pack

¹¹¹ Ibid.

down) to allow the flow of water through the substrate. Effective media should not react chemically with the water or degrade over time. Most natural aggregates are obtained by quarrying, which produces a number of environmental problems. Quarrying creates large cavities in the landscape and the mining and processing produces noise and dust pollution. At the same time the gravel sources have become scarcer and more expensive, a search has begun for the re-uses of bulky products such as used tires, glass, and concrete rubble, instead of sending them to a landfill ... Maintenance requirements for these gravelless systems are similar to the those for standard aggregate Systems.”¹¹²

Shredded Tires: Tire chips are more porous and are three times lighter than stone aggregate. In fact: “tire chips increase the drainfield storage capacity by 30 percent because the void space between the tire chips is greater than the void space for gravel. Several studies have shown that effluent showed similar values for most of the important biological parameters used to measure effectiveness.”¹¹³ More than 17 states currently permit the use of tire chips or shreds as an alternative media in septic system drainfields.¹¹⁴

Recycled Crushed Concrete:

RCC appeared to have all the qualities required of an effective media: it could be crushed to specific sizes with few fines, retained good porosity, and had strength so it would not pack down after installation. Anecdotal observations suggested that the concrete pieces were becoming cemented together upon exposure to effluent, restricting the movement of the wastewater through the media. Researchers concluded that there were no signs of deterioration of the concrete chunks in the trenches. As long as quality control is of the highest standards in the production (i.e., fines are controlled), RCC is an effective substitute for ordinary gravel in soil absorption systems.”¹¹⁵

Crushed Glass: Crushed glass can be used as a substitute for sand, resulting in: “higher infiltration capacity and pore space, cleanliness, and use of a “low value recycled product.”¹¹⁶

Gravelless Systems

A gravelless system is simply a system that uses wide fiber-wrapped pipe, expanded polystyrene foam, or chamber technology instead of gravel in the drainfield trenches.

Advantages: The advantages of a gravelless system are faster installation, less soil compaction, less need for heavy equipment, increased volume and voiding per unit of length, and ability to be used in remote site where transportation is an issue.

¹¹² (Spring 2005) “Alternatives to Gravel Drainfields” in *Pipeline Magazine*. Vol. 16, No. 2 <http://www.nesc.wvu.edu/pipeline.cfm>

¹¹³ Ibid.

¹¹⁴ Ibid.

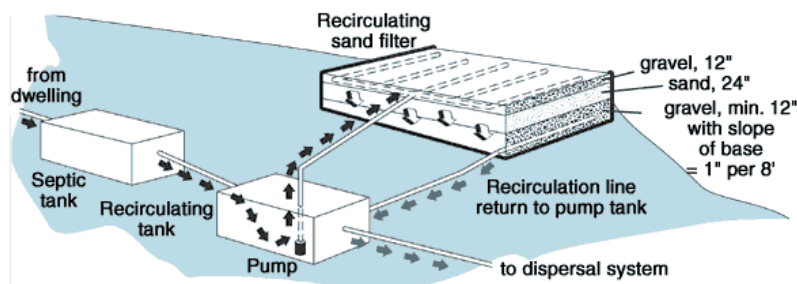
¹¹⁵ Ibid.

¹¹⁶ Ibid.

Recirculating Media Filters

How they work: Recirculating media filters (RMFs) circulate septic tank effluent through a medium of sand, gravel, peat or alternative filter in order to pre-treat the waste before it enters the soil treatment system:

Sand is the most reliable and widely used medium. Recirculation means cycling wastewater through the filter a number of times, allowing for continued filtering and increased bacterial decomposition. Wastewater moves from the house into a septic tank where solids settle out and some organic matter is decomposed. Liquid effluent moves, usually by gravity, to the recirculation tank. Here effluent that has been recirculated through the filter is mixed with septic tank effluent. Effluent is pumped repeatedly through a lined filter and then back (by gravity or pump) to the recirculation tank. In the filter, biological treatment occurs as the effluent passes the surfaces of the filter media. Treated effluent is collected at the bottom and returned to the recirculating tank where the cycle begins again. After the effluent has gone through the filter several times a controlling mechanism sends the effluent to the soil for final treatment. Depending on the site, final treatment could be trenches, a mound, at-grade, or drip distribution.¹¹⁷



Source: <http://www.extension.umn.edu/distribution/naturalresources/DD7670.html>

Advantages: RMFs can process higher strength waste while using less land.¹¹⁸

Disadvantages: RMFs require weekly maintenance and can experience problems in cold weather. Their media may be costly if it is not easily available.¹¹⁹

Costs: Overall operational costs for pumping, repairs, maintenance, and electricity are about \$200-\$500 per year.¹²⁰

¹¹⁷ -- (2001) "Recirculating Media Filter" *Innovative Onsite Sewage Treatment Systems*. University of Minnesota, <http://septic.umn.edu/professionals/systemoptions/index.htm>

¹¹⁸ -- (2002) "Recirculating Media Filter" University of Minnesota <http://www.extension.umn.edu/distribution/naturalresources/DD7670.html>

¹¹⁹ Environmental Protection Agency. (1999) "Recirculating Sand Filters" Environmental Protection Agency http://www.epc.gov/owm/septic/pubcs/finalr_7e6.df

Variations: See sand and peat filter sections

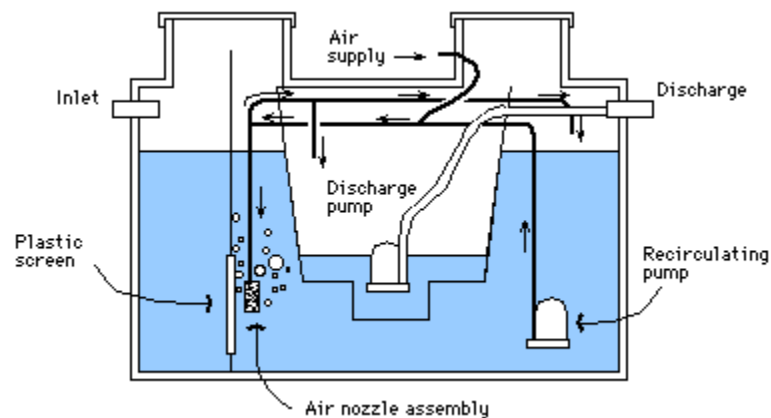
Availability: Requires further research

Known Laws and Regulations: Requires further research

Aerobic Treatment Units

How do they work: Aerobic treatment units (ATUs) also pre-treat waste by adding air. This helps to break down organic material through the following process:

By bubbling compressed air through liquid effluent in a tank, ATUs create a highly oxygenated (aerobic) environment for bacteria, which uses the organic matter as an energy source. In another stage bacteria and solids settle out of the wastewater and the cleaner effluent is distributed to a soil treatment system.¹²¹



Source: <http://septic.umn.edu/professionals/systemoptions/index.htm>

Advantages: ATUs use less water than other methods that pretreat waste. They provide an alternative in areas where septic tanks cannot be used. They can extend the life of a drainfield and require little installation space. Additionally ATUs may be a good option when: The soil quality is not appropriate for a septic system, there is high groundwater or shallow bedrock, a higher level of wastewater treatment is required, a septic system has failed, and/or there is not enough land available for a septic system.¹²²

¹²⁰ (2002) "Recirculating Media Filter" University of Minnesota
<http://www.extension.umn.edu/distribution/naturalresources/DD7670.html>

¹²¹ Anderson, J., Christopherson, S., and Gustafson, D. (2001) "Aerobic Treatment Units" *Innovative Onsite Sewage Treatment Systems*. University of Minnesota, <http://septic.umn.edu/professionals/systemoptions/index.htm>

¹²² National Small Flows Clearing House. (Winter 1996) "Home Aerobic Units" in *Pipeline Magazine*. Vol. 7, No. 1,
<http://www.nesc.wvu.edu/pipeline.cfm>, Anderson, J., Christopherson, S., and Gustafson, D. (2001) "Aerobic Treatment Units"

Disadvantages: ATUs may release more nitrates into the ground than septic systems. They are also more expensive to operate, require electricity and routine maintenance, and contain mechanical parts that can break down.¹²³

Cost: The electrical cost to operate an aerobic system is about the same as that required of a well pump – about 2% of monthly consumption or approximately \$4 per month. The systems have regular maintenance demands and thus municipalities require home professional maintenance contracts.¹²⁴ The cost of a maintenance contract will run in the \$50-75 range.”¹²⁵ ATUs have many components and while the ATU itself may cost between \$2500 and \$5000, determining the cost of the entire system requires further research.

Availability: Requires additional research

Known Laws and Regulations:

Aerobic systems are not accepted in all areas; check with the local health department. Some jurisdictions do not allow for a reduction in drain field area for aerobic systems, but some jurisdictions do allow for a reduction or elimination of a reserve area, with pretreatment. In other areas, aerobic systems are being allowed on an experimental or trial basis, or to repair failed systems. Approval usually comes from the state or local health department. NSF/ANSI 40 - 2000 Standard for Residential Wastewater Treatment Systems details requirements for approval of the system. Aerobic units are required to include two years of manufacturer maintenance service and renewal options, and to have alarms to alert the homeowner of malfunctions.”¹²⁶

Constructed Wetlands

How they work: Constructed wetlands use a natural process of settling, filtering and bacterial decomposition to treat wastewater:

As in tank designs, bacteria break down organic matter in the wastewater, both aerobically and anaerobically. Oxygen for aerobic decomposition is supplied by the plants growing in the wetland. Solids are filtered and finally settle out of the wastewater within the wetland. After about two weeks in the wetland, effluent is usually discharged by gravity to an unlined wetland bed.”¹²⁷

Innovative Onsite Sewage Treatment Systems. University of Minnesota,
<http://septic.umn.edu/professionals/systemoptions/index.htm>

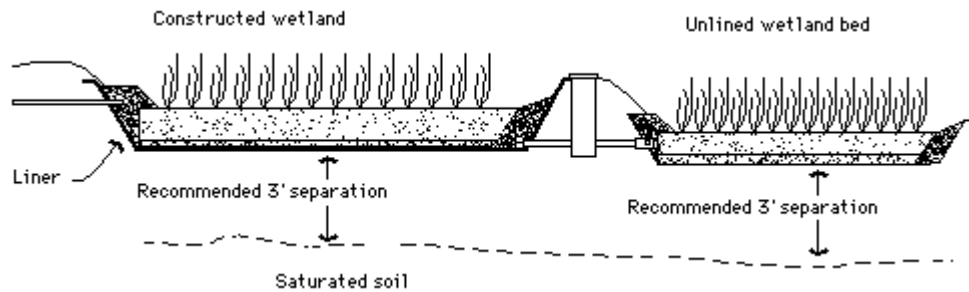
¹²³ Ibid.

