THE AUSTIN GREEN BUILDING PROGRAM: AN ANALYSIS OF THE PROGRAM'S EFFECTIVENESS

A Dissertation

by

AUDREY KRISTEN TINKER

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

December 2003

Major Subject: Architecture

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ABSTRACT

The Austin Green Building Program: An Analysis of the Program's Effectiveness.
(December 2003)
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Current water shortages in the United States and Texas are expected to only worsen so that by 2050, approximately 40% of both U.S. and Texas residents will live in areas of water scarcity (U.S. House Committee, 2003; Texas Water Development Board, 2003). In response to these grim projections, both lawmakers and environmentalists are calling for conservation measures so that future shortages or costly new supply initiatives are avoided. One area where substantial consumption decreases could be made is the municipal sector, which is projected to account for 35% of all water consumed in Texas by 2050 (Texas Water Development Board, 2002). Both organizations and voluntary programs have been established to reduce water consumption in this area. One of the largest and most innovative programs in the state is the Austin Green Building Program (AGBP). It was the first program of its kind in the U.S. that rates new homes and remodels in regards to five categories related to sustainability: energy efficiency, water efficiency, materials efficiency, health and safety and community (City of Austin, 2001).

This research identified the factors (weather, home size, lot size, appraised value, and existence of a pool) that effect water consumption for residences qualifying as "Austin Green Homes", and identified those green features or designs that had the greatest effect on water consumption, that were most commonly included, and the reasons why contractors incorporated them. Non-green features such as temperature, rainfall, home and lot size, appraised value and a pool seemed to have the greatest impact on water consumption, from an analysis of R^2 values, albeit a positive relation for each variable. When green features were investigated, findings showed that different features were effective in reducing water consumption for different builders and in many cases, water-conserving features actually led to increased use. Finally, results showed that large builders incorporated fewer water-related green features in their homes and achieved lower star ratings in general than small green builders.

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INTRODUCTION

Significance of the Study

This research proposes to identify the factors that effect water consumption for residences qualifying as "Green Homes" through the nation's oldest functioning green building program, the Austin Green Building Program, and to identify those features or designs that have the greatest effect on water consumption, are most commonly included and the reasons why contractors incorporate them. In response to environmental scares of shortages and pollution, green programs have begun proliferating throughout the country. The question is: are these programs really making a difference in regards to resource conservation? If not, projections that estimate that almost 40% of the U.S. population will live in areas with water shortages by 2050 will come to fruition (U.S. House Committee, 2003). This could result in huge expenditures as cities scurry to find and create new water resources. Additionally, as is already occurring in many cities, growth will be restricted because insufficient water supplies are available for new development. On the bright side, if green programs are succeeding, an analysis of feature effects could serve as proof for future programs and homeowners that time and money invested both in the programs and homes for the sake of green development is worthwhile. Very few studies have been conducted concerning the effectiveness of these programs. Thus, proactive research must be conducted to either show that the programs are successful, leading to greater implementation around the country, or demonstrate otherwise, and then corrective action must be taken to ensure conservation.

Background

The availability of water within the State of Texas is attracting increased attention and

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action. Periodic drought conditions and a population that is expected to double over the next 50 years are causing concern for water suppliers from districts throughout the state (Texas Water Development Board, 2002). In fact, projections to 2050 used in the 2002 State Water Plan show that in drought conditions, 43% of the state's municipal demand will not be met. Thus a great need exists for a more sustainable approach to water usage and increased conservation (Texas State Soil and Water Conservation Board & Texas Water Development Board, 2002).

The City of Austin stands out as a leader in sustainable construction and development, including water conservation, in Texas and around the country. The City has developed and accepted a Sustainable Communities Initiative which since 1996 has created plans, performed evaluations and educated city staff and the public on ways to make the city more sustainable. Besides the Sustainable Communities Initiative, the City of Austin leads the country in sustainable practices through its numerous other programs such as the Green Building Program, Water Conservation Program, Air Quality Program, Watershed Protection Department, 'Dillo Dirt program, Smart Growth Initiatives and Recycling Programs (City of Austin's Sustainable Communities Initiative, 2001).

One of he City's most well-known programs is the Austin Green Builder Program. It was the first sustainable residential program developed in the country and has now spread into other areas of construction and development. The Program uses a weighted point scale to grade homes on a level of one to five stars. Certain measures or products incorporated into a home are assigned point values (Austin Green Building Program, n.d.) related to their supposed benefit to the environment. These point values were subjectively assigned by a panel of experts at the Austin Energy department. Points are then totaled and star-ratings awarded based on predetermined point ranges. The single-family Green Builder checklist is included in Appendix B.

Statement of the Problem

This research is needed in order to determine what designs, products or absence there of reduce residential water consumption in the Austin area. Many claims have been made that items such as Xeriscape and rainwater collection systems reduce consumption, but site studies have not been done to provide evidence. The Austin Green Builder program currently awards points for these two items as well as other water conservation features and the effectiveness of each feature should be verified so that builders have evidence to provide to homeowners and program organizers have information on the success or deficiencies of the program.

Finally, developers and municipalities should be aware of which items can reduce water consumption so they can incorporate these measures into their plans. This could lead to reductions in water infrastructure, possible permission to build in sensitive areas where water is a concern and possible tax credits or incentives to developers who design per the water-saving guidelines. Proof and implementation of water conserving features could save cities and developers money in infrastructure and maintenance costs and provide opportunities for developers that may have been restricted otherwise. Additionally, if the decision makers on future developments accept and utilize water saving ideas, water supplies could be minimally impacted, thus saving ecosystems and money required to create future water sources.

Definitions

The Austin Green Building Program incorporates the following ideas and terms in their philosophy:

- Green. A term synonymous with sustainability, meaning minimal ecological impact (Talarico, 1998).

- Sustainable design. Designing a structure with the intention of minimizing the building's impact on the environment.

Format

To keep the study and findings more manageable, research was divided into four sections, each contributing to answering questions on the effectiveness of the Program. The first section involves an analysis of trends and frequencies in the incorporation of green builder items into rated homes. Both the most and least frequently included checklist items are analyzed with an assessment made in regards to the cost of each feature to include. Trends in item popularity are also included with both those that have increased during recent years and those that have declined. Proposed answers to why items are more or less frequently included or why they change in popularity are also addressed. Finally, a telephone survey of all participating Program builders was conducted to assess why they participate in the program, how they decide which items to incorporate in their homes and their level of commitment.

The second study investigates the weather conditions and home/property characteristics that effect water consumption among Austin Green Building homes. This study was conducted for two reasons. First, for conservation programs or requirements to be effective, sources of current water consumption must be identified. Secondly, the study will illustrate the magnitude of the effect for non-program related variables, so that the exact effects of the AGBP water-related checklist items can then be assessed.

Next, the third study investigates the effects of Austin Green Building Program water-related checklist items on monthly water consumption in green homes. Information on green feature incorporation was provided by the Austin Energy department. Regression will be used to develop a formula for predicting water consumption based on a variety of

Program and extraneous water-related items. The formula should also indicate the effects each item has on water consumption – either positive or negative.

Lastly, an in-depth analysis of builder group differences will be conducted to determine the significance of various builders and their practices on green home water consumption and to identify which builders reduce water consumption in comparison to others.

Hypotheses

The first hypothesis is that builders choose to participate in the Austin Green Builder Program to differentiate themselves from the competition and to charge more for a home because of the value added in life-cycle savings. The choice of green features they include is affected by the builder's familiarity with the product or concept and its cost (with less expensive items being more popular).

The second hypothesis is that weather and lot size will have a significant affect on green household water consumption.

The third hypothesis is that twenty-seven measures, with a majority from the Austin Green Building Program builder checklist, significantly affect water consumption. However some, such as the use of a minimum 90% Xeriscape and/or 50% natural landscape, inclusion of a rainwater catchment system and landscape irrigated with reclaimed water, are expected to have a greater effect in reducing water consumption than others.

The fourth hypothesis is that small builders will experiment with new and a variety of green technologies/features and will take time to ensure the products installed or designs implemented perform as expected. Thus, more water conservation will take place in the homes of small builders as opposed to larger builders.

Objective

The hope in this study is to determine which green features are being included in Austin Green Building Program homes and the effect water-related features have on household water consumption. If some features within the Program are found to effectively reduce water consumption, then these items might either be awarded higher point values to encourage their incorporation or features which have no or a positive effect on water consumption might be removed or improved. Additionally, if some items are found to significantly reduce water consumption for some builders and not for others, then practices of the successful builders should be investigated and their strategies either mirrored or incorporated into the plans of other builders experiencing ineffective results.

CONTRACTOR MOTIVATION AND TRENDS IN
AUSTIN'S GREEN BUILDER PROGRAM

The purpose of this paper is to describe and assess one of the first comprehensive residential green-builder programs in the U.S., comparing trends of green building items used in residential construction during the past five years and surveying participating builders to determine why they participate, chose to incorporate the items that they do and their level of commitment . This description provides a baseline of strategies to investigate the effect of this program in developing sustainable communities. The study population was analyzed from a database comprising all registered "green" residences built during 1998-2002 in the greater Austin, Texas area (2,335 homes and 73 listed builders). Almost half the builders constructed just one "green" home, whereas two builders built almost 75% of the green homes during the 5-year study period. Only seven homes received a perfect 5-star rating (less than 1%), whereas 87% of the homes were rated 1 or 2 stars. The frequency of implementing the 122 green features were compared for trends over time and analyzed for their correlation with cost and star-value. Findings showed that cost was the significant factor in item use frequency. Builders revealed many insights in the survey, but for the most part concurred that the program was successful and especially beneficial to homeowners while participation generally required more work with little financial reward for the builders themselves. Thus, the findings reveal that cost is still one of the most important issues for homeowners, and thus, builders as they try to work with or attract clients. While much can be done with low-cost environmental solutions, long-term interests may be better served with the incorporation of some or many higher cost features (BuildingGreen, Inc., 1999). Additional public education is needed so that present and future homeowners will begin to consider long term benefits. This may then encourage builders to incorporate even more green features to benefit the environment.

Background

Need for Sustainable Development

In response to environmental scares of shortages and pollution, green residential programs have begun proliferating throughout the country. The question is: are these programs really making a difference in regards to resource conservation? Significant increases in home construction (from 80 million to 112 million from 1980 to 1998) (Household and Housing Unit Estimates, 1999), as well as home size (from an average of 1,400sf in 1970 to 2,200sf in 2001) (What is the Average Home Size, 2001) progressively result in the displacement of important ecosystems and habitats. Also, the use of inexpensive synthetic building products, many of which have never been tested, is increasing indoor air pollution which is considered by the EPA as one of the "most serious potential environmental risks to human health" (Baker, Elliott, & Banta, 1998). Projections estimate that almost 40% of the U.S. population will live in areas with water shortages by 2050 (U.S. House Committee, 2003), not to mention damages to the environment caused by lack of water or in the construction of new water resources. Estimates predict that the United States' demand for energy will outpace the supply as soon as 2020 and emissions from the use of fossil fuels will increase over 40% by 2010 (Valone, 2003). With these bleak projections, it seems imperative to stop these trends of environmental destruction. Thus, we need to better understand factors that encourage green building.

For green programs to succeed and expand, an analysis of feature incorporation could serve as proof for future programs and homeowners that time and money invested both in the programs and homes for the sake of green development is worthwhile. This research proposes to identify which environmental features are most commonly included and the reasons why contractors incorporate them in residences qualifying as "Green Homes" through the nation's oldest functioning green building program, the Austin

Green Building Program. From this analysis, baseline trends and the extent of builder involvement will be evaluated for this innovative Program so that an assessment can be made as to whether such programs really make a difference in turning the tides of resource depletion.

Definition of Green Construction/Green Builder

The exact definition of green construction varies among sources and people. Many define green as synonymous with sustainability (Talarico, 1998). Steve Loken, keynote speaker at the 1999 Green Building Conference in Denver, said that green building is the "appropriate use of technology and resources" (Defining What "Green" Means, 1999). The United Nations' Bruntland Commission (World Commission on Environment and Development, 1987) defined sustainable development as "Development which meets the needs of the present without compromising the ability of future generations to meet their own needs." Adapting this community development definition to building construction, Burt (2002) defined sustainable construction as "those materials and methods used to construct and maintain a structure that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Thus, green construction is not merely a component-by-component substitution for traditional building products, but is instead, a "whole-building" approach to design (Bynum, 1999), that takes into consideration not only construction techniques, but also reduced energy consumption, protection of ecosystems and occupant health (Environmental Building News, 2001). The U.S. Green Building Council, creators of the Leadership in Energy and Environmental Design (LEED) "green" commercial building program, defined green building as the "design and construction practices that significantly reduce or eliminate the negative impact of buildings on the environment and occupants in five broad areas:

- sustainable site planning,
- safeguarding water and water efficiency,

- energy efficiency and renewable energy,
- conservation of materials and resources, and
- indoor environmental quality" (USGBC, 2003)

A description of the green building program in Austin, Texas provides a unique opportunity to better understand the scope and characteristics of one of the nations' earliest and most comprehensive residential green-building programs.

History of the Austin Green Builder Program

Austin, Texas has been ahead of the sustainability curve since the 1980's. The city launched its first green program in 1985, the Austin Energy Star Program, which gave marketing assistance to builders who exceeded sustainability-related criteria in the City's Energy Code. Over 6,000 homes were rated under this program (Green Building Program, 2001). However, in the early 1990's, the city decided more could be done to stop the environmental damage caused by development and construction. With the assistance of several green movement leaders in the Austin area, the City's Green Building Program was created to promote alternative building techniques and environmental education for residential construction-related activities (Green Building Program, 2001). More than 2,300 homes have been certified as "green homes" and over 70 builders have had homes qualified through the Austin Program. Some builders have had several hundred homes qualified for this program. Austin's Program received the "2002 Green Builder Program of the Year" award at the first International Green Builders Conference.

Green Building Rating System

The Austin Green Building Program rates new and remodeled homes according to five main categories: (City of Austin, 2001)

1. energy efficiency,
2. water efficiency,

3. materials efficiency,
4. health and safety,
5. community.

The Program calculates a total score on a scale of 1 to 5 stars, with higher scores indicating a greater number of features and/or incorporating features with higher point value. Designated green features, such as double pane windows, total fill insulation, natural flooring and Xeriscape are assigned point values ranging from 1 to 6. The point value assigned to each green feature was determined by a panel of experts from the Austin Energy Department and has undergone several revisions. Thirteen basic requirements must be completed for all homes to be included in the program:

1. Durable finish for at least 80% of exterior walls
2. One recycled-content material (min.50%recycled)
3. City of Austin Energy Code requirements met including the Shading Code
4. Efficient and effective cooling and dehumidification system
5. Two ceiling fans
6. City of Austin Building Code requirements met
7. No vapor barrier (including vinyl wallpaper) installed on inside of perimeter wall
8. One-inch minimum pleated-media filter installed in heating and cooling system
9. Low-VOC (volatile organic compound) paints used in interior
10. Any chemical termite control used is pyrethrin or borate based
11. Any planting beds are mulched to a minimum of 2" depth.
12. Rating Certificate and Homeowner Info packet presented to homeowner.
13. AGBP Member submits rating for all homes in the Greater Austin Area.

Points are then accumulated for additional features included in a checklist of 122 items (See Appendix B for a list of green features and scoring criteria). A minimum score of 40 points is required for a 1-star rating and a minimum of 180 points is required for a 5-star designation. Besides rating homes, the Program also provides consultation services and marketing support for members, technical seminars for designers, a directory of Green Building professionals for consumers and a resource library for all (City of Austin, 2001).

Green Builder Incentives in Austin

There are innumerable benefits for those who choose to become Green Builders. Of course, it is assumed that one of the greatest incentives is consumer preference for a sustainable community, hence, for "green" construction. In addition, there are no membership dues, only a requirement to attend a "Green Building Basics" course within one year of joining and two free environmental seminars each year. However, opportunities to attend additional seminars are provided regularly and definitely encouraged. Consulting services and publications are also available on green topics that can assist builders on their journey towards a green future, such as the Sustainable Building Sourcebook. Also, use of the Green Builder logo and marketing assistance help set participating builders apart from their competition. In return, builders are expected to promote green building in the community and in their own practices. Builders who construct registered green homes are not required to be members of the Program, but, they do receive an additional three points if they and the designer are full members (Austin Green Building Program, n.d.).

Spread of Green Builder Programs

The idea and development of green building programs is spreading across the country. As of July, 2002, 19 residential green builder programs were functioning in the United States with seven additional programs in the development stages (NAHB, 2002). A listing of these Programs is included in Table 1.

Table 1

U.S. Green Building Program Locations as of July 2002

Program Name and Location	Number of Registered Homes
Green Built Home (Wisconsin)	202
Build a Better Kitsap Home Builder Program	278
EarthCraft House (Atlanta)	500
Built Green Colorado (Denver)	9646
Built Green (King and Snohomish Counties)	1600
Green Home Designation (Florida)	2
City of Boulder Green Points	116
Green Building Program (Austin)	2475
City of Scottsdale Green Building Program	129
New Mexico Building America Partner Program	830
County of Santa Barbara Innovative Building Review Program	890
Build a Better Clark (Washington)	26
Earth Advantage Program (Portland)	100+
G/Rated (Portland)	35
Home Builders Association of Greater Kansas City	N/A
City of Frisco (TX) Green Building Program	1,600 (not yet certified)
Hawaii Built Green	N/A
California Green Builder Program	N/A
Green Built Program (Grand Rapids)	4

(NAHB, 2002b)

Numbers of registered homes vary considerably within these programs from almost 10,000 in the Built Green Colorado Program to only a few homes in some of the newer programs (NAHB, 2002b). Program functions also vary, but they all share the primary goal of increasing education and acceptance of green building as a necessary component for future growth. Regardless of the increases, because Austin's Green Builder Program was the first of its kind and contains so many green considerations, it may still be considered one of the nation's model programs.

Data Analysis

Green Builder Study Population

Austin, Texas has undergone remarkable growth in the past decade, increasing its population by almost 40% between 1990 and 2000 (Texas Almanac, 2001). To accommodate this population growth, residential home building has expanded enormously. In 1998, a database was created by the Austin Green Building Program to track information regarding registered green-built homes in the greater Austin area. Information was included for each home on the: builder, architect, address, square footage, house type, "green" features included, and the total point value (i.e., "star rating") achieved. Thus, this study is one of the most comprehensive analyses of green-built residential homes, including all green-built homes that were registered with the city's Green Building Program over the past five years, 1998-2002.

During the study period, there were 74 builders of the 2,335 homes registered (15 of these homes did not have a builder identified and were therefore removed from the analysis below). The number of "green" homes completed by each builder ranged from 1 to 879. Almost half of the builders (49%) had completed only one qualified green home and approximately another third (33%) had built 10 or fewer (Table 2). In contrast, two builders accounted for almost 75% of the green-built homes during the past 5 years, and another two builders accounted for an additional 10% of the green building homes.

Table 2

Number of builders per number of green homes and group percentages

Number of Homes Qualified	Number of Builders	Total Homes in Group	% of Builders
1	36	36	49%
2-5	18	56	24%
6-10	7	57	9%
11-50	6	135	8%
51-100	2	179	3%
101-250	3	538	4%
250+	2	1314	3%
Totals	74	2315	100%

Additionally analyzed were the number of homes qualified by star rating for the same five-year time period. Star ratings are assigned by the number of points achieved from incorporating various green features which are worth 1-6 points, depending on their expected environmental impact. Star requirements from the AGBP are given in Table 3.

Table 3

Requirements to achieve AGBP star-ratings

Rating	Requirement	% of Homes
One Star	40-59 points	26%
Two Star	60-89 points	61%
Three Star	90-129 points	11%
Four Star	130-179 points including E11, E18, E38 (or E10), and H20	2%
Five Star	180 or more points including E11, E18, E38 (or E10), and H20	<1%

During the five year period, only 7 homes received a perfect score, and only 2% received a high score of 4 (n=37). Over a quarter of the homes received the lowest rating of 1 (n=593), and almost two-thirds of the green homes registered during the past five years received a star-rating of 2 (n=1,418).

Table 4

Small vs. large builder analysis by star rating

Star Rating	% Within Star Rating Small	% Within Star Rating Large	% Within Builder (Comparison to Other Small Builders)
1	2.2	97.8	4.5
2	5.4	94.6	26.9
3	58.0	42.0	53.1
4	100.0	0.0	12.9
5	100.0	0.0	2.4

Comparing builder size and star-rating, a majority of the 3-star ratings were achieved by small builders (58%) (Table 4 above) and 100% of 4 and 5-star ratings were achieved by small builders. Small builders constructed less than 8% of the 1 and 2-star rated homes in the Program. Therefore, it definitely appears that these smaller builders are making more of an effort to include a greater number of green features or high point value features into their homes.