¹²⁴ Inspectapedia.com “Aerobic Treatment Unit Failure Rates & ATU Installation & Operating Costs” inspectapedia.com,
<http://www.inspectapedia.com/septic/AerobicFailures.htm>

¹²⁵ Ibid.

¹²⁶ Toolbase.org. “Aerobic Wastewater Treatment Systems” toolbar.org,
<http://www.toolbase.org/Techinventory/TechDetails.aspx?ContentDetailID=899&BucketID=6&CategoryID=11>

¹²⁷ Anderson, J., Axler, R., Christopherson, S., and Gustafson, D. (2001) “Constructed Wetlands” *Innovative Onsite Sewage Treatment Systems.* University of Minnesota, <http://septic.umn.edu/professionals/systemoptions/index.htm>



Source: <http://www.extension.umn.edu/distribution/naturalresources/DD7671.html>

Advantages: Well-constructed wetlands can remove up to 70% of solids and bacteria. The cost of operation and maintenance is low. They recycle and retain water while providing an environment for wetland organisms. They can be an attractive component of the landscape and be well received by the public.

Disadvantages: Constructed wetlands require the periodic removal of excess plant material. Their performance and efficiency may not be consistent and can vary with seasons or changing environmental conditions. They are sensitive to chemicals that many households use, such as ammonia and pesticides. They remain a largely experimental method of dealing with wastewater and thus there is little data about their optimal design or long-term performance.

Costs: Cost vary widely; some estimations include:

Complete system for a house (not including design) [is] \$2,000-\$10,000. Costs vary enormously depending on the chemical qualities of the wastewater and the site conditions. Downsizing the leach field can offset other costs depending on codes and local regulations. A properly constructed and maintained wetland can last much longer than conventional septic systems.¹²⁸

Daily running costs for a wetland are based on the operation of a small submersible pump and average less than a dollar per month for an individual home. Overall operational costs of \$200-\$500 per year includes pumping, repairs, maintenance, and electricity.¹²⁹

Variations: There are many varieties of constructed wetlands; we list three examples:

Free water surface wetlands are man-made equivalents to natural marshes. These systems feature open water and create the most wildlife habitat, Horizontal subsurface flow - Water flows horizontally through a gravel bed planted with reeds. These wetlands are ideal for residential sewage treatment since no water is exposed during the treatment process. Vertical flow wetlands apply water vertically through the plant zone. They are

¹²⁸ -- "Constructed Wetland for Wastewater Treatment" toolbase.org, <http://www.toolbase.org/Technology-Inventory/Sitework/constructed-wetlands#initialcost>

¹²⁹ Anderson, J., Axler, R., Christopherson, S., and Gustafson, D. (2001) "Constructed Wetlands" *Innovative Onsite Sewage Treatment Systems*. University of Minnesota, <http://septic.umn.edu/professionals/systemoptions/index.htm>

much more compact than horizontal flow systems. Additionally, in areas where winter freezing is a concern, they can be insulated with a mulch layer. This makes them ideal for small-scale applications, where the wetland can be combined with a septic tank and a soil absorption system.

Tidal flow wetlands use fill-and-drain sequence for batch treatment of water. They are very efficient for certain applications, such as nitrification/denitrification.

Reed bed systems use plants (usually *Phragmites*) to aid in dewatering and stabilization of wastewater sludges.¹³⁰

Availability: Requires further research and depends on design

Known laws and regulations: Constructed Wetland – Code 656

Lagoon Systems

How they work:

Lagoons are pond-like bodies of water or basins designed to receive, hold, and treat wastewater for a predetermined period of time. If necessary, they are lined with material, such as clay or an artificial liner, to prevent leaks to the groundwater below. In the lagoon, wastewater is treated through a combination of physical, biological, and chemical processes.¹³¹

The treatment is achieved through natural disinfection mechanisms.¹³²

The raw sewage stabilization pond.... is a primary treatment pond. After water has been treated in a raw sewage stabilization pond or in some other type of primary treatment facility, the water can move on to an oxidation pond, which is a type of secondary treatment. Finally, a polishing pond is a type of tertiary treatment.¹³³

Lagoons must be individually designed to fit a specific site and use. Designs are based on such factors as type of soil, amount of land area available, and climate. An important design consideration for lagoons includes the amount and type of wastewater to be treated and the level of treatment required by regulations. Wastewater leaving a lagoon

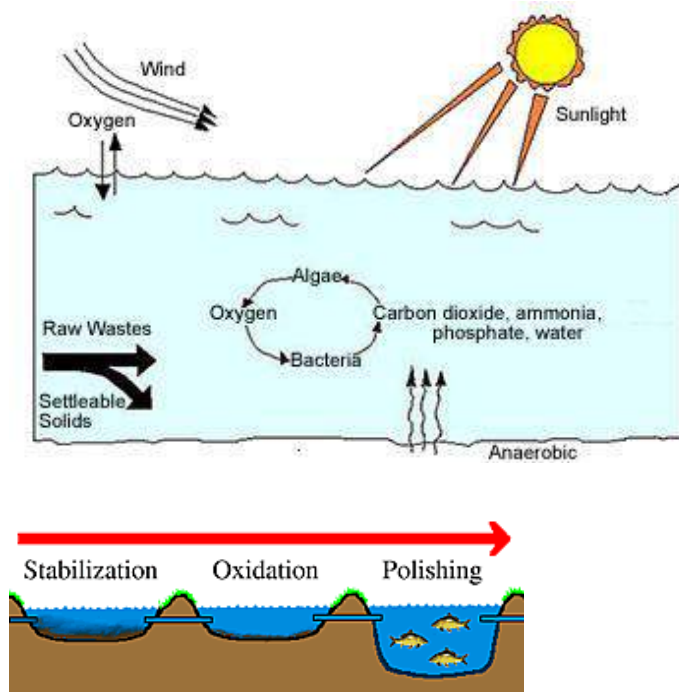
¹³⁰ North America Wetland Engineering. "Wetland Treatment Systems." <http://www.nawe-pa.com/docs/technology.pdf>.

¹³¹ "Design, Operation and Regulation of Lagoons in Maine." (2003) Lagoon Systems in Maine <http://www.lagoononline.com/desopreg.htm>

¹³² Peña Varón, M.R. (2003) "Waste Stabilization Ponds for Wastewater Treatment." IRC International Water and Sanitation Center, <http://www.irc.nl/page/8237>

¹³³ "Stabilization Ponds" Water/Wastewater Distance Learning Center <http://water.me.vccs.edu/courses/ENV110/lesson18.htm>

may require additional treatment, or "polishing," to remove disease-causing organisms or nutrients from the wastewater before it can be returned to the environment.¹³⁴



Source: <http://water.me.vccs.edu/courses/ENV110/lesson18.htm>

Advantages: Lagoons work well in hot or tropical climates because sunlight and heat help to break down waste. Lagoons use less energy than most wastewater treatments. They can be simple to operate, though they require a part-time staff. They can handle large and intermittent loads better than other methods, which makes them ideal for campgrounds and seasonal properties. They remove pathogens from the wastewater, which lowers the risk of disease and makes their effluent suitable for irrigation.¹³⁵

Disadvantages: Lagoons do not perform as well in colder climates and may need more land or more time to process the same amount of wastewater. Lagoons require more land than other methods. Unless they are well maintained they can become a breeding ground for insects and their odor may become offensive. Even after natural processes their effluent may contain algae

¹³⁴ "Design, Operation and Regulation of Lagoons in Maine." (2003) Lagoon Systems in Maine
<http://www.lagoononline.com/desopreg.htm>

¹³⁵ "Design, Operation and Regulation of Lagoons in Maine." (2003) Lagoon Systems in Maine
<http://www.lagoononline.com/desopreg.htm>

and be in need of additional treatment to meet discharge standards. They do not effectively remove heavy metals from wastewater.¹³⁶

Cost: Requires further research and depends on design.

Spray Irrigation

How it works: Spray irrigation is a secondary means of disposing of wastewater rather than a primary means. Water must first be treated by one of the methods listed above:

*Because spray systems apply effluent above ground, the wastewater must be treated to a high enough level to protect public health and reduce odors. In general, regulations require that effluent used for surface irrigation at least meet secondary treatment standards plus disinfection. With spray systems, therefore, after primary treatment in a septic tank or community treatment plant, the wastewater usually goes to a home aerobic treatment unit, sand filter, recirculating sand filter, or other filter, and then to a dosing tank or pump chamber. The wastewater is then disinfected with chlorine, ozone, or ultraviolet light before it is stored in a lagoon or holding tank for later use or just prior to its application to land. In some community systems, aerated or facultative lagoons provide treatment as well as additional storage area for the wastewater. After treatment, filtration, and disinfection, a pump equipped with timers sends the wastewater under pressure through the mains and lines of the spray distribution system at preset times and rates as needed for irrigation.*¹³⁷

Advantages: Spray systems reduce discharge into streams and apply it instead to plants. This form of irrigation increases important nutrients in the soil, such as nitrogen and phosphorus. The systems are above ground so they are easier to inspect and maintain than below ground systems. This form of irrigation can have a cooling effect on plants during mid-day heat. Evaporation also speeds up the rate of wastewater disposal.¹³⁸

Disadvantages: The key drawback of spray systems is that they produce aerosols. Public health regulations may thus require minimum setbacks or buffers for their use. The wet soil they generate may encourage weed growth and make maintaining the soil with equipment difficult. Additionally wet soil encourages bacteria growth.

Cost: Requires further research and depends on design

Availability: Requires further research

Known Laws and Regulations: Requires further research

¹³⁶ Ibid.