Description of the Austin Green Building Program, 1998-2002

Over a 100 (122) green-building features are used to qualify as a green home and to calculate the star-rating (see Appendix B). Builders may choose items from whichever categories they choose (Energy, Water, Materials, Health and Safety and Community) to meet the minimum point requirements for the star-rating they wish to achieve. Some features were used frequently, whereas others were rarely or never used. Some were used consistently year-to-year, whereas others varied widely in their application over time. The frequency and trend of features is first described, then analyzed for patterns reflecting differences in cost and point value. As little research has been found regarding other residential green-builder programs, these findings may help to form a baseline for comparison to other programs or to analyze changes and patterns over time within Austin's Program.

Frequency of Using Green Items

The AGBP database indicated that 2,329 homes qualified as green homes from 1998-2002. Builders received points for incorporating green features or processes from the list of 122 options with point values for each option ranging from 1 to 6 points. Within this period, builders averaged approximately 65 points per home. Thirteen green features were consistently used in 75% or more of Austin's green built homes during the 5-year study period (Table 1.5). Also included in the table are estimates of the approximate cost for each item in contrast with a non-green item. Methods used to approximate cost levels included use of Means Cost Estimation Books (RSMeans, 2001, RSMeans, 2002). Specific features are listed alpha-numerically according to their scoring code, where E= Energy, M= Materials, W=Water, C= Community, and H= Health and Safety, with the specific characteristics of each feature defined below Table 5.

As seen in Table 1.5, the more frequently incorporated green items were low cost. The most frequently used item (E21), (in 98% of the homes), was the exclusion of any skylights, which would in fact save money. Items such as light-colored exterior walls, finger-jointed trim packages, reuse or donation of excess materials, and metal or plastic separators for wood-to-concrete connections all cost little or no money as well. It is generally accepted that double-pane windows offer significant utility savings over the single pane alternative, and thus, homeowners for the most part demand them. Additionally, other items are included in almost all homes, green or not, such as venting of gas logs and exhaust fans to the exterior.

Table 5

Most frequently used green features, 1998-2002

Item*	**H5**	**E36**	**E24**	**M9**	**H26**	**E2**	**M22**	**E43**	**H19**	**E32**	**M13**	**E22**	**E21**
% homes	76%	77%	78%	79%	79%	82%	87%	88%	90%	90%	91%	97%	98%
N=	1770	1793	1817	1840	1840	1910	2026	2050	2096	2096	2119	2259	2282
Point value	4	2	2	4	1	2	2	3	1	1	2	2	2
Estimated cost	low	low	no cost	low	low	low	no cost	low	no-low	low	low	medium	no cost

*Item definitions (Austin Green Building Program, 1997)

H5 = Exhaust fans installed and vented to outside for cooktop/stove and any room with tub or shower
E36 = Supply system air flow tested by qualified technician
E24 = Light colored exterior walls
M9 = Built-in recycling center in kitchen, pantry, or utility room
H26 = Exterior wood-to-concrete connections are separated by metal or plastic
E2 = Design created by design team, including designer, builder and mechanical contractor
M22 = Excess building materials are reused, give/sold to salvage, or donated to Habitat RE-store
E43 = All recessed can lights are ICAT type (insulatable and sealed); or no recessed cans installed
H19 = No unvented gas logs
E32 = Ducts cut to exact length and supported to manufacturer's specs, original diameter maintained
M13 = Entire trim package is finger-jointed/engineered/MDF/reused or local species
E22 = Double pane windows
E21 = No skylights

Interestingly, there was no relationship between point value and cost to incorporate (Kendall's Tau = .19, p-value = .48). For instance, omission of skylights, which saves money, is worth two points as is the use of double-pane windows which costs a moderate amount. This may be due to point allotment for perceived environmental benefit instead of cost. Skylights can cause considerable heat gain and lead to durability problems for a home. Double-pane windows reduce heat gain and may have a similar effect to avoiding skylights. Regardless, the assignment of point value was unrelated to cost.

Twenty features were rarely (1%) or never used in constructing green homes (Table 6). Whereas low cost was associated with likelihood of including green features, in this case, it was related to why items were not used. Most of the features rarely or never used cost a moderate to high amount to incorporate into a structure. Even a design with a minimum of 700 square feet of space per ton of cooling could cost a significant amount as alternative construction techniques such as earth or thermal mass type structures would be required to meet such a goal and achieve comfort. Therefore, it appears that buyers may still not be willing, or builders may not perceive them to be willing, to invest considerable amounts on green features initially, even when potential savings could be large.

Table 6

Least used green features, 1998-2002

Item	**H 7**	**E 41**	**E 29**	**E 42**	**E 46**	**W 16**	**H 22**	**E 13**	**E 26**	**W 15**	**H 16**	**M 4**	**M 12**	**M 16**	**E 7**	**H 10**	**W 2**	**C 1**	**W 13**	**E 12**
% of homes	0%	0%	0%	0%	0%	0%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Point value	2	2	3	4	4	4	1	1	1	1	2	2	2	2	2	3	3	3	4	6
Estimated cost	M	H	M	H	H	H	M	M	M	M	M	M	M	M	M	M	M	H	H	L

L= low, M= medium, H=high

H7	=	Bathroom fan connected to timer or humidistat
E41	=	Gas combo space/water heating system with minimum 76% recovery efficiency
E29	=	15.0 SEER cooling equipment efficiency
E42	=	Solar domestic hot water or swimming pool heating system
E46	=	Photovoltaics installed on home
W16	=	Landscape irrigated with reclaimed water
H22	=	EMF-reducing wiring methods
E13	=	Raised-heel roof truss construction to allow for increased insulation and ventilation
E26	=	Whole-house fan with insulated cover
W15	=	Drip irrigation system for non-turf areas
H16	=	Lockable hazardous-material cabinet, sealed off from living space/attached garage, vented out
M4	=	Alternate roof structure (I-beams, LVL, SIPS, steel)
M12	=	Doors or cabinet wood is reused or local species
M16	=	Structural floor is finish floor for minimum 1/3 of floor
E7	=	Operable thermal chimney/cupola/clearstory/monitor designed for stack effect ventilation
H10	=	Interior paint has no VOC's or is plant-based
W2	=	Horizontal axis clothes washer of Energy Star rated clothes washer
C1	=	Remodeling of an existing structure
W13	=	Rainwater catchment system installed
E12	=	Home design allows for a minimum of 700 s.f. of living space per ton of cooling

Here, point values seem to be slightly more related to cost (Kendall's tau = .36, p-value = .08), which is evident in the instances of solar use, rainwater catchment systems and the use of reclaimed water. All of these are relatively expensive, but are correspondingly allotted a high point value of four. The highest rating of six points was given to design for 700 square feet of space per cooling ton. Alternative methods to achieve this goal could cost considerable amounts, but in some instances, alternative structures such as compressed earth block or straw bales could help achieve this goal and, depending on availability and labor costs, might actually cost less than conventional construction.

Trends in Using Green Building Features over Time

Over 70% of the green features were used consistently by green builders during the 5-year study period (approximately 28% (N=34) changed more than 20% from 1998 to 2002). However, ten features showed a greater than 30% decrease in use during the 5-year study period (Table 7), whereas 9 features showed a greater than 20% increase during this time (Table 8). While increased or decreased usage of items occurred fairly steadily between years for the below tables, in some instances, there was a considerable drop between years. For example, in the past year, inclusion of a detailed mechanical plan shot up considerably, doubling from a 12% to 24% inclusion rate. Also, conducting duct pressure tests increased by almost 30% and use of at least 90% Xeriscape shot up 22% so that in 2002, 99% of homes had a minimum of 90% of their vegetation from the City of Austin's Xeriscape brochure list.

Table 7

Decrease in use of green building features, 1998-2002

Date	# Green Homes	E2	M3	M18	H24	M9	E24	E1	C1	E37	M19
1998	173	99%	86%	92%	95%	99%	99%	94%	91%	82%	94%
1999	597	73%	32%	65%	87%	96%	95%	42%	41%	42%	21%
2000	645	94%	22%	88%	78%	88%	94%	30%	42%	58%	45%
2001	325	96%	27%	89%	66%	80%	71%	37%	39%	59%	38%
2002	589*	66%	44%	48%	50%	46%	41%	35%	29%	17%	25%
Difference		33%	42%	44%	45%	53%	58%	59%	62%	65%	69%

*As of 10/17/02

E2 = Design created by design team, including designer, builder and mechanical contractor
M3 = Engineered roof trusses
M18 = Trees removed from site are used; or house is designed to avoid tree removal
H24 = Any wood reused is at least 1' above soil
M9 = Built-in recycling center in kitchen, pantry, or utility room
E24 = Light colored exterior walls
E1 = Home designer and builder are full Members of the Green Building Program
C1 = Remodeling of an existing structure
E37 = Main bedroom has dedicated return air duct or pressure balancing mechanism
M19 = Wood scraps longer than 2' are reused/recycled

Table 8

Increase in use of green building features, 1998-2002

Date	# Green Homes	H26	E23	E47	E38	H6	E44	E3	E36	W8
1998	173	0%	1%	6%	0%	14%	14%	20%	20%	14%
1999	597	3%	0%	25%	1%	11%	79%	65%	70%	60%
2000	645	5%	5%	3%	0%	55%	58%	66%	79%	62%
2001	325	10%	12%	33%	11%	79%	68%	71%	85%	77%
2002	589*	22%	24%	44%	40%	76%	77%	95%	96%	99%
Difference		22%	23%	38%	40%	62%	63%	75%	76%	85%

*As of 10/17/02

H26 = Exterior wood-to-concrete connections are separated by metal or plastic
E23 = Tile or metal roof or roofing material for Cool Roofs list
E47 = Installed appliances are Energy-Star certified
E38 = Direct "duct blaster" pressure test by qualified technician results in 10% or less air leakage
H6 = Laundry room exhaust fan installed, vented to outside or washer/dryer outside of envelope
E44 = Minimum of 3 light fixtures are installed with fluorescent lamps/bulbs
E3 = Detailed mechanical plan made concurrently with, & part of, the construction plans & specs
E36 = Supply system air flow tested by qualified technicians
W8 = At least 90% plants, shrubs and trees selected from the City of Austin Xeriscape brochure list

Similar results have also occurred in the opposite direction. For example, use of a design team has dropped 30% in the last year as has the use of light colored exterior walls. Inclusion of a dedicated return air duct in the master bedroom has dropped over 40% in the last year as has using trees from the site or avoiding tree removal. Finally, there has been a 34% drop in the inclusion of built-in recycling centers in the kitchen, pantry or utility room. These year to year variations may be the result of one or a few large builders changing the items or practices they use for home design and construction. Since such a high percentage of AGBP homes are constructed by a few large builders, any changes they made would definitely have a large impact on the Program overall.

There are many possible reasons for the overall declines in the use of certain features. Some of these declines may be the result of an increased commitment by some large builders to participate in the Green Building Program. These builders often perform the design work and construction themselves, often build in large developments (and sometimes clear a majority of trees) and tend to give homeowners a wide range of choices in exterior colors. Hypotheses can also be drawn for the noted increased incorporation of some features. Increases in Xeriscaping may be due to the fact that the AGBP has begun offering cash incentives for the use of native vegetation (City of Austin, 1995). Some of the other increases (such as a detailed mechanical plan, air flow testing, laundry exhaust, pressure test and exterior to wood connections separated by plastic or metal) may be due to increased public concern about air quality and the avoidance of mold in residences.

The implications of these findings of feature incorporation may be especially important for items which increased the most. It appears that when particular attention is drawn to a certain topic (such as air quality/mold avoidance) which has a risk of potential financial trouble for a builder, changes are soon made. Additionally, when incentives are offered to utilize certain items, builders are more likely to comply. Thus, it appears that financial incentives (either to gain more money or to avoid losing money) are major drivers in the decisions builders make of what to include in a home. Therefore, if the Program wishes to increase usage in a particular category or for particular features, they would most likely succeed if either incentives were provided or penalties for not incorporating items could be enforced (which would most likely have to come from the government).

Discussion of the Checklist Analysis

For the most part, it seems that large numbers of Austin green builders are achieving lower-level ratings and incorporating lower cost items into their structures. Approximately 82% of builders with homes registered in 1998-2002 had 10 or fewer homes qualify for green ratings. Of the homes that were rated, less than 2% qualified for four or five-star level ratings. When items were analyzed in regards to frequency of use, it was found that for the most part, the most frequently used items had low to no associated cost. The use of double-pane windows was the one exception with a medium, but not substantial, resulting cost increase. It was also found that the least used items tended to have medium to high associated costs which might explain their minimal use by most contractors and owners.

As far as trends go, there appeared to be an increase in items associated with increased indoor air quality and liability related to such. For example, inclusion of a detailed mechanical plan, air tests for supply and pressure, inclusion of a laundry room exhaust fan and metal or plastic separators between wood and concrete to prevent water suction all relate to air or mold issues.

No clear trends were observed for those items decreasing in usage. Many have little or no associated cost such as the use of light colored exterior walls or reuse/recycling of 2'+ wood scraps. Also the use of a design team has declined possibly due to the effects of a few large custom builders who build the same or similar homes over and over and thus do not require reviews and input by designers or subcontractors for each home.

Builders Survey Data

In 2002, builders listed as having homes registered in the Austin Green Building Program for the period of 1998-2002 were surveyed to determine their degree of commitment to the green program, their attitudes regarding checklist items, their feelings regarding the profitability of green construction and their decision making process for including green items in a home (Appendix A). Of the seventy-three builders originally identified as taking part in the Program, the list was reduced to sixty-four after it was found that many of the builders were part of the same parent company, such as Hammonds and Legacy Homes, Newmark and Frederick Harris Estate Homes and A.I.L. Green Builders, Casa Verde, and American Youthworks as well as others. Also, one company was listed simply as "Builder" with no contact information and was thus removed from the group. From the group of sixty-four, 69% (45) were reached. Two that were reached chose not to provide answers, one because the architect had dealt with the green features and thus the builder did not have sufficient knowledge of the Program and the other because they "weren't interested". Twenty percent were unreachable, even after repeated attempts and messages, with the final 8% unreachable due to either disconnected or unlisted phone numbers. Thus, the response rate was 69% (N=45) of all green builders and 96% of those eligible to participate.

The results of the survey indicate that an average of 63% of each builder's homes constructed in the last two years were custom homes. As many as 78% of each builder's homes would qualify as green homes, even though many were not registered because they were outside the Austin city limits. When asked if they thought checklist point values were related to the cost of incorporating them in a home, on average there was a feeling of neutrality with an average of 2.98 on a scale of 1 to 5 with 1 indicating strong agreement and 5 strong disagreement. Alternately, when asked if they felt checklist item point values were related to their environmental impact, they agreed more, with an average response of 1.71 on the same 5-point scale. Builders were then asked to rate a series of factors that might influence their decisions about which checklist items to include in a home. The rating scale ranged from 1 to 5, with one indicating "very important" and five, "not important at all". Responses are reflected in Table 9.

Table 9

Builder influences on choosing checklist items

Influential Factors	Ratings				
	1	**2**	**3**	**4**	**5**
Expected Environmental Impact	27%	33%	31%	7%	2%
N=	12	15	14	3	1
Cost	42%	38%	20%	0%	0%
N=	19	17	9	0	0
Public Perception	24%	22%	20%	24%	9%
N=	11	10	9	11	4
Familiarity	29%	38%	22%	4%	7%
N=	13	17	10	2	3
Point Value	9%	24%	38%	20%	9%
N=	4	11	17	9	4

When asked whether "green homes are more profitable than non-green homes", 16% of builders indicated they were much more profitable, 14% stated somewhat more profitable, approximately 31% indicated that greenness made no difference, 18% said they were somewhat less profitable and over 21% stated they were much less profitable. Finally, results showed that when making decisions about which green items to include in custom homes, the highest percent of builders worked as a team with their clients (47%), 39% make the decisions themselves and 14% of buyers made their own decisions.

Discussion and Conclusions

The findings of this study reflect a unique compilation of green builder preferences and choices. Builders tended to choose checklist items more on the basis of cost than on the basis of point value. This fact was reinforced by the survey results where 80% of builders indicated that the consideration of cost was somewhat to very important. Meanwhile, only 33% indicated that point value was somewhat to very important. This finding coincides with a prior survey of Atlanta area homebuilders that found that cost-effectiveness most influenced builder decisions to use environmentally-friendly products or measures (NAHB, 2000).

Trends were also observed in regards to air quality and mold reduction related items. This may stem from the recent onslaught of court cases against builders in Texas regarding toxic mold syndrome. Builders are making changes in relation to the mold problem regardless of involvement in the Green Building Program, but may emphasize it to get points for those items on the checklist.

Anecdotal comments by builders during the survey are worth noting. In the survey, builders commented that the greatest improvements in green participation would be found if suppliers were convinced of the benefits and started offering more options and better prices for their environmental goods. Many of the builders interviewed stated that they had been building green all along and that it was simply the "right thing to do" regardless if their homes were rated or not.

There was a variety of answers in regards to whether green building was more profitable than non-green construction. Those that felt it was not profitable had strong feelings either that it was morally wrong to receive a higher profit or that the time outlay was considerably greater than conventional construction which in turn reduced profits. Many simply said that green building was still not a high priority for most buyers and that if it cost more, they were not interested. This corresponds with findings in the 2000 Atlanta builder survey in which 71% of builders said there was no consumer demand for resource efficient homes and 62% of the public does not understand or accept green building (NAHB, 2000). Builders in the Austin study stated that green homes were more profitable when clients were educated thoroughly on their benefits or when cost-plus work was being performed because the construction costs were higher, resulting in a higher profit. Comments repeatedly concurred that the real benefits were gained by the homeowners in the form of lower bills, better health and higher resale value.

For the most part, builders were very supportive of the Austin Green Builder Program and the efforts of those working with this Program. Some complained that there were not enough rating items to cover all aspects that might be incorporated or that some items were included just for political reasons. However, even these comments were followed with overall satisfaction with the Program and its administrators. Survey results also indicated that builders felt the checklist item point values were for the most part (80%) based on environmental impact. In contrast, only 32% rated that point values were based on their cost to include in or on the property. This corresponds with findings that implied few checklist item cost estimates related to their allotted point value.

Finally, smaller builders tended to choose checklist items more for their environmental impact than large builders. Cost, on the other hand, was more important in choosing green features for large builders as opposed to small. Perhaps, the large builders cater more to homebuyers more concerned with initial cost than custom home buyers.

In both the survey and the trend analysis, cost had the greatest impact on builder decisions of items to incorporate. Green features that are expected to have significant environmental impacts may not be implemented simply because they cost more upfront, for example rainwater collection systems, solar heating and photovoltaics. To better encourage their use, program organizers may consider requiring implementation of some of these higher cost fixtures or to increase point requirements favoring use of these items. Also, tax or other rebates for these items may heighten utilization. This has actually started recently for rainwater collection barrels in Austin.

For homebuilders, exceptional energy performance, water conservation or homeowner satisfaction could be documented and marketed as well. Future homeowners might then accept these additional costs for the future benefits they provide. Additional training is needed however, for builders to become familiar with these innovative processes. Therefore, builders should be encouraged to request information from the green building program and to get additional training for implementing these innovative technologies.

The next step in understanding motivation of builders would be to compare green and non-green homes for those builders constructing both to determine actual profitability and costs of green versus non-green homes. Research regarding energy and water use as well as occupant satisfaction in green homes could provide additional insight into the benefits of green construction for consumers. With additional understanding of green programs and benefits, greater validity and improved programs should result.

FIXED EFFECTS CONTRIBUTING TO RESIDENTIAL WATER DEMAND IN AUSTIN, TEXAS: THE EFFECTS OF WEATHER, SIZE, COST AND POOLS

Water conservation in Texas is becoming a heated topic as city water supplies dwindle and alternatives for new sources become increasingly expensive. To prevent both shortage and extra costs, the State and various cities within the state are investigating conservation tactics to reduce current levels of consumption. In order for conservation programs or requirements to be effective, however, sources of current water consumption must be identified. If for example, temperature is found to significantly affect water use, then temperature-related demands should be investigated and changes made, such as reducing landscape or turf which requires high amounts of water in the heat. Also, if lot size is considered a major factor affecting water consumption, then smaller-lot subdivisions might be considered. This study found that temperature, rainfall, evaporation, home square footage, lot square footage, appraised value and the existence of a pool all significantly and positively affect residential water consumption. Levels of each differ however, so variables with a particularly large affect should be investigated and related conservation techniques explored. Findings also indicate that variable effects fluctuate substantially by builder, indicating that certain designs, features, costs or sizes characteristic of different builder groups result in either higher or lower water use in comparison to others.