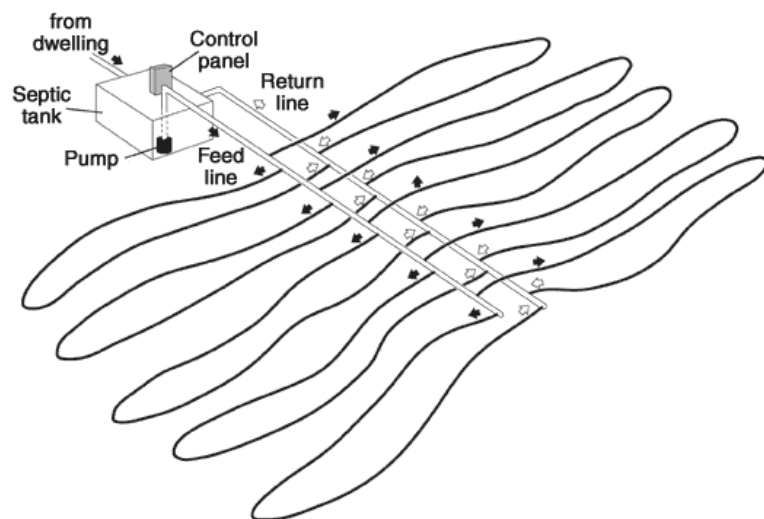
¹³⁷ (Winter 1999) "Spray and Drip Irrigation for Reuse, Disposal" in *Pipeline Magazine*. Vol 10, No. 1, <http://www.nesc.wvu.edu/pipeline.cfm>

¹³⁸ Ibid.

Drip Distribution

How it works: Similarly to spray irrigation, drip distribution is a secondary treatment method. This method uses pretreated wastewater as a source of moisture and nutrients for plants but applies the water under ground:

The pretreated effluent "drips" out of tubing at regular intervals, allowing a small amount of wastewater to irrigate a large vegetative area. Topsoil with vegetation is an excellent environment because it maximizes the treatment of sewage and minimizes the risk of untreated water flowing quickly through the soil. Drip distribution is often used in places where standard trenches are hard to install, such as steep slopes and forested areas. It is also used in places that only operate during the warmer months of the year, such as resorts and golf courses. Drip distribution systems are often used after a pretreatment system, such as an aerobic treatment unit or sand filter, is used. The basic principles for drip distribution are the same as for other soil-based treatment systems: filtering and bacterial decomposition of waste. The difference is that a drip distribution system distributes the effluent evenly over a large area. A drip distribution system has four main parts: a pretreatment device, a pump tank, a filtering/flushing device, and the distribution system. The *pretreatment device* depends on the drip tubing and the manufacturer's recommendations. Some drip systems require advanced pretreatment, but others work with only a septic tank. All systems can plug without a good filtering device. The pump tank stores the water until the drip field is ready for a dose of effluent. A high head pump is needed for even application of the wastewater. Pump selection and installation follows typical onsite treatment system design practices.¹³⁹



Source: <http://www.extension.umn.edu/distribution/naturalresources/DD7668.html>

Advantages: Drip distribution conserves water because water is applied directly to plant roots and less is lost through evaporation. The water is more evenly distributed to plants. Issues

¹³⁹ (2002) "Drip Distribution " University of Minnesota, <http://www.extension.umn.edu/distribution/naturalresources/DD7668.html>

stemming from wet soil are avoided because the topsoil remains dry. There is less runoff and flexible tubing can be used to water unusual grades or hills. No aerosol is produced. Crops watered through a drip system can often be harvested sooner than with other irrigation methods. There are generally fewer operation and maintenance requirements than with spray systems.¹⁴⁰

Disadvantages: Tubing can clog and because it is underground it may be difficult to diagnose and fix problems. Drip systems are not best for germinating plants; a spray system may still be needed. Freezing temperatures may affect their efficacy.¹⁴¹

Cost: Installation of a drip system runs about \$9,800 including new septic tank, sand bed, drip tubing, and control unit.¹⁴² Yearly maintenance costs range from \$200-\$500 per year, including a periodic pump-out of the septic tank, electricity, and maintenance visits.¹⁴³

Availability: Requires further research

Known Laws and Regulations: Requires further research

Evapotranspiration

How it works: The evapotranspiration (ET) method:

*... employs the combined effects of evaporation from soil and transpiration from plants to dispose of wastewater effluent. Wastewater flows from a septic tank or aerobic unit into a vegetation-covered distribution and storage area. From this storage area, moisture is wicked up to plant roots and to the soil surface. The plants use the moisture in their growing processes and subsequently transpire the excess through their leaves. Moisture that migrates up to the soil surface evaporates into the atmosphere as relatively clean water.*¹⁴⁴

Advantages: Works well in hot climate and requires little maintenance. Can be used when geological factors prohibit drip systems. Works well in areas like Texas where evaporation and transpiration are greater than rainfall. The cost of ET systems is comparable to other systems.¹⁴⁵

Disadvantages: ET systems require a large surface area. ET systems are very susceptible to

¹⁴⁰ (Winter 1999) "Spray and Drip Irrigation for Reuse, Disposal" in *Pipeline Magazine*. Vol 10, No. 1, <http://www.nesc.wvu.edu/pipeline.cfm>

¹⁴¹ Ibid.

¹⁴² (2002) "Drip Distribution " University of Minnesota, <http://www.extension.umn.edu/distribution/naturalresources/DD7668.html>

¹⁴³ Anderson, J., Gustafson, D., Heger, S., and Luikkonen, B. (2002) "Choosing an Alternative Septic for a Homesite with Thin Soil Over Bedrock" *Innovative Onsite Sewage Treatment Systems*. University of Minnesota, <http://www.extension.umn.edu/distribution/naturalresources/DD7569.html>

¹⁴⁴ (Winter 2000) "Evapotranspiration" in *Pipeline Magazine*. Vol. 11, No.1 <http://www.nesc.wvu.edu/pipeline.cfm>

¹⁴⁵ Ibid.

wind, temperature, humidity and solar intensity. They have limited storage capacity and excess precipitation may overload them. They are not as effective in the winter and evapotranspiration must always “exceed rainfall by at least 24 inches for the system to be effective.”¹⁴⁶

Cost: ET systems can be very costly: “Figures of approximately \$10,000 or higher are typical for a three-bedroom home’s septic tank and ET system.”¹⁴⁷

Availability: Requires more research

Known Laws and Regulations: Requires further research

¹⁴⁶ Ibid.

¹⁴⁷ Ibid.

APPENDIX A14: SUSTAINABLE RECYCLING AND SOLID WASTE TECHNOLOGIES AND PRACTICES

Reduction and Reuse

Reducing the amount of waste produced by a household is perhaps the single most cost-effective and environmentally conscious technique for solid-waste related sustainability. On the other hand, it is often overlooked and it can be difficult for people to be convinced to change their routine purchasing and consumptive practices.

There are several household practices where reduction and reuse can be employed and make significant difference.

- Grocery and Shopping bags
 - Americans use 100 billion plastic bags a year (roughly 325 bags per person per year). Using canvas or other reusable bags when going to the grocery store in particular makes a significant difference in the amount of waste produced. Nonetheless, consumption of reusable shopping bags can actually be less sustainable if the bags are not used, as initial material inputs for reusable bags are far higher.
 - Some grocery stores are charging small fees (~\$0.05 per bag) or offering savings for customers who bring reusable bags.
 - Reusable shopping bags cost relatively little.
- Replacing disposable materials with reusables: Avoiding disposable plastics in favor of reusable glass containers, using rags instead of paper towels, etc.
- Avoiding overpackaged items and buying in bulk
- Borrowing or renting seldom-used items instead of purchasing (see Freecycle website)

Issues Involved

Technology: None

Suppliers: N/A

Cost: Some reusable items may cost small or negligible amounts initially, but generally reducing consumption and reusing result in significant savings

Public Acceptance: Varies, generally accepted if not glamorous

Regulatory: None, except for contrary imperatives from our political leaders to "go to your malls"

Education: The primary component of changing practices: education and peer pressure may be some of the best ways to realize these practices

Compost Systems:

Composting increases plant growth, and replaces the need for chemical fertilizers and pesticides in gardens and lawns. Organic materials and certain types of waste can be used in a much more beneficial way through composting than deposition into a landfill. Composting also serves as a neat alternative to using an in-sink garbage disposal or throwing away kitchen scraps.

Types and Applications of Composting:

- Vermiculture uses worms to decompose food waste, involving relatively few material inputs or expenses. It is effective and can be more robust than passive composting.¹⁴⁸
 - A bin or container with roughly two square feet of surface area per person in the household
 - Bedding for worms to live in made of sawdust, moistened strips of newspaper, 2-3 inches deep at the bottom of the bin, and/or coffee grounds or crushed eggshells
 - Worms - freely available wherever worms are found. Redworms are preferred, particularly *Eisenia foetida* (commonly known as red wiggler, brandling, or manure worm) and *Lumbricus rubellus*. Worms can also be purchased for \$25-30 per 1lb.
 - Food - worms are not choosy eaters, and should eat just about any form of food waste coming out of household kitchens. Just as in other forms of composting, however, meat and dairy leftovers should be avoided as they tend to putrefy and attract pests and other vermin.
- Active (hot) composting¹⁴⁹
 - Mostly used for large scale operations, although many composting toilets (see *the Water and Wastewater section*) may use these methods
 - Thermophilic bacteria can break down many elements (e.g. human waste) that other composting methods either cannot digest or not digest in time enough to avoid putrefaction.
 - Requires a specific Carbon:Nitrogen ratio, usually controlled by what inputs are introduced, regular aeration or stirring, and a proper moisture balance
 - Generally more intensive and technically complex than other forms of composting, although useful for certain relevant household applications particularly human waste
 - Composting toilets can be bought commercially for \$1000 and up. They are considered "cost competitive" with septic installation. They can be built for minimal cost by people with some knowledge of handicraft and how the systems operate.
- Passive Composting¹⁵⁰
 - The most popular form of composting and the most widely applicable for domestic use, passive composting is simply the addition of kitchen scraps to a container with some drainage and access to airflow. This can be as simple as a few yards of chicken wire and some dowels in a backyard.
- Piggery

¹⁴⁸ Microbial Earth. (2010). Microbial Earth -Vermiculture: <http://www.microbialeearth.com/cms/> and Earth 911. (2007). Composting With Worms: <http://earth911.com/news/2007/04/02/composting-with-worms/>

¹⁴⁹ Compost Manual. (2008). Compost Manual. <http://www.compostmanual.com/>

¹⁵⁰ Bray, P. (1997). Cold/Passive Composting. Michigan State University Extension, Genesee County: www.msue.msu.edu/%2Fobjects%2Fcontent_revision%2Fdownload.cfm%2Fitem_id.207912%2Fworkspace_id.30%2FOC0353%2520Cold%2520Passive%2520Composting.pdf

- Pigs have long been used to digest household and some types of organic municipal waste
- The *Zabbaleen*, a community of trash collectors in Cairo, Egypt, have historically used pigs for this process. see:
<http://www.nytimes.com/2009/05/25/world/middleeast/25oink.html>
- **Biogas/Biodigester**¹⁵¹
 - Biogas use organic waste to create anaerobic digestion and produce gas suitable for cooking. Theretically any kind of organic material is good for producing gas through this system; manure (including human waste) tends to be most successful. However, a good mix of the waste a family produce is more than enough for their own household needs. On average a biodigester that measures 1.9 meters X 1.5 meters X 3 meters, that works well, will produce about six hours of cooking time daily. This should be sufficient for all the cooking for a large family.