Importance of the Study

Many studies have been conducted to determine factors affecting water consumption in order to better predict how much water various use groups will require in the future, for example, agriculture, industry and public consumption. Additionally, various measures have been investigated to test for their influence on water conservation. A problem with this task is the great variability between geographic and socioeconomic areas. In addition, occupant behavior has a significant influence but is typically quite erratic (Baumann, Boland, & Hanemann, 1998). None the less, attempts should be made to determine the components of water consumption in the hopes that better predictive models will be developed and implemented and so that conservation efforts can be designed appropriately. However, if water consumption is dependent primarily on atmospheric and socioeconomic variables that are beyond control, the policies and planning would need to shift priorities to finding new sources of water to keep up with, instead of curbing the growing demand.

The purpose of this study is to determine the effects of (1) socioeconomic (home size, lot size, appraised value and pools) and (2) atmospheric (temperature, rainfall and evaporation) factors on residential water consumption. Austin, Texas was selected for this study for two reasons. First of all, the city has recently experienced water crises as the city's source aquifer has experienced greater than average declines. Additionally, Austin has the oldest and one of the largest Green Building Programs for residential construction in the country. The idea and development of green building programs is spreading quickly across the country with 19 residential green builder programs functioning and seven additional programs in the development stages (NAHB, 2002b). Little research has been done, however, on the homes involved with these programs. It was therefore of interest to investigate homes registered with the Program to determine if findings vary from prior residential studies. Also, the conservation techniques purported in the Program (Xeriscaping, rainwater catchment systems, natural vegetation…) can later be analyzed to determine if any reductions in water consumption actually result. Thus, once the fixed effects of weather and residence size can be determined one can then account for the isolated effects of green building for water conservation.

Literature Review

Texas Water Consumption

Texas is one of the largest (top four) water consuming states in the U.S. (Wagner & Kreuter, 2002). Currently, agricultural irrigation accounts for the largest percentage, but by 2050, municipal demand is projected to greatly increase its share from 25% to 35% (an increase from 4.23 to 7.06 million acre-feet/year)(National Wildlife Federation, Environmental Defense, & Lone Star Chapter of the Sierra Club, 2001) of the total state water used (Wagner & Kreuter, 2002). Over half of municipal water use has been attributed to residential demands (Howe & Linaweaver, 1967). Hence, in the search for conservation alternatives, residences will become increasingly important.

With the State's escalating demand for municipal water comes increasing anxiety about water shortages. The Governor's task force in 2000 identified limited water supply as one of the two "most serious natural resource issues facing Texas today" (Wagner & Kreuter, 2002). Part of the reason for this concern is the fact that conventional fresh water supplies in Texas are already 75%-80% developed (Texas Water Development Board, 1995) whereas the population of the state is anticipated to double in the next 50 years (National Wildlife Federation, et al., 2001).

Created in 1997 to address growing demand issues, The Texas State Water Plan recommended a range of actions to ensure water for the future, ranging from conservation measures to dam construction. Related poll results indicated that Texas residents favored conservation efforts as opposed to costly supply side initiatives. This has not, however, been reflected in the plans of the various water groups (municipal, agricultural, cities and counties…). Only 21% has included water conservation to any extent in their plans for future supply (National Wildlife Federation, et al., 2001).

Over 600,000 acres of forested wetlands in Texas have already been replaced with deep-water aquatic habitats as a result of reservoir construction (Texas Environmental Profiles, 2003). The 1997 Texas Water Plan proposed the conversion of an additional 52,000+ acres of wetlands to deep water habitats. Opponents claim this harms existing wildlife and penalizes users downstream with decreased water flow. Alteration also increases costs for water treatment as discharged water must meet higher standards because it flows into more diluted rivers and streams (Texas Environmental Profiles, 2003).

Texas currently spends approximately $1 billion a year on new water treatment, sewage and drainage (Texas Environmental Profiles, 2003). Additional costs are expected to approximate $65 billion by 2050 for proposed new water treatment, supply and drainage infrastructure (Texas Environmental Profiles, 2003). However, these estimates and past costs did not take into consideration and include conservation alternatives. These alternatives may curb the costs as well as preserve the supply for the predicted increasing demand.

Austin Water Consumption

Austin currently has the 10th highest per capita water consumption in Texas - 213 gallons/person/day (National Wildlife Federation, et al., 2001). Approximately 120,000 gallons of water were used by the average single family household in the City per year. Of this amount, about 45% of summertime water use has been attributed to exterior watering (City of Austin, 2000). Variations in the time of day and season have been shown to significantly affect outdoor water use, raising it to levels several times that of indoor water consumption in arid regions of the country in summer months (Hanke & Mare, 1984). This temperature-dependent increase is attributed to the additional water requirements of lawn irrigation, air conditioning and swimming pools (Hanke & Mare, 1984).

Past Findings in Regards to the Effects of Weather,
Size and Cost in Residential Water Use

Several studies have attempted to determine the effect of weather, residence cost and size-related factors on residential water consumption. Rainfall and temperature have been shown to be significant variables affecting water use in a number of studies (Anderson, Miller, & Washburn, 1980; Morgan & Smolen, 1976; Hansen & Narayanan, 1981). For example, Fourt (1958) found in a 1955 survey of 21 large cities that rainfall days, average number of people per meter and cost of water were significant factors affecting household water consumption (R^2 of .839) (Grima, 1972). R^2 represents the coefficient of determination which is a statistical term defined as "the proportion of the variability in the dependent variable … that is accounted for by the independent variables…."(Ott, 1993). However, in studies conducted by Linaweaver, Gyer, and Wolff (1967) and Haver and Winter, (1963) climatic factors were not found to be highly significant (Grima, 1972).

Evapotranspiration (ET) has been found in various studies (Danielson, Feldhake, & Hart, 1980; Duble, 1997; Mayer, 1995; Stadjuhar, 1997; Aquacraft, Inc., 1997) to affect outdoor water consumption. In a 1999 study, when outdoor use was calculated as the amount above an indoor baseload calculated from a data logger, an R^2 of .59 was yielded when average usage was compared for twelve cities. However, when ET was compared to individual residences throughout each city, an R^2 of only .16 was derived (Mayer, DeOreo, Opitz, Kiefer, Davis, Dziegielewski, & Nelson, 1999).

In a 1989 study of residential water use throughout Texas, Griffin and Chang found climate to be one of several significant factors affecting water use. An R^2 value of .39 was achieved with the dependent variable of per capita residential and commercial water consumption and independent variables of: average water price, number of days without rainfall times average monthly temperature, annual income per capita, percent of

Hispanic origin population and the average annual precipitation from 1951-1980. Price increases, increased Spanish population, and increased precipitation were found to lower water consumption while increased income and number of days without rainfall led to increases (Griffin & Chang, 1989). Similar findings resulted from a study conducted by Hanke and Mare (1982) in Malmo, Sweden where a formula was developed that included income per home, number of adults and children per home, age of home, rainfall, and water price. Rainfall and price reduced water consumption, while all other factors increased usage. The R^2 for this study was 0.259 (Hanke & Mare, 1982).

The largest residential water end use study in U.S. history was recently completed. The study, sponsored by the American Water Works Association, included data from twelve U.S. cities comprised of: billing records from 12,000 homes, survey information from 6,000 residences, flow trace data from 1,188 homes and weather records from each city. This data was then used to develop predictive formulas for water use (Mayer, et al., 1999). On average, 58% of water was consumed on outdoor purposes, although this number was higher in warmer climates (up to 67%). The mean annual water use for the cities was 146,100 gallons per households per year, with a median of 123,200 gallons. Homes with pools were found to use more than twice as much exterior water as those without. Findings also indicated that outdoor water use was positively correlated with home and lot square footage (Mayer, et al., 1999).

Income or economic level has also been held as a significant factor influencing residential water consumption. It is generally assumed by researchers that those with higher incomes have more water-utilizing appliances or features (such as pools) and often have larger lots (Bauman, et al., 1998; Grima, 1972) However, while many studies report this finding, few have significant evidence aside from a study by J.D. Headley (1963) that found a correlation coefficient of .81 between water usage and median family income (Grima, 1972), a 1967 study of residential water use in the Toronto area which found that home value, lot size and number of residents increased water usage, while variable price and minimum bill in cents decreased usage (R^2=.49) (Grima, 1972) and two studies that found water consumption was positively correlated with income per capita (Danielson, 1979), and lot size (Linaweaver, Geyer, & Wolff, 1966).

The lack of consistency between studies may be due in part to homeowner's behavior which has been found to have a significant affect on water consumption with no real continuity. A 1990 Southern California study found that just 11% of households irrigated within +/-10% of what the landscape required, 39% overirrigated and 50% underirrigated (Baumann, et al., 1998). A 1999 study produced similar findings with approximately 22% of the population using less than 10% of a theoretically required water amount, and approximately 17% applying more than needed (Mayer, et al., 1999). Thus, it is difficult to predict with total certainty how much water homeowner's will consume.

Sustainability and Water Conservation in Austin

The City of Austin stands out as a leader in sustainable construction and development, including water conservation, in Texas and around the country. The City has developed and accepted a Sustainable Communities Initiative (SCI) which since 1996 has created plans, performed evaluations and educated city staff and the public to make the city more sustainable. The SCI program is part of Austin's Transportation, Planning, and Sustainability Department, and program staff report to the City's Sustainability Officer. Besides the Sustainable Communities Initiative, the City of Austin also leads the country in sustainable practices through its numerous other programs such as the Water Conservation Program, Air Quality Program, Watershed Protection Department, 'Dillo Dirt program, Smart Growth Initiatives, Recycling Programs and one of he City's most well-known programs, the Austin Green Builder Program (City of Austin's Sustainable, 2001).

The average Austin family uses 120,000 gallons of water a year although newer homes, built under the requirements of the current plumbing code, use approximately 100,000 gallons (City of Austin Environmental and Conservation Services, 2003). It has been projected that Green Building Program homes could reduce water use to just 36,000 gallons per year. This reduction would be the result of six key water conservation techniques:

1. efficient fixtures
2. xeriscape
3. efficient irrigation systems
4. rainwater collection
5. graywater use
6. landscape designed to prevent run-off (City of Austin Environmental and Conservation Services, 2003).