Issues Involved

Technology: Already developed, low-tech, readily accessible

Suppliers: Prefabricated compost bins, Composting toilets.

Cost: Passive compost systems cost = \$10-\$30

Public Acceptance: Widely accepted, although certain types of composting can be odorous or attract vermin. These negatives can be mitigated with individual management and care.

Regulatory: Improperly maintained compost systems may conflict with public health regulations.

Considerations:

- Separate yard waste from household waste (although both can be composted). The City of Austin converts the yard waste into eDillo which is used in city parks and public lands as an organic fertilizer.
- Avoid animal-based food products (it attracts rodents and other pests), although composting toilets and other active systems may be able to effectively digest these materials.
- Avoid odors and difficult labor.
- Prefabricated composting bin systems are available commercially and can function well with minimal maintenance.

Traditional Home Recycling

70% of the millions of tons of garbage Americans produce each year, could be recycled. Buy products with little or no packaging (called precycling) can reduce what goes into the waste stream. Home recycling is a valuable means of diverting much of this waste, however it requires pickup and processing

¹⁵¹ Green, N. S. (2005). Emerging Biodigester Technology in Honduras: Biophysical Processes and Operation. www.cfc.umt.edu/grad/ICD/pdf/Green_Stuart.pdf and Rural Costa Rica. (2007). Small Scale Biogas Use with Biodigesters: <http://www.ruralcostarica.com/biodigester.html>

Issues Involved

Technology: On site no technological intervention is required, although households are often encouraged to separate recyclables by type of material. Off-site, recycling centers are generally technologically intensive and limited to a few locations in any given region

Suppliers: Many cities and counties offer traditional municipal recycling. Rural areas may contract with a recycler at the residential subdivision level or it may be possible that individual pickup of recyclables could be scheduled.

Cost: Costs of individual recycling bins may vary, often provided for free to subscribers of a recycling program. Some recycling services include the cost of containers with the cost of hauling and collecting. Desk side (blue bins) containers cost the same as wastebaskets (\$5.00 each). Hauling and collection costs depend on container size, frequency of pickup, material value, and anticipated volume. Cost of constructing the hazardous materials storage. Recyclers may charge users of the service a fee by volume or a subscription fee.

Public Acceptance: Widespread, but there are few ways for small groups to meaningfully interact with the large, vertically stratified systems that characterize most traditional recycling efforts.

Regulatory- There are some municipal regulations regarding recycling in place, but particularly within informal areas or outside of municipal ETJs, there is little to no regulation regarding recycling.

Considerations:

- Americans throw away glass, aluminum, paper, and kitchen and yard waste (called organic waste). Recycling is more likely to occur if it can be accomplished in a neat convenient manner, which is why built-in systems are encouraged.
- Although pickup is not required, it seems unlikely that households with trash pickup would separate recyclables and take them to a recycling center on their own.
- A recycling center ultimately is needed.

Recycling Cooperatives

Another technique of providing sustainable recycling is through the collaborative work of cooperative efforts, typified by some work in Curitiba, Brazil. These types of efforts can be organized privately or as a public-private partnership between an organized group that works jointly in the collection of recyclable waste within a certain area. The cooperative members accumulate recyclable materials disposed by households in a warehouse loaned by the government (or possibly owned jointly or individually by one of the members) to later divert them, separate them by type and mechanically compress them (In machines provided by a government or again, owned by the cooperative) to produce commercial standardized bricks suitable for sale to the major buyers of recyclables and processing facilities.

- In Curitiba Brazil, this type of alternative is called "eco-citizen" and recruits up to 30 participants per venue to work in a cooperative. They normally involved former informal collectors and formalize them providing them with healthcare and childcare in addition to the previous mentioned benefits. The ability to divert and compress the recyclables increases their retail price from 250 to 400% depending on the material.¹⁵²

¹⁵² Tamashiro, E. (2008). A model of organization, development and economic inclusion of recyclable material pickers. Ashoka.org Businesses for Social Change: www.changemakers.com/es/8949

- Since individuals within the community are adding value to the recyclables, they are able to capture that value, opposed to a traditional municipal context.¹⁵³

Issues Involved:

Technology- Technologically intensive, requiring mechanical means of transporting and compressing waste materials

Suppliers- N/A

Cost- Significant. Investment by governments may represent a savings over traditional municipal recycling, and ancillary benefits of the sale of recyclables may be used to pay off equipment or to subsidize the activities of the cooperative and its members.

Public Acceptance- Seems to be accepted in Curitiba, however virtually unknown and novel in an American context

Regulatory- Significant regulatory issues, either in the organizational structure or the cooperative-government partnerships or in the storage and treatment of the waste materials

Considerations- This has been a highly successful and integrated social welfare approach to sustainability and solid waste handling in Brazil. Its costs suggest significant investment or buy-in from government actors is needed

Informal recycling as a business opportunity

In developing countries such as Peru, there are people who work as recyclers in districts where municipalities are not able to provide garbage collection services. Most of them work in the informal sector but recently there are initiatives to help them become formal. This model consist in fostering home recycling awareness and teaching families to separate their garbage at home, and allow recyclers to visit each household and collect each separated garbage bags for free. That way, both communities and recyclers benefit from the service. The household disposes of the garbage and keeps their houses and streets clean, and the recycler can sell the materials and make a profit. The main purpose of this initiative is to keep recyclers healthy since once families separate the garbage, recyclers will not have to scavenge inside trashcans. This model also helps recyclers save time and collect more materials. For more Information see the Northeast Recycling Council, *Implementation Guide for Small Business Recycling Cooperatives*, www.nerc.org/documents/coop/nerc.pdf. Also, see a Texas-specific group, Cooperative Teamwork and Recycling Assistance, working on this issue at: <http://www.recyclingassistance.org/> i.e.

Commercial Recycling

Commercial Recycling, though it may have limited applicability in the residential context of most low income informal homestead subdivisions, should still be considered as many of these areas also support small businesses or in the case of some consolidating neighborhoods may have many nonresidential uses. Commercial establishments, particularly small manufacturing or workshop type locations, may produce different types of waste than residential neighborhoods

¹⁵³ Curitiba's Environmental Department. (2009). Institutional Video of Eco-Cidadao, Social Communication Department of Curitiba. YouTube: www.youtube.com/watch?v=qEskTZaQ4LU

- Formal Commercial Recycling is a 3 step process:
 - collecting and separating materials
 - manufacturing and processing
 - purchasing of recycled content products.
- Additionally, certain types of commercial ventures likely found in informal subdivisions may provide direct recycling opportunities at a low-intensity scale
 - A carpenter's workshop, for instance, could be a valuable source for sawdust and wood chips, which can be valuable inputs to a composting or vermiculture system
 - Restaurants and area schools could similarly divert much of their food waste to a decentralized composting system serving gardens or other uses within their neighborhoods, or for sale or distribution elsewhere. See, for example: <http://breakitdownaustin.org/>

Issues involved:

Technology: Containers for storage and collection

Suppliers: Many local providers

Cost: Some recycling services include the cost of containers with the cost of hauling and collecting. Desk side (blue bins) containers cost the same as wastebaskets (\$5.00 each). Hauling and collection costs depend on container size, frequency of pickup, material value, and anticipated volume.

Public Acceptance: An easy to use, convenient system encourages participation. Education reinforces the program.

Regulatory: CoA Ordinance 981022-P Chapter 12-3, art. VI, Commercial and Multi-Family Recycling requires that all multi-family communities (>100 units) and businesses (>100 employees) establish an on- site recycling program.

Education- Find the facility's recycling coordinator program. Continuing education program is also essential. Plans for purchasing products made from recycled materials.

Guidelines:

"Upcycling"

Upcycling is a catch-all term to describe types of reuse of waste materials by repurposing them.

- One potential use for a lot of waste plastics, packaging, etc. can be the production of crafts and other "quirky" objects like purses, wallets etc. six examples, all "crafting" projects: <http://blog.sustainablog.org/six-creative-upcycling-projects/>
- Although these products are currently en vogue, it's probably unlikely that these sorts of crafting practices could be a widely applicable practice.

Issues Involved:

Technology: none, only skills

Suppliers: none

Costs: Small or negligible costs for tools or supplies needed to repurpose items

Public Acceptance: As mentioned upcycled products are currently en vogue as "sustainability chic", although actually producing these often labor intensive craft projects can limit its usefulness as a widespread practice.

Regulatory: None

Municipal Solid Waste

Trash collection within cities and counties may be organized by the jurisdiction or a corporate entity. The sustainability relevance here is relatively limited, as the removal of waste to a landfill in a traditional context is only nominally better than burning or illegal dumping of household waste

Issues Involved:

Technology- Limited at the household level; if no formalized pickup exists then some access to hauling vehicles is necessary. A large transport and processing chain exists through municipal and corporate waste handling

Suppliers- Municipal and Corporate, varies by region

Cost- Garbage bag charge policies; prepaid taxes for collection and for recycling

Public Acceptance- So normalized that it almost makes little sense to consider its acceptance. On the other hand it is increasingly recognized that these methods may be less desirable under certain sustainability frameworks

Considerations- Policies which promote explicit incentives such as a waste charge may induce households to choose the option of illegal disposal. Options of optimal waste management policies depend crucially on households' waste separation behavior. In fact, researchers suggest that a combination of policies such as waste collection charge on the households, explicit monitoring of illegal waste disposal and an environmental tax on the services provider (either public or private).