The Program also awards points for limiting the size of a home below a certain square footage (maximum 1,200 s.f. for a 2-bedroom + 250 s.f for each additional bedroom) (Austin Green Building Program, 2003). In addition to gaining points for incorporating water-conserving features in a home and limiting home size which go toward a 1-5 star rating, the Green Building Program now offers financial incentives to reduce water usage. A $1,000 per home stipend is available with $600 towards a minimum 25% compost topsoil and $400 for approved low-water use trees and shrubs (City of Austin, 2002).

One of the future challenges of the Green Building Program is to document the effect of these factors on actual water use. Thus, the purpose of this study is to determine the financial and environmental benefits (American Council for an Energy Efficient Economy, 2003) to builders, homeowners and the community. To date, little research has been conducted on Program results in regards to water conservation.

Use of Regression in Determining Water Usage Effects

Previous studies have used a variety of methods to determine both the end uses of water and variables that influence consumption. Technological advances have even given researchers the ability to monitor end uses directly as they occur. One example was a 1990 study conducted in Oakland, California on a sample of 25 residences in which micro-meters were installed on major fixtures and monitored via personal computer. While precise data was gathered, the cost of this study was almost $10,000 per home (Mayer, et al., 1999). Since then, flow trace analysis tools and software that record and identify the source of water use in a residence have been developed that are considerably less expensive and achieve the same great detail in water use analysis (Mayer, et al., 1999).

Even with these cost reductions, for larger, more economical studies, statistical methods are most common. Multiple coefficient methods use statistical formulas with independent variables related to water use based on past correlations. The number and type of independent variables included in these models varies with local conditions, the choice of variables deemed as potentially important, the availability of data and the desired accuracy. Using time-series data in multiple coefficient models relates future water use to past levels and factors contributing to these levels (Prasifka, 1994).

One of the earliest studies utilizing statistical models was conducted in 1940 by Roy Hunter in which typical water demands for fixtures were determined using a probability function. The results of this study were used for almost 60 years to size water meters and service lines (Mayer, et al., 1999). More recent regression-utilizing studies include a 1993 study in Pasadena in which billing records and socioeconomic data were used to measure the effects of a conservation program (Kiefer, Dziegielewski, & Opitz, 1993). A similar study was conducted in 1994 using 494 homes in the Phoenix area.

Recommendations from this study included the use of metering devices to verify modeling results (Mayer, et al., 1999).

The City of Austin has used a regression formula for water forecasting called WATFORE to predict the potential for extreme water use amounts (Shaw & Maidment, 1987). The parameters in the model include daily water use as the dependent variable, and independent variables of: estimated base winter use, a trend coefficient for seasonal use, and estimated potential water use, which is a function of temperature and a short-memory water use variable (Shaw & Maidment, 1987).

Methods

Four datasets were used to determine how much of an affect weather and home-related variables have on water consumption. The first dataset required included monthly temperature, rainfall and evaporation data for the two-year period of March 2001 to March 2003. Monthly temperature and rainfall information was gathered from the National Weather Service's Southern Regional Headquarters website. Evaporation data was gathered from the Ft. Worth District's Reservoir Control Office of the US Army Corps of Engineers website for Lake Travis/Marshall Ford Dam. Monthly water consumption records were obtained from the Austin Energy Department. An open records request was sent to the department along with a compact disk containing addresses for each home broken out by number, street and suffix so that a query could be written by the department to obtain the consumption information. Records were then e-mailed to the researcher in database form.

The second dataset included the square footage of each home and lot, the appraised value and the existence of a pool for each home registered with the Green Builder Program that had a record at the Appraisal District. Information on the square footage of the homes and lots, the appraised value and the existence of a pool for each green residence was obtained by typing in each address at the Travis County Appraisal District and recording the information on site. Hand-written details were then transferred to computer database form and verified by a third party.

The third dataset consisted of monthly water consumption records (gallons per month) for each home registered in the Austin Green Builder database that were on record at the Travis County Appraisal District. The span of the monthly records was from March 2001 to March 2003, corresponding with weather information gathered from the sources named above.

The final dataset consisted of information supplied in database form from the Austin Green Building Program for all qualified homes from 1998 to 2002. Included in this information were the addresses of each home and the homebuilder. Homebuilder information would later be used to determine if builder characteristics had an effect on water consumption. Because multiple datasets were not available to test findings upon completion of the analysis, it was determined that regression results from a random sample of 20% of the cases would be compared to findings with the complete dataset to determine if the information would be applicable for future data.

Analysis

Monthly average temperature (in degrees), total monthly rainfall (in inches), average monthly evaporation (in inches), home square footage, land square footage, appraised value and pool data (yes or no) were compared to household gallons consumed per monthly billing period for each home using stepwise regression in SPSS© to determine statistically significant relationships ($p \leq .05$). Only variables with p-values $< .05$ were considered further. Multicollinearity of the independent variables was analyzed using the Variance Inflation Factor (VIF) with values over 10 considered problematic (Neter, Kutner, Nachtsheim, & Wasserman, 1996). To control for equal variance, only those cases in which the absolute value of the residuals was +/-4 were included because it is common statistical practice to consider residuals as outliers in large data sets if their absolute value is 4 or more (Neter, et al., 1996). This process reduced the number of cases by less than 1% (N=16,477 from 16,605). Cases with missing information, were deleted in the multivariate analysis, with the majority or these missing lot square footage data. Finally, all cases related to one home recorded as having a square footage of 240 were removed as it was assumed that this must just be an addition. The resulting number of cases for analysis was 16,455.

Results

Descriptive statistics were analyzed for each variable (Table 10).

Table 10

Descriptive statistics for weather and home-related variables

	Water Use in Gallons Per Month	**Monthly Avg. Temp. ^{0}F**	**Monthly Rainfall Inches**	**Monthly Avg. Evap. Inches**	**Appraised Value $**	**Home S.F.**	**Lot S.F.**
Mean	10,148.60	68.57	3.32	0.19	223,986.56	2,186.40	8,277.10
Median	7,900.00	69.50	2.46	0.16	225,000.00	2,279.00	7,680.00
Std. Deviation	7,876.67	12.91	2.63	0.10	106,632.47	773.65	2,653.12
Minimum	100.00	49.60	0.34	0.07	42,365.00	451	3,300.00
Maximum	57,700.00	87.20	10.00	0.39	952,004.00	4,853.00	3,0056.00

The distribution of water use is illustrated in Figure 1. For a majority of the homes, water use is fairly low when compared to Austin averages. For instance, 2% of households use less than 1,000 gallons of water each month and 50% use less than 7,900 gallons per month. On the high end of the population, 10% use more than 20,400 gallons per month and 1% use 37,000 gallons per month or more.

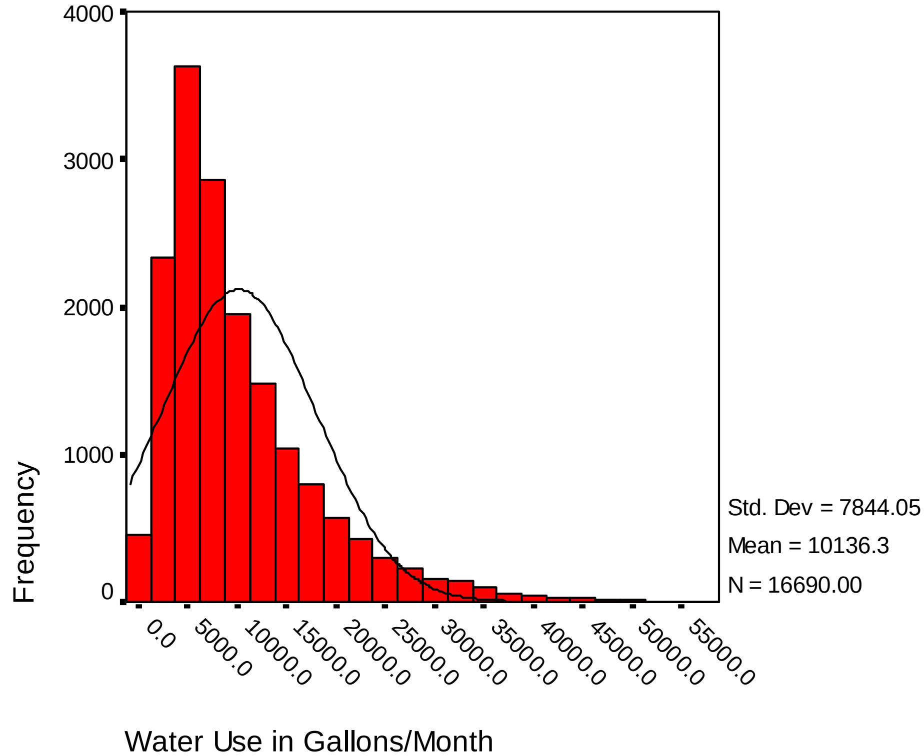

Figure 1: Distribution of water usage in gallons per month

Home values range from $42,365 to $952,004. However, almost 50% of the study homes are valued between $200,000 and $300,000 with approximately 1% over $500,000. Approximately 14% of homes are valued below $100,000. Home value distributions are shown in Figure 2.

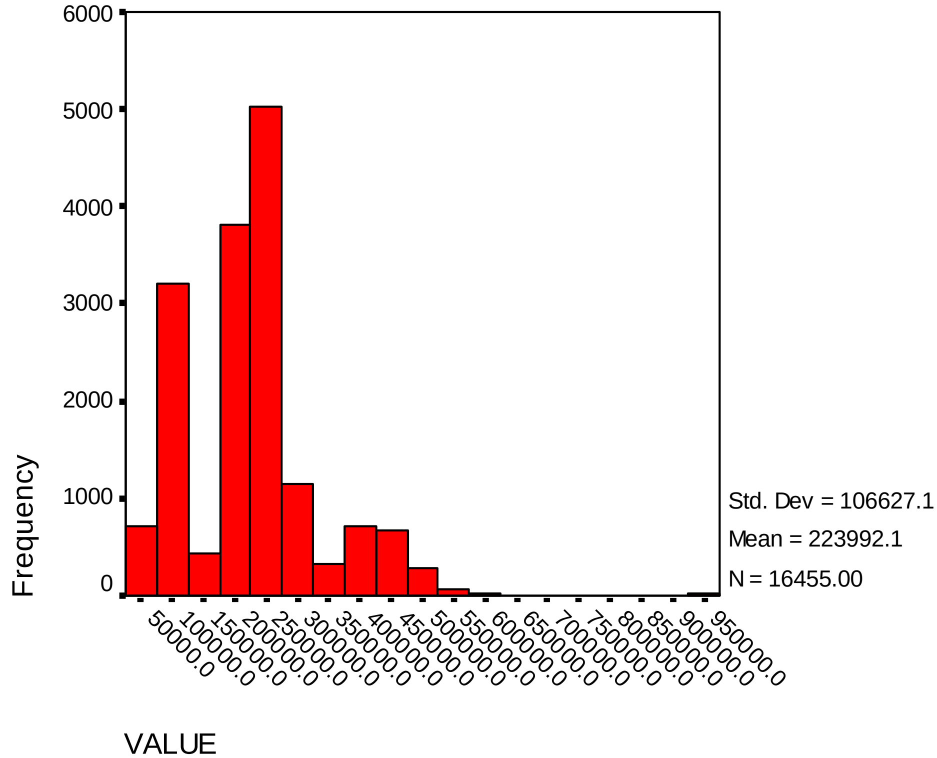

Figure 2: Distribution of home values for green homes

Home square footages range from 451sf to 4,853sf. Less than 2% are below 1,000s.f. and less than 2% above 3,500s.f. Lot square footages range from approximately 8,240sf to 30,056s.f. Almost 60% of lot square footages fall within the 6,000-9,000sf range with just 3% above 14,000sf and approximately 2% under 5,400sf. This distribution is shown in Figure 3.

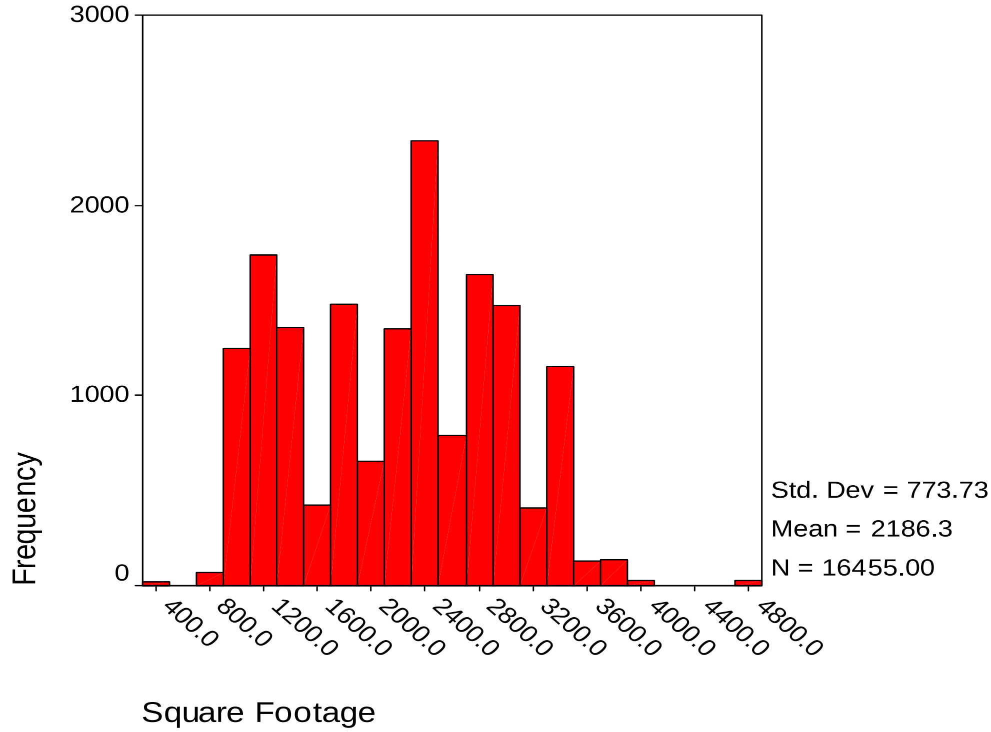

Figure 3: Distribution of home square footages for green homes

Only approximately 2% of Green Program homes have pools (N=306). The mean cost for homes with pools is $329,654 as opposed to $223,987 for all green builder homes. Also, the mean square footage for homes with pools is 2,907s.f. This is over 700s.f. larger than the average Austin Green Builder home (2,186s.f.).

When the seven factors of average temperature, total monthly rainfall, average monthly evaporation, home square footage, land square footage, appraised value, builder and pool data were analyzed using stepwise regression, the following formula resulted and is expanded in Table 11:

$$Y = -9{,}925.9B_o(\text{constant}) + 167.90\text{Temp.} + .0048\text{Value} + 355.15\text{Rain} + .253\text{LotSF} + 3{,}699.26\text{Pool} + 1.31\text{HomeSF} + 6{,}998.52\text{Evap.}$$

Table 11

Regression coefficients and p-values for significant variables

Variable	Regression Coefficient	P-value
Constant	-9,925.9	.000
Temperature	167.9	.000
Value	.0048	.000
Rainfall	355.15	.000
Lot Square Footage	.253	.000
Pool	3,699.26	.000
Home Square Footage	1.31	.000
Evaporation	6,998.52	.000

The builder variable did not increase the R-value at all and was close to insignificant (p=.048) so it was omitted from the formula. The p-values of all other variables (shown above) were .000 with an adjusted R^2 of .205 for the model. All variables were positively related to water consumption. Also, no VIF's were at or above 10, so multicollinearity was not a problem. Finally, an 80% sampling of the data set was compared to the full data set using the same model with a Pearson Correlation coefficient of 99.4%, a 20% sample was compared to the above model with a correlation coefficient of 95.4% and the 80% and 20% groups were compared with a resulting correlation coefficient of 91.7%. Based on these fairly high correlation rates as tests for accuracy, the model should be applicable for future data. An example applying the formula to the average Austin home is provided in the Summary section.

Next, data were analyzed to determine if factors had similar effects between Green Building homebuilders. Of the thirty-three builders participating in the Austin Green Building Program for which home water consumption records were available, four of the builders had constructed 65 or more homes in a three year period, while the other twenty-nine builders had 24 or fewer homes. Therefore, builders were divided into five major groups, Builder 1, which consisted of the twenty-nine small builders with a total of 169 homes, Builder 2 with 65 homes, Builder 3 with 79 homes, Builder 4 with 115 homes and Builder 5 with 402. Table 12 below illustrates the differences in affect the variables contribute to explaining water consumption between builders.

Table 12

Variable coefficients by builder group for each independent variable

Variable	Small Builders N=169	Builder 2 N=65	Builder 3 N=79	Builder 4 N=115	Builder 5 N=402
Intercept	**-2,676.464**	-2,013.435*	-1,386.797*	-3,176.721*	**-1,5974.560**
Temperature	**100.375**	48.435*	53.717*	**224.788**	**231.903**
Rainfall	**211.355**	**241.830**	**221.875**	**572.928**	**433.593**
Evaporation	742.679*	**29,096.630**	**10,724.705**	**15,045.402**	4,075.062*
Value	**-0.015**	**-0.038**	**0.028**	**-0.086**	**0.017**
Home S.F.	**3.409**	**3.536**	-0.051*	**7.407**	**0.488**
Lot S.F.	**0.106**	**0.247**	0.116*	0.018*	**0.323**
Pool	**4,634.752**	**2,501.306**	0.000*	0.000*	**3,759.223**
Adjusted R-Square	0.083	0.293	0.088	0.321	0.253

* Unbolded means not significant at .05

When all green homes were analyzed together, the seven variables (weather, size, value and pool) were found to be positively related to water consumption and significant at the .05 level. However, when builders were analyzed individually, all seven variables were not found to be significant for any one builder and some relationships changed from positive to negative. For example, home value was found to be inversely related to water consumption for small builders (Builder 1) and Builders 2 and 4. Also of interest is the fact that lot square footage is not significantly related to water consumption for Builders 3 and 4. Home square footage was not significantly related to water consumption for Builder 3, but had a very high value for Builder 4. Temperature affected Builders 4 and 5 similarly, with a lesser effect for Builder 1 and no significant effect on Builders 2 and 3's homes. Rainfall, again is positive for all builders, but had a greater effect on Builders 5 and especially 4. Evaporation was highly significant for Builders 2 and 3, although temperature was not.

The above affects may be caused by variance in home characteristics between builders. Table 13 illustrates some of the differences. For example, Builder 3 had the smallest homes on average which may explain why home square footage was not a significant contributor to water use in these homes. However, many of the differences can not be described, such as the inverse relationship of value and water consumption for Builders 1, 2 and 4 when these builders produce neither the highest or lowest price homes. Also, the insignificance of lot area for Builder 3 and 4 has no clear explanation from these statistics.

Finally, correlations between the various factors were analyzed to determine their relationships using Pearson Correlations. Results are displayed in Table 14. Appraised value and home square footage were highly correlated which might be expected. Also, average monthly temperature and evaporation are highly related although not enough to cause multicollinearity from analysis of variance inflation factors. Rainfall and temperature are also positively correlated but to a lesser extent. Because a positive relationship was not expected between temperature and rainfall or between rainfall and water consumption from the earlier analysis, total monthly rainfall data for the study was compared to Austin average monthly rainfall totals. A departure from normal was found with a Pearson Correlation Coefficient of -.14 for the two years of rainfall in the study when compared to average years. This may explain the positive coefficients for rainfall when negative coefficients would be expected.