APPENDIX B1: HOUSEHOLD ENERGY SAVING MODEL SPREADSHEET

In a separate Microsoft Excel file included with this report is a household energy saving spreadsheet. The purpose of this spreadsheet is to support decision making regarding residential energy efficiency investments by providing a cost-benefit analysis tailored to a specific project. The principal output is the forecasted net present value of an intervention given data on historical consumption, housing characteristics, and price and efficacy of proposed investments.

Although the exact monetized benefits of specific investments vary given environmental factors, this model should serve to effectively compare alternative investments. A guide to using the spreadsheet is included in the following appendix, **Appendix B2: “Rough Valuation of Energy Saving User Model Guide.”**

APPENDIX B2: ROUGH VALUATION OF ENERGY SAVING MODEL USER GUIDE

Note on Formatting:

The model consists of nine worksheets: five input sheets, one output sheet, and three static reference sheets. Numerically formatted cells are color-coded as blue, green, red or black to designate the following statuses:

Blue: user input cells. These are for data to describe the unique characteristics of the household and the proposed investments.

Green: formula cells that refer to inputs or calculations from another worksheet.

Black: formula cells that refer to inputs from the same worksheet.

Red: input cells that rely on not readily observed data

Input Sheets:

Miscellaneous Input: The inputs within this cell are the square footage of the home and an assumption about historical electricity and water prices. Assumptions regarding future utility prices can be inferred from the following input sheets and adjusted based on the user's perspective and expectations.

Electricity Usage Input: The input cells for this sheet are based on data readily available upon request from the utility and from local weather records. Ideally, this would represent a time series of the 12 months of kWh consumption prior to the implementation of the efficiency investment. The immediate outputs from this sheet are the average daily consumption for the pay period and the price paid per kWh. This information will help the user to make assumptions about future energy prices. The 'climate control relevant' column is a proxy indicator of whether or not energy-consuming climate control systems are in use during the month in question. This can be inferred either by plotting the increase in electricity consumption or by regressing the electricity consumption as a function of the deviation of the average monthly temperature from a comfortable range, such as 78 degrees Fahrenheit (as is shown in the reference cell, 'electricity usage model').

The baseline electricity consumption forecast simply extrapolates out historical prices over 20 years with no adjustments.

Water Usage Input: This is very similar to the 'Electricity Usage Input' worksheet except that no adjustments are assumed to be needed for seasonality in water use. If there is a reason to model seasonality for a particular case then the methods used for electricity modeling should suffice once the relevant periods are identified.

Interventions: This sheet is intended as a control panel for determining which investments to model and whether to run them simultaneously or separately. The hidden cells (columns H through K) contain the cost and offsets of the interventions coded as conditional statements to only be considered if chosen by the user. The discount rate should represent the opportunity cost for the benefit derived by other investments not designed to be captured by this model. Common examples include the risk free rate on US Treasuries or the yield on certificates of deposits. Given the low yield of such investments and the variability of returns on efficiency

investments users may wish to add a 'risk premium'; alternately, a lower discount rate may be used to represent non-monetary benefits of efficiency investments which make them preferred to conventional securities. Ultimately, this figure is subjectively determined.

Intervention Specs: This worksheet provides a format for the user to build a specific intervention to be modeled. The first input, the labor rate, should be based on the standard cost for an hour of construction or weatherization labor for the region being modeled.

The relevant parameters modeled for each intervention are the materials content and the labor content. The materials costs may vary by region, but using a search engine to refer to prices for retailers should give an accurate proxy for a residential buyer. The labor content of the materials is somewhat trickier, and users should feel free to consult the Labor Content (WAP) worksheet for the standard labor content for weatherization work.

The red values representing the estimated offsets are a rough proxy for the actual expected efficiency value of an intervention. For a particular house the user can estimate the R values of walls and ceiling based on the current materials content, and the increase in R value given the new investment. The marginal change in the U value ($1/R$) should be used to determine this figure.

These rough estimates are not substitutes for cost estimates by local contractors and efficiency estimates by trained energy auditors, and those values should be used if they are available.

Static Reference Sheets:

Energy Star AC Specs: This sheet serves only as an automated calculator for recommended Btu value of air conditioning units given the square footage of the home.

Labor Content WAP: As mentioned above, this contains the labor content specifications for a comprehensive selection of energy efficiency interventions. This is a valuable reference when building a model for a particular investment option.

Electricity Usage Model: This is an example of the regression output used to verify the validity of assumptions regarding seasonality of electricity usage and which months are 'climate control relevant' in terms of energy usage. The model compares kWh usage to the deviation in monthly high temperature from 78 degrees Fahrenheit. The base temperature can be adjusted as appropriate for different households.

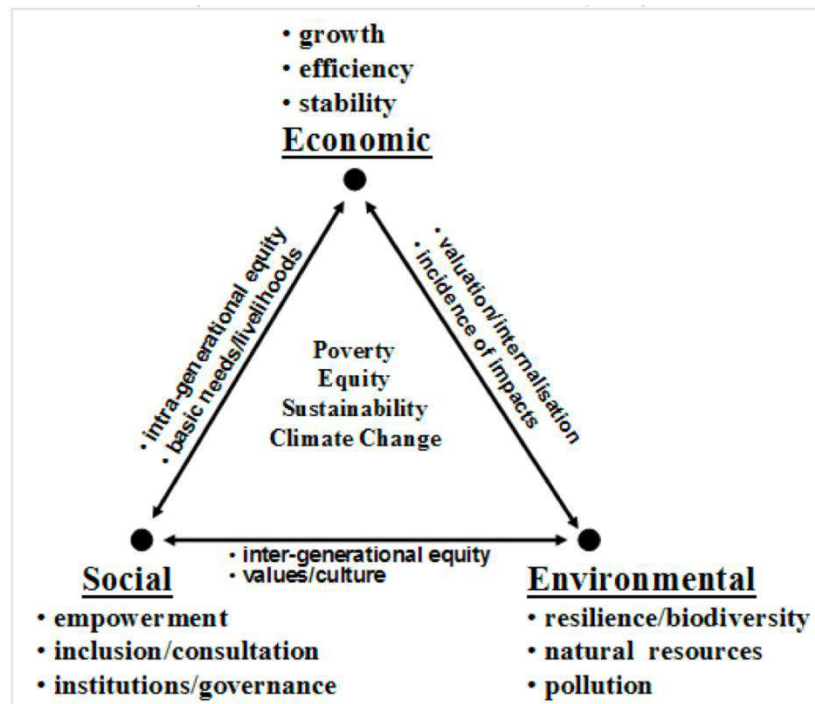
Output Sheet: The Scorecard sheet contains the total cost in the present period of the interventions chosen and the monetized and discounted value of the forecasted offset in electricity usage. The net present value is the difference between the benefit and the cost and the return on investment (ROI) represents the obtained benefit. It should be noted for those unfamiliar with financial modeling that the present value of the future monetized benefits and the ROI will move inversely with changes in the discount rate chosen on the Interventions worksheet.

Final Note on Purpose: As with any decision making tool, this model is only as strong as the relevance of its underlying assumptions. Its best use is as a comparison tool rather than a forecasting tool. By modeling several investment alternatives of varying costs and efficacies a user can optimize the value of their investment by comparing the NPV and ROI of the various alternatives. Although financial and resource conservation considerations do not comprise the

whole of the home and community investment decision making process, this model should serve as a valuable platform for quantifying and weighing those dimensions.

APPENDIX B.1 THE SUSTAINABILITY PYRAMID

The below figure is one version of the Sustainability Pyramid which attempts to capture the relationship between the environmental, economic and social equity aspects of the sustainable agenda:



Caption: Munasinghe's Sustainable Development Triangle

Source: Harsha Padmal Munasinghe, "Environmental Economics and Sustainable Development," 1992.

APPENDIX C2: TRAINING AND CAPACITY BUILDING PROGRAMS

Accessible and effective training and capacity building in sustainable technology implementation is essential to upgrading the existing housing stock as well as expanding job opportunities and local economic growth. In the context of low-income communities, if local building professionals have this capacity, they may be able to engage in self-help community projects while building lucrative businesses in broader markets as well. This section explores training and capacity building programs at the state and local level that may be useful in identifying opportunities for self-help projects for low-income communities in informal settlements and innerburbs.

State Level Opportunities: Weatherization Training Academy

The Texas Department of Housing and Community Affairs recently created a Weatherization Training Academy with federal ARRA funding. The advanced weatherization training provided by the WTA is available to all approved weatherization contractors: the TDHCA requires that all of its sub-recipient agencies submit contractor lists for approval (for eligibility information, see <http://wxtraining.tdhca.state.tx.us/Eligibility.aspx>). The website also offers a wide variety of useful resources to weatherization professionals.

The WTA training opportunities cover a wide range of topic areas, including health, safety, basic installation and cutting edge technology. The courses include:

- Basic weatherization course
(<http://wxtraining.tdhca.state.tx.us/docs/TDHCABasicOutline.pdf>)
 - Energy auditing and blower door testing
 - Building science and principles of energy
 - Insulation and the building shell
 - Heating and cooling equipment
 - Health and safety
- Advanced weatherization course
(<http://wxtraining.tdhca.state.tx.us/docs/TDHCAdvancedOutline.pdf>)
 - Customer education, health and safety
 - Innovative weatherization techniques
 - Mobile home weatherization
 - Zone pressure testing and duct systems
 - Advanced heating and cooling
- Weatherization Management, especially for sub-recipients, not contractors
(<http://wxtraining.tdhca.state.tx.us/docs/TDHCAManagementOutline.pdf>)
- Mobile Home Weatherization
(<http://wxtraining.tdhca.state.tx.us/docs/TDHCAMobileOutline.pdf>)
- EPA certified Lead Safe Remover courses
(<http://wxtraining.tdhca.state.tx.us/docs/TDHCALeadSafeRenovatorOutline.pdf>)

The depth and quality of these programs are an excellent resource for serving low-income communities in Texas through the Weatherization Assistance Program. Access to these training opportunities is largely controlled by sub-recipient agencies, which are generally small community action agencies that deliver a range of social service to low-income households. To

be eligible for these services, local building professionals must apply through the sub-recipients to be on a list of accepted contractors. That being stated, these contractors may often still hire sub-contractors from the local community if they are given supervision and training.

Local Model Training Programs: Austin Case Study

The City of Austin has three different programs designed to provide green building career opportunities to community members: Casa Verde Builders, Austin Community College's Building Construction and Technology Program and Renewable Energy Program, the SkillPoint Alliance's Gateway Construction Program, and 1House At A Time. All of these programs could offer potential lessons for training opportunities in other areas of Texas, especially the ACC programs since their curriculum can be shared with other community colleges throughout the state. We suspect that self-help programs are most successful and sustainable when they include skill and knowledge enhancement that will provide long-term economic opportunity as well.

Casa Verde Builders

Casa Verde Builders (CVB) has been a provider of practical green building education since 1996. Operated by American Youth Works, CVB trains at-risk youth to build affordable, green homes in their own neighborhoods while earning a high school diploma and developing valuable teamwork, life, and green building skills.¹⁵⁴ As AmeriCorps volunteers, CVB members also receive a stipend, health care benefits, and an education award upon completion of their year of service.

Today, CVB's 800 graduates have built over 100 green homes for low-income, first-time homebuyers. Richard Halpin, CVB's Founder and Chief Executive Officer, says that CVB has also built more 4- and 5-Star Austin Energy rated homes than another other builder.¹⁵⁵ The program's successes have won it many awards and have made it a national model of effective green collar job training in the green building sector. CVB is now working with other YouthBuild programs throughout the United States to help them build greener. In the past year they have also developed a weatherization team, including professional Building Performance Institute (BPI) certification and Home Energy Rating System (HERS) certification.

One of the central challenges to CVB's work has been working with youth who have serious disconnection problems. Most come from troubled backgrounds that make concentration difficult. They also did not come to the program with a sense of environmental responsibility – even recycling seemed to be a foreign concept for most. However, as Halpin explains “we found that if we challenge them, they can do it under strong supervision.”¹⁵⁶ By the time they graduate, program leaders say that students are excited about promoting a more sustainable

¹⁵⁴ Dick Pierce, special programs officer of American Youth Works in 2005. “Spotlight on Casa Verde Builders” *YouthBuild Bulletin*, Fall 2005, p. 13

¹⁵⁵ Phone interview with Richard Halpin, June 17, 2008.

¹⁵⁶ Ibid.

way of life and have experienced firsthand that they can effect change.¹⁵⁷ Many appear to find related jobs, pursue higher education, and careers in environmental fields.¹⁵⁸

Perhaps this type of program could be replicated in rural areas outside of Austin, or some of the CVB weatherization crews could be employed as sub-contractors to do weatherization in the informal homestead settlements.

Austin Community College's Building Construction Technology Program

Austin Community College's Building Construction Technology Program prepares Central Texans for careers in the construction trades. Although the curriculum is not specifically advertised as a "green" building program, it has offered one green building elective for decades. BCT also acts on its commitment to green building by providing in depth information about building materials and practices and their relative environmental costs and benefits throughout its required classes.¹⁵⁹ BCT was the first community college in Texas to offer a green building class when Laurence Doxey, an internationally recognized green builder who developed the original concept for Austin's Green Building Program, began teaching one in 1985. At that time the focus was primarily on "building for energy conservation." The name has changed over the years – to "resource conservation" and "green building" now – but, with the exception of some passing green building trends, Heatwole says that most of the core principles have been taught consistently. The green building class usually involves at least one major hands-on project. Students have built strawbale houses in the past and regularly install some rainwater catchment systems on model structures.

Interest in green building is rapidly growing across the state. A decade after other Texas community colleges wanted Austin to keep green building to itself while they were all trying to standardize their curricula, many of those community colleges are now replicating Austin's green building course on their own campuses. If there are community colleges in rural areas near informal homestead settlements, they would have access to this curriculum.

Construction Gateway Program

The SkillPoint Alliance partners with the Austin Community College's Building and Construction Technology program to offer the Construction Gateway Program. This five-week, 11am-6pm "boot-camp" in the construction trades is made available free of charge to unemployed, underemployed, homeless or formerly incarcerated residents of Travis County.¹⁶⁰ Although Construction Gateway does not currently have a "green" focus, it has already been very successful in helping individuals with barriers to employment get on a track towards well-paying jobs with good benefits and opportunities for professional advancement. In 2008, the SkillPoint Alliance, ACC and other partners submitted a large grant proposal for Construction Gateway

¹⁵⁷ Dick Pierce, special programs officer of American Youth Works in 2005. "Spotlight on Casa Verde Builders" *YouthBuild Bulletin*, Fall 2005, p. 13

¹⁵⁸ Walsh, E. A. (2008). *Green Jobs for All: A Case Study of the Green Building Sector in Austin, TX*. Austin, TX: University of Texas at Austin.

¹⁵⁹ Ibid.

¹⁶⁰ <http://www.skillpointalliance.org/index.php?option=content&task=view&id=95>

Plus, which would take the existing Gateway program and add training in certain green building and renewable energy skill areas.¹⁶¹

In its current form, Construction Gateway is already having a transformative effect on Central Texans who participate in it and the employers who hire those graduates. As a graduate expressed at his commencement ceremony, signing up for Construction Gateway is “one of the best decisions of my life. It’s given me a foundation to choose a new path for me and my family.” The numbers support his assertion: 80% of graduates find jobs, 84% increased their wages from previous jobs, and 76% earned at least \$9 per hour. Annually, Construction Gateway offers eight five-week sessions for as many as 96 students, with over 800 graduates to date. Katie Kizziar, Director of Technology & Education Executive Council at Skillpoint, also notes that it is easier for individuals with criminal records to advance in many construction trades than in other careers. Master Electricians and Master Plumbers cannot have criminal records.¹⁶²

Designed to meet the training needs established by the National Center for Construction Education and Research (NCEER), Gateway builds its program off of the ACC Building Construction Technology (BCT) Program. Students receive hands-on training in blue print reading, construction math, site layout, roofing, electrical, plumbing, carpentry, sheet metal, masonry/concrete, and heating, ventilation, and air-conditioning (HVAC). The program is challenging and, according to one professor, “specifically designed to be too hard for any one person to do alone.” Through construction of a storage shed, students get to do everything involved with the construction of a house with high quality instruction. The approach naturally helps students develop pride in their highly visible work and get a full introduction to the trades that will help them choose a specialty.¹⁶³

Students also participate in employability workshops including resume preparation, job fairs, and job search skills training. Throughout the course of the program, students have many opportunities to meet with potential employers. SkillPoint also dedicates considerable staff time to maintaining a strong network of employers who hire students and advise on program adjustments. Post-graduation, SkillPoint continues to offer job-placement support through *WorkSource* career centers that help students connect with job opportunities. Students also graduate with Occupational Safety and Health Administration (OSHA) construction site safety certification, Red Cross cardiopulmonary resuscitation/automated external defibrillation (CPR/AED) certification, and First Aid certification, following training in these areas. At their graduation ceremony, students are also awarded with nine college credit hours from ACC, a Marketable Skills Award from ACC’s BCT program, and six months of credit towards an Associated Builders and Contractors (ABC) sponsored apprenticeship program. As Miller says, students graduate “imminently qualified to go get a job.” Construction Gateway’s rigorous program emphasizes both hard and soft skills needed to excel in the construction field. As Ed

¹⁶¹ Walsh, E. A. (2008). *Green Jobs for All: A Case Study of the Green Building Sector in Austin, TX*. Austin, TX: University of Texas at Austin.

¹⁶² Ibid.

¹⁶³ Walsh, E. A. (2008). *Green Jobs for All: A Case Study of the Green Building Sector in Austin, TX*. Austin, TX: University of Texas at Austin

Miller, adjunct professor and leader of Gateway Construction, puts it, Gateway is “not just about construction – it’s also about how to be a valued employee.”¹⁶⁴

1House At A Time

While the previous examples of training programs have an explicit and singular focus on training green building professionals, 1House At A Time is a nonprofit organization that focuses primarily on building local community capacity for implementation of sustainable technologies and behaviors, house-by-house, through the efforts of volunteers and green building professionals in training. The 1House model first trains teams of volunteers in best practices (technologies and behaviors) for sustainable homes and the volunteers. After the volunteers learn how to implement these practices, they apply and share this knowledge with low-income households living in resource-inefficient homes *and* commit to doing the same in their own homes. 1House also offers solar installations when applicable, using the volunteer labor of students in ACC’s renewable energy programs. This supervised training helps prepare them for future careers. For more information on 1House At A Time, see <http://www.1houseatatime.org/>.

This model holds significant potential for informal housing settlements, as long as there is enough social capital and free time for people to make volunteer time commitments. 1House At A Time also provides technologies at no cost to the recipients. Finding continued financial support for these interventions may be difficult.

¹⁶⁴ Ibid.

APPENDIX D1: SAMPLE LAND REGULATIONS: SAN MARCOS ETJ

Both of our study areas, Rancho Vista and Redwood, are located within the extraterritorial jurisdiction of San Marcos. The City of San Marcos has issued specific regulations applicable to its ETJ. The San Marcos Municipal Code, Part II, Subpart B, Chapter 2, Article 1, "Development in the Extraterritorial Jurisdiction", §2.1.1.1 establishes the regulatory standards governing land use and development within the ETJ. Namely, municipal ordinances on water quality and certain municipal environmental standards are made to apply. Nonetheless, these regulations are rather limited and generally target new development at a much larger scale than the communities targeted by this study. Most of the extensions of San Marcos' municipal ordinances into the ETJ are only permissible in situations of specific developer agreements, and the water regulations that are generally applicable have to do more with municipal servicing and Texas Commission on Environmental Quality (TCEQ) standards for municipal utilities and development than the construction of individual septic systems, etc. Some state-level regulation of sewage and septic systems will apply, however (see below).¹⁶⁵

In addition, Article 8, Chapter 6 of the Land Development Code establishes standards for manufactured homes, mobile homes, and recreational vehicle parks that are applied to the San Marcos ETJ. The Section 6.8.1.2 defines the design requirements that any mobile home or manufactured housing park or any extension or addition to it constructed after the effective date of the ordinance from which this Section derives should follow. This regulation also establishes minimum space requirements, particularly concerning to lot and dwelling size, soil and ground cover, drainage, and the usage of accessory buildings which, by definition, are detached from the main building and used as a washroom, storage room or garage. However, as we stated before, the Texas Local Government Code Sec. 212.049, that regulates building permits in extraterritorial jurisdiction, establishes that municipalities are not authorized to require municipal permits or enforce the municipality's building code in its extraterritorial jurisdiction.

Occupations Code

The Texas Manufactured Housing Standards Act contains other provisions that can be also applied to the Rancho Vista and Redwood communities and similar low-income communities in Texas. §1201.302 prescribes that the director may by contract provide for a Federal agency or an agency or political subdivision of Texas or another state to perform an inspection or inspection program. The purpose of these inspections is to ensure that a manufactured home sold or installed in Texas complies with the standards code.

¹⁶⁵ In the City Limits and 3 1/2 -Mile Extraterritorial Jurisdiction Map, Rancho Vista and Redwood lie within the extraterritorial jurisdiction. See map attached.

APPENDIX D2 : TEXAS COMMISSION OF ENVIRONMENTAL QUALITY ADMINISTRATIVE CODE, WATER AND WASTEWATER

Water and Wastewater Permitting Considerations

In addition to the general regulatory powers of local jurisdictions, the Texas Administrative Code, Title 30, Part One, Chapter 90 is potentially relevant when considering low-income sustainable housing regulations. This chapter deals with innovative programs for dealing with pollution as part of implementation of TCEQ's authority under Texas Water Code to provide regulatory flexibility to an applicant who proposes an alternative method or alternative standard to control or abate pollution and its authority relating to Environmental Management Systems. The previously mentioned regulatory flexibility entails that for a sustainable self-help project a community proposing innovative treatment of pollutants and environmental hazards would be allowed to avoid certain regulatory requirements regarding these issues. Any such project must not be inconsistent with federal law, including any requirement for a federally approved or authorized program and must include documented evidence of the benefits to environmental quality that will result from the proposal.

It should be noted that this statute and TCEQ's activities in this arena are largely within industrial and business sectors, and it is almost certainly the case that the majority of TCEQ's dealings are with corporate and industrial actors polluting on a large scale. Nonetheless, at first glance, the statutory language seems inclusive enough to allow for even small communities or individual homeowners even to avoid certain regulatory issues related to environmental pollutants and water quality.

In the same Title, Part 1, Chapter 332 on Composting, the purpose of the chapter notes that it seeks to "establish regulations that will divert organic material from the typical solid waste stream, and promote the beneficial re-use of those material while maintaining standards for human health and safety and environmental protection. The general requirements for composting shall comply with the Texas Water Code, Chapter 7 to prevent the discharge of material to or the pollution of surface water or groundwater." In this chapter it is also mentioned that "composting, mulching, and land application of material shall be conducted in a sanitary manner that shall prevent the creation of nuisance conditions as defined in 330.2 of the same title and as prohibited by the Texas Health and Safety Code, Chapter 341 and 382." If a given project seeking to implement low-cost sustainable technologies such as composting, it will be exempt from permitting or licensing requirements due to the "backyard composting" nature of the project. It is interesting enough to note, however, that neighborhood level composting is contemplated and may be considered equivalent to "backyard" composting as long as the combined annual output of the neighborhood composting is less than or equal to 50 cubic yards per year. However, it is unforeseeable that it would cause any actual alarm or censure were a neighborhood to actually exceed this, as, again, the statute is intended more for commercial or industrial enterprises.

Finally, in Title 10, governing the Texas Department of Housing and Community Affairs (TDHCA) Chapter 5 on Community Affairs Programs describes the Comprehensive Energy Assistance Program, which among its other purposes is to assist low income households in meeting their immediate home energy needs. These services include: energy education, needs assessment, budget counseling, utility payment assistance and heating and cooling system replacement.

APPENDIX D3: TEXAS STATE LEGISLATIVE EFFORTS IN COLONIAS AND RURAL AREAS

Pertaining to Waste and Wastewater Service and Management

Senate Bill 2, 1989

Created Economically Distressed Areas Program (EDAP) to provide water and wastewater services to counties bordering Mexico and within bottom 25% of income and top 25% in unemployment. A *colonia* is eligible if 80% of the lots are occupied.

Government agency responsible for administering grants: Texas Water Development Board (TWDB)

Agency responsible for proposals: Local counties

- Adopted Model Subdivision Rules that require water and wastewater service to be installed in any new rural subdivision before seeking final plat approval
- Assure adequate drinking-water supply
- Prohibit establishment of lots of five acres or less without proper water/wastewater service
- Prohibit construction of more than one detached single- family home per lot
- Establish setbacks.

Analysis - HB 2 has several problems, most of which deal with the narrow locations and definition of a *colonia*. EDAP requires that an area can only be along the border and that the entire county must be very poor. It also discourages densification or families sharing lots.

Senate Bill 818, 1991

Established *Colonia* Plumbing Loan Program to offer low- interest loans for water/wastewater systems and indoor plumbing improvements

Government agency responsible for funding: The U.S. Environmental Protection Agency (EPA)

Analysis - While self- help and government assistance is sometimes a positive solution, in many cases shifting the burden to the homeowner/individual of providing utilities, which should either fall on government or developers, may be a questionable precedent to set.

House Bill 997, 1993

Encouraged regional projects to increase efficiency and lowered EDAP *colonia* lot occupancy from 80 to 50 percent if involved in regional project

Pertaining to Land Regulation: Stopping Future Colonia Development or Renewing Colonias

House Bill 1001, 1995

Counties had to apply Model Subdivision Rules to subdivisions outside extraterritorial jurisdiction if there are more than 4 lots

- Prohibits sales of subdivided lots in specific counties if without water/wastewater service and if not platted according to model subdivision rules
- Subdividers must provide bilingual explanations of service delivery; plats must be certified by engineer or surveyor to ensure following of rules and standards
- Prohibits delivery of natural gas and electric service to subdivisions without water/wastewater
- Strengthens enforcement and allows for criminal and civil penalties leveled against violators of model subdivision laws
- Restricted ability to grant exemptions from following these rules.

Government agency responsible for legal enforcement: Office of the Attorney General

Analysis – This bill largely inhibits density. Economically speaking, one way to address service delivery and in a properly planned development, impervious cover (shared roads, utility runs, etc.) is to maximize density. Additionally:

... there is a continuing and urgent need (and opportunity) to settle new families in *colonias*, if only to raise the threshold of population that will make further public- and private- sector improvements financially viable, and to enhance cost recovery that will help to retire existing bonds and finance new ones...current legislation inhibits the sale of unsold lots, particularly in those *colonias* which are not fully serviced, thereby making densification in such cases even less likely.¹⁶⁶

To the extent that plot occupancy and electricity installation may be inhibited, it seems that good faith efforts like HB 1001 may exacerbate the problem rather than relieve it. Creating alternative land strategies that embrace the realities that cause a problem and working within that understanding to find solutions seems necessary in this situation. This may mean creating a density or overall land- use map that is different for what people may expect for this area.

House Bill 2079, 1993

Authorizes counties to solicit help to enforce state health and safety laws related to nuisance and on- site sewage issues.

Allows for Injunctions levied against violators of subdivision rules and lawsuits for damages

Government agency responsible for enforcement: Office of the Attorney General

Senate Bill 1512, 1997

Permits some *colonia* residents to apply for utility service, even if residents are non-compliant with Model Subdivision rules.

¹⁶⁶ Ward, Peter. (1999) *Colonias and Public Policy in Texas and Mexico: Urbanization by Stealth*. Austin: The University of Texas Press, p. 245.

Senate Bill 89, 1999

Revises the municipal annexation process to require cities to implement advance annexation planning procedures and ensure the timely provision of services to the annexed areas; provides penalties for violations.

House Bill 1982, 1999

Allows *colonias* to participate in state- funded programs for a period of five years after being annexed by a city to encourage municipal annexation of *colonias* by alleviating some of the financial burden on the city

House Bill 1053, 2001

Authorizes municipalities and counties to create commercial and industrial development zones in areas of pervasive poverty, unemployment, or economic distress to promote and encourage commercial and business development

Analysis - In reference to *colonia* nonproliferation through land regulation, Esparza and Donelson write, "It is important to remember, however, that many of these land use regulations came on board long after communities were in place. As such, they will influence future growth and development but will not affect existing conditions."¹⁶⁷

Pertaining to Education and Assistance

House Bill 2726, 1995 (Colonias Legislation : History and Results, 5).

Converts Contract for Deeds (CFDs) into mortgages

Government agency responsible for implementation: The Texas Department of Housing and Community Affairs (TDHCA)

Senate Bill 1509, 1995 Establish self- help centers in *colonias* along border, assisting with home building and maintenance, loan and grant for home counseling, and infrastructure achievement guidance

Government agency responsible for implementation: The Texas Department of Housing and Community Affairs (TDHCA)

Analysis – Should establish smaller self- help centers in areas outside of border where there is a recurrence of *colonia* developments

House Bill 2252, 1997

Provides funding to a variety of *colonia*- related social service programs

¹⁶⁷ Esparza and Donelson. (2008). *Colonias in Arizona and Mexico: Border Poverty and Community Development*. The University of Arizona Press, p. 32.

Agency responsible: Centers for Housing and Urban Development

House Bill 540, 1997

Provides for educational programs to be offered to *colonia* residents

Government agency responsible: Texas Department of Housing and Community Affairs

Senate Bill 1287, 1999

Provide housing loans to low- income owner- builders through the *colonia* self- help centers

Government agency responsible: Texas Department of Housing and Community Affairs

Recommendations

- Strip all *colonia* definitions of place- specific and county economic markers, so that problem can be treated on a case- by- case basis.
- While most *colonias* occur on the border, due to economic pressure, current laws make it so there is no state enforcement or federal/county funds for *colonias* outside of populated areas. Cities often create circumstances where *colonias* could develop and Texas needs to adjust its law- making to account for that reality.
- Encourage community and environmental regime involvement.

APPENDIX E1: INNOVATIVE FINANCING FOR SUSTAINABLE TECHNOLOGIES WITH HIGH PAYBACK

As our energy and other resource supplies diminish in quantity and their prices increase, investments in sustainable technologies will have increasingly significant positive rates of return. When these rates of return are high but upfront costs are still a barrier for some households, opportunities emerge for strategic public and private investments to bridge the gap. Even today, the rate of return for residential energy efficiency interventions is significant. According to the American Council for an Energy Efficient Economy, energy efficiency interventions have a better return and lower risk than corporate bonds, common stocks, and small company stocks (the average annual rate of return is 22%, with 5% year-to-year volatility).¹⁶⁸ Since the rate of return for many energy-efficiency interventions is already high compared to upfront costs, there are already innovative financing programs emerging throughout the country, notably in Milwaukee, WI (the Me2 program) and in Portland, OR.

On-Bill Financing: An Overview

In Portland, the new Clean Energy Works program is using “on-bill financing,” an innovative approach that allows residents to weatherize their homes with no upfront costs and pay for the interventions over time through their utility bill payments. The program begins with an energy audit by a Home Performance contractor and a home visit by an Energy Advocate to determine the potential energy and cost saving available through weatherization. If the savings meet threshold requirements, the Energy Advocate sends documentation to the lender for loan processing. Once approved, the lender notifies the contractor and homeowner to commence work. The lender pays the contractor directly and the homeowner receives a monthly charge that corresponds with the energy savings generated by the retrofit. To date, loans have averaged roughly \$9000 with monthly payments \$46 on average.¹⁶⁹

The financing mechanism for this program involves partnerships between public, private, and non-profit organizations. The City of Portland and outside investors created a \$2.5 million revolving loan fund, cobbled together with federal stimulus funds. Socially responsible investors interested in economic, environmental, and social gains find can expect a safe yet modest 2-3 rate of return on their investment. The revolving loan fund is managed by a Community Development Financial Institution, which administers loans and pays contractors. The utility companies agree to collect payments for the loans as part of the utility bill and send these payments to the bank for loan re-payment.¹⁷⁰

¹⁶⁸ Laitner, J. A., Karen, E.-M., & Prindle, W. R. (2007, April). The American Energy Efficiency Investment Market: A White Paper Prepared for the Energy Efficiency Finance Forum. Retrieved April 12, 2010, from ACEEE: <http://www.aceee.org/conf/07finance/financeforumwp.pdf>

¹⁶⁹ Green for All. (2010). Clean Energy Works Portland: A National Model for Energy-Efficiency Retrofits. Oakland, CA: Green for All.

¹⁷⁰ Ibid.

Limitations of Model: Innovative funding mechanisms like the revolving loan fund in Portland have the potential to increase the rate of adoption of weatherization retrofits and other sustainable technologies with high payback rates. However, this model may be significantly constrained in informal homestead settlements and other low-income communities for several reasons. First, in order for the loan to be approved, the energy audit must reveal that there will be a viable rate of return from investment in weatherization (where the rate of return is based on a calculation of energy savings) and that the household can pay off the loan (reflected by past payment record on utility bills). Unfortunately, in older homes in disrepair, the investment needed to make a home weatherization-ready may be more significant than in more well off neighborhoods. Additionally, the rate of return calculation is based on past utility bill history and if a household was refraining from using the air conditioner or other energy intensive appliances in order to save money, their bills may be artificially low and future savings would be difficult to demonstrate. Second, if households had such significant energy burdens in the past that they were unable to make utility payments reliably, they may not be approved.

APPENDIX E2: ELIGIBILITY FOR USDA DIRECT HOUSING LOANS

Income Limits/Eligibility Criteria for Direct Housing Loans			
	San Antonio, TX MSA	Austin-Round Rock, TX MSA	Houston-Sugar Land-Baytown, TX MSA
One Person			
Very Low Income	\$17,550	\$25,650	\$20,300
Low Income	\$28,050	\$41,050	\$32,500
Adjusted Median Income	\$35,100	\$51,300	\$40,600
Five People			
Very Low Income	\$27,050	\$39,600	\$31,300
Low Income	\$43,300	\$63,350	\$50,100
Adjusted Median Income	\$54,100	\$79,200	\$62,600
From http://www.rurdev.usda.gov/RHS/sfh/DSFH_Income_Limits/TX%20Direct.pdf			

APPENDIX E3: GUIDELINES FOR WEATHERIZATION ASSISTANCE PROGRAM FUNDS

The U.S. Department of Energy funds and manages the WAP federally. Funds from this program are typically coupled with funds from the Low Income Home Energy Assistance Program (LIHEAP) and support from Investor Owned Utility program (IOU) funds to expand the toolkit of energy efficiency interventions available to each household. While WAP funding tends to focus more on building related interventions, LIHEAP provides funding directly for appliance replacement. In Texas, the Texas Department of Housing and Community Affairs' (TDHCA's) Weatherization Assistance Program is responsible for allocating these funds.

Once TDHCA receives the funds, it distributes them to sub-recipients throughout the state who then manage contractors to deliver a variety of weatherization services. These services include:

- Energy audits, wherein a skilled building rater will use a computer program to enter in building and site specific information to determine the potential for energy savings through different types of interventions;
- Tightening of the building envelope, including caulking, weather-stripping, additional insulation in ceilings, floors and walls, patching modest holes in the building envelope,
- Improvement of heating and cooling systems, including duct work and tune up, repair or replacement of energy inefficient heating and cooling systems

Households are only eligible for such services if they are their home meet certain requirements:

- Services are only available for low-income households and the elderly, disabled, and very young are given priority;
- The home must be structurally sound and free of immediate indoor air quality threats such as unvented combustion appliances (although if a home's primary heating system is based on unvented space heaters, DOE funds can be used to replace the primary heating system).
- Specific measures implemented depend on the energy audit's cost-benefit analysis: interventions must be demonstrated to have a benefit/cost ratio of at least 1.
- Materials and technology choices are also subject to restrictions.¹⁷¹
- If a home's primary heating system is based on unvented space heaters, DOE funds can be used to replace the primary heating system.

¹⁷¹ <http://www.waptac.org/si.asp?id=496>

APPENDIX E4: LOCAL UTILITY INCENTIVE PROGRAMS

Local Utility Incentive Programs*		
AEP SWEPCO - Commercial Solutions Program	AEP SWEPCO - SCORE Program	AEP SWEPCO - Smart Source PV Rebate Program
AEP Texas Central Company - CitySmart Program	AEP Texas Central Company - Commercial Solutions Program	AEP Texas Central Company - SCORE Program
AEP Texas Central Company - Smart Source PV Rebate Program	AEP Texas North Company - CitySmart Program	AEP Texas North Company - Commercial Solutions Program
AEP Texas North Company - SCORE Program	AEP Texas North Company - Smart Source PV Rebate Program	American Electric Power - Standard Offer Demand Response Program
Austin Energy - Commercial Energy Management Rebate Program	Austin Energy - Commercial New Construction Efficiency Rebates	Austin Energy - Energy Miser Vending Products Program
Austin Energy - Free Home Energy Improvements Program	Austin Energy - Multi-Family Energy Efficiency Rebate Program	Austin Energy - Residential Energy Efficiency Rebate Program
Austin Energy - Residential Solar PV Rebate Program	Austin Energy - Small Business Energy Efficiency Rebate Program	Austin Energy - Solar Water Heating Rebate
Bryan Texas Utilities - Commercial Lighting Program	Bryan Texas Utilities - Solar Hot Water Rebate Program	Bryan Texas Utilities - Solar PV Rebate Program
CenterPoint Energy - CitySmart Program	CenterPoint Energy - Commercial and Industrial Standard Offer Program	CenterPoint Energy - Residential and Small Commercial Standard Offer Program
CenterPoint Energy - SCORE Program	College Station Utilities - Residential Energy Back II Rebate Program	CPS Energy - Commercial Energy Efficiency Rebates
CPS Energy - Residential Energy Efficiency Rebate Program	CPS Energy - Solar Hot Water Rebate Program	CPS Energy - Solar PV Rebate Program
Denton Municipal Electric - GreenSense Energy Efficiency Rebate Program	Denton Municipal Electric - GreenSense Solar Rebate Program	Denton Municipal Electric - Standard Offer Rebate Program
El Paso Electric Company - Commercial and Industrial Standard Offer Program	El Paso Electric Company - Residential Standard Offer Program	Entergy Texas - CitySmart Program
Entergy Texas - Energy Star Homes Program for Builders	Entergy Texas - Large Commercial and Industrial Standard Offer Program	Entergy Texas - Residential and Small Commercial Standard Offer Program
Entergy Texas - Solar PV Pilot Program	Farmers Electric Cooperative - Marathon Water Heater Rebate Program	Farmers Electric Cooperative - Residential/Agricultural Energy Efficiency Rebate Program
Garland Power & Light: Energy Efficiency Rebate Programs	Guadalupe Valley Electric Cooperative - Renewable Energy Rebates	Guadalupe Valley Electric Cooperative - Residential Energy Efficiency Rebate Programs
Magic Valley Electric Cooperative - Value Incentives Program (VIP)	New Braunfels Utilities - Energy Efficiency and Water Conservation Rebate Programs	Oncor Electric Delivery - Energy Star Homes Program
Oncor Electric Delivery - Home Energy Efficiency Rebate Program	Oncor Electric Delivery - Large Commercial and Industrial Rebate Program	Oncor Electric Delivery - PV Incentive Program
Oncor Electric Delivery - Solar Water Heating Incentive Program	Pedernales Electric Cooperative - Commercial Lighting Rebate Program	Pedernales Electric Cooperative - HVAC Rebate Program
Texas Gas Service - Commercial WashWise Energy Efficiency Rebate Program	Texas Gas Service - Commercial Water Heating Energy Efficiency Program	Texas Gas Service - Food Service Equipment Program
Texas Gas Service - Residential Energy Efficiency Rebate Program	Texas New Mexico Power Company - Solar PV Pilot Program	Texas-New Mexico Power Company - Commercial and Industrial Energy Efficiency Standard Offer Program
Texas-New Mexico Power Company - Energy Star Homes Market Transformation Program	Texas-New Mexico Power Company - Residential and Small Commercial Energy Efficiency Standard Offer Program	Tri-County Electric Cooperative - Energy Efficient Water Heater Rebate Program
United Cooperative Services - Residential Energy Efficiency Rebate Program	Xcel Energy - Large Commercial and Industrial Standard Offer Program	Xcel Energy - Residential & Small Commercial and Hard-to-Reach Standard Offer Program
<p>* From http://www.dsireusa.org/incentives/index.cfm?re=1&ee=1&spv=0&st=0&srp=1&state=TX Each link goes to an explanation of each individual utility program</p>		