Table 13

Descriptive statistics comparison of builders

Builder 1	**Value**	**Home S.F.**	**Lot S.F.**	**Water Use**
N=3,343				
Mean	156,050	1,475	8,186	8,616
Median	109,252	1,152	7,555	6,800
Std. Deviation	123,910	685	3,271	6,632
Minimum	42,365	451	3,300	100
Maximum	952,004	4,853	30,056	51,200
Builder 2				
N=1,439				
Mean	198,692	1,911	7,904	8,762
Median	200,000	1,845	6,941	6,700
Std. Deviation	25,376	319	2,759	6,688
Minimum	54,000	1,425	5,750	100
Maximum	250,000	2,438	19,529	47,600
Builder 3				
N=1,851				
Mean	99,301	1,256	7,163	8,597
Median	101,539	1,226	6,815	7,200
Std. Deviation	8,804	145	1,231	5,934
Minimum	82,509	1,008	5,750	100
Maximum	130,000	1,497	12,377	43,700
Builder 4				
N=1,231				
Mean	271,013	2,400	8,336	11,755
Median	273,920	2,314	8,125	9,600
Std. Deviation	35,039	558	1,120	8,922
Minimum	200,000	1,572	6,999	100
Maximum	339,799	3,580	12,898	55,000
Builder 5				
N=8,591				
Mean	274,784	2,678	8,605	11,081
Median	245,045	2,730	8,096	8,600
Std. Deviation	85,762	502	2,671	8,500
Minimum	166,000	1,570	5,609	100
Maximum	561,216	3,885	29,748	57,700

Table 14

Pearson correlation coefficients of 'between variable relationships'

	Monthly Water use in Gallons	Average Monthly Temperature	Total Monthly Rainfall	Average Monthly Evaporation	Appraised Value	Home Square Footage	Lot Square Footage
Monthly Water Use in Gallons	**1**	**.211**	**.088**	**.188**	**.084**	**.134**	**.075**
Average Monthly Temperature		**1**	**.019**	**.927**	-.001	.000	.000
Total Monthly Rainfall			1	**-.092**	.000	.000	-.001
Average Monthly Evaporation				1	-.001	.000	.000
Appraised Value					1	**.873**	**.470**
Home Square Footage						1	**.373**

Discussion and Conclusions

Overall, results show that only a fraction (approximately 20%) of residential water consumption can be explained by the factors of temperature, rainfall, evaporation, appraised value, home square footage, lot square footage and the existence of a pool. Nevertheless, each factor contributes to explaining monthly water use. For example, if one compared the minimum sized home (451sf) to the maximum size home (4853sf) in this study, based solely on the square footage coefficient (1.31), there would be a difference of 5,767 gallons per month between the two homes and that only takes into account one of the related factors. For a mean square footage home in this study group of approximately 2,200sf, the water usage would start off at 2,282 gallons per month (1.31*2,200) above the constant coefficient. Additionally, if the lowest ($42,365) cost home is compared to the highest cost home ($952,004) in the survey, the difference in water usage based on the regression coefficient (.0048) would be a difference of 4,366 gallons per month when only value was considered. The average home of approximately $222,000 would have 1,066 gallons contributed by cost alone. While value and home size are more proxies of behavior and family size and are arguably unchangeable, this information is of value in controlling for the effects of climate on a home water use. These variables provide a starting place for calculating water consumption which then varies based on weather-related conditions.

Weather-related variables and pools significantly effect water consumption. For example, each additional degree in average temperature raises consumption by 168 gallons. Thus, in comparing a 48 degree day in January to an 87degree day in July, the difference in a home's water consumption would be 6,552 gallons per month – that's quite substantial. Also, a home with a pool utilizes an additional 3,699 gallons of water per month. That's over 44,000 gallons a year. A property with average home and lot area, and value with no pool during average weather (temperature, rainfall, an evaporation) would utilize 10,068 gallons per month. If multiplied by 12 months in the year, this gives a total yearly consumption rate of approximately 120,800 gallons. In comparison to the 100,000 gallon per year projected figure for Austin homes under the new plumbing code and hopeful 36,000 gallons per year for Austin Green Building Homes (City of Austin Environmental , 2003), this tells that green features will need to have a very significant inverse correlation with water consumption if these goals are hoped to be reached. For those homes without any water reducing features however, this consumption figure would be quite high.

While the fairly low correlation coefficient is disappointing, other studies have encountered similar results. One factor that was not investigated in this study was the number of occupants per household. This has been shown in some previous studies to be a substantial variable in explaining water consumption. Unfortunately, in this study, use of the Green Building database was contingent on the agreement that no homeowners would be contacted.

However, even with survey information included, most studies of residential water usage and corresponding regression models have not had high predictive ability. This is probably due to the great disparity in water use habits that exist among residential consumers as evidenced in prior research. Efforts should still be made to determine those variables that effect residential water consumption regardless. Even if a model can not be derived that explains most of the variation, researchers can still determine which factors significantly affect residential consumption and then either future predictions can be made with these findings in mind or changes can be made so that water consumption in relation to these factors is reduced. For example, if temperature is found to significantly affect residential water consumption, then possible solutions to temperature-related water use should be investigated, such as replacing turf with native vegetation or planting more shade trees. Also, by determining the effects of climate, home and lot size, appraised value and presence of a pool, these variables can be controlled for and isolated in future studies so that the contributions of specific green building factors can be analyzed. Hence, even with fairly low predictive power, regression models that attempt to explain residential water use are still of benefit.

Recommendations

Future research should attempt to not only gather information for one particular program group, but to compare findings between groups. Thus, studies with Austin Green-Rated homes and non-rated homes in the Austin area should be conducted so that similarities and differences can more easily be assessed instead of simply using average consumption data for comparison. Additionally, if possible, surveys should be conducted that assess issues not available in public databases such as the number of people per household, watering habits, vegetation types and shade cover. These might offer additional clues that would help explain more of the variability in residential water consumption and lead to more accurate predictive models. Finally, a longer time period of study could be beneficial to help overcome the affects of unusual weather patterns. If this study were conducted over many years, findings may have been different in regards to rainfall effects on consumption and resulted in a more logical model.

AUSTIN GREEN BUILDING PROGRAM ANALYSIS: THE EFFECTS OF WATER-RELATED GREEN BUILDING FEATURES ON RESIDENTIAL WATER CONSUMPTION

The green building movement has grown tremendously in the last decade with no signs of stopping. A major impetus for this movement was the creation of the Austin Green Building Program. It created the first green rating system in the country to give direction and recognize builders for efforts to make residences more sustainable. Today, almost 20 similar programs are functioning throughout the country. While these programs are assumed to provide benefit to both homeowners and the environment, little research has been conducted on the effect they are actually having in regards to water conservation. This study investigates the results of installing either water-conserving features or incorporating water-conservation ideas into homes registered with the Austin Green Building Program. It was hoped that if these items were shown to reduce water consumption, the Program would receive recognition for a job well done and other programs would be able to use their rating system as a model. If items were shown to be ineffective, then further investigations would need to be conducted to find the reasons and new water-saving strategies devised.

In actuality, a mix of findings emerged. One of the most important findings was that the effect of water-conserving features varies considerably by builder. Also of interest is the relatively small number of water-related features builders are incorporating. Finally, only a few items were found to consistently reduce water consumption while others had either no or varied effects or even increased water consumption. While these findings are interesting, further research will no doubt be required to provide definite confirmation.

Need for Conservation

Water supplies around the world are in jeopardy as populations increase and sources dwindle. Current projections estimate that 3 billion people will live in areas classified as under water stress or scarcity by the year 2025, up over 6 times from the year 2000 level of 480 million (Gleick, Burns, Chalecki, Cohen, Cushing, Mann, Reyes, Wolff, & Wong, 2002). The United States shares this problem of increasing water scarcity. Projections estimate that by 2050, almost 40% of the U.S. population will live in areas that will either need to be conserving water or developing new water sources to cope with water shortages (U.S. House Committee, 2003).

Texas is one of the largest (top four) water consuming states in the U.S. (Wagner & Kreuter, 2002). With a population expected to double by 2050, water needs are expected to increase from 4.23 to 7.06 million acre-feet/year (National Wildlife Federation, Environmental Defense, and Lone Star Chapter of the Sierra Club, 2001). To complicate the issue, conventional fresh water supplies in the State are already 75%-80% developed (Texas Water Development Board, 1995). This is why the Governor's task force in 2000 identified limited water supply as one of the two "most serious natural resource issues facing Texas today" (Wagner & Kreuter, 2002).

The purpose of this study is to determine the effects of (1) socioeconomic factors (home size, lot size, appraised value and pools), (2) atmospheric factors (temperature, rainfall and evaporation) and water-related features from the Austin Green Building Program single-family checklist on residential water consumption. Austin, Texas was selected for this study for two reasons. First, the city has recently experienced water crises as the city's source aquifer has experienced greater than average declines. Additionally, Austin has the oldest and one of the largest Green Building Programs for residential construction in the country. The idea and development of green building programs is spreading quickly across the country with 19 residential green builder programs functioning and seven additional programs in the development stages (NAHB, 2002b). Little research has been done, however, on the homes involved with these programs. It was therefore of interest to investigate homes registered with the Program to determine if findings vary from prior residential studies and if conservation techniques purported in the Program (Xeriscaping, rainwater catchment systems, natural vegetation…) significantly reduce water consumption.

Austin Green Building Program

Developed in the early 90's as the first U.S. program to promote sustainable residential construction, the Austin Green Building Program's (AGBP) mission is to "accelerate the integration of sustainable building products and practices with mainstream building through marketing, education, and technology transfer." (American Council for an Energy-Efficient Economy, 2003). One of the main ways this is accomplished is through the Program's "green" rating system. The Program rates new homes and remodels on a scale of one-to-five stars, with more stars indicating a greater number of green features or design considerations. Features and designs are subdivided into five main categories: (1) energy efficiency, (2) water efficiency, (3) materials efficiency, (4) health and safety and (5) community (City of Austin, 2001). Points are given for incorporating items from a few or all of the five categories. Besides rating homes, the AGBP also provides consultation services and marketing support for members, technical seminars for designers, a directory of Green Building professionals and a resource library for members (City of Austin, 2001).

The Program is gaining immensely in popularity. In 2002, 57% of all new homes built in the Austin area were rated by the Program. Also, all new city-supported housing is now required to meet the 2-star compliance level or higher (American Council for an Energy-Efficient Economy, 2003). Program success can also be assessed from the growth in similar programs throughout the nation. As of July of 2002, 19 programs were functioning nationwide with an additional seven in the development stages (NAHB, 2002b).

While reports vary concerning the profitability of green building, almost all involved builders believe the AGBP rating system point values are based on environmental impact (80%) and that the Program makes a positive environmental difference in the community. The largest builder involved in the Program reported that their commitment to green building in the Austin area has resulted in "increased sales, market position, and customer satisfaction." (City of Austin, 2002). While support for the Program may be high in the community and among builders, little research has been done regarding the water conservation aspects of the AGBP and their resulting effect. Evidence of conservation effort effectiveness could assist in strengthening the Program (Mayer, DeOreo, Opitz, Kiefer, Davis, Dziegielewski, & Nelson, 1999). The findings of this study will measure correlations between green home water consumption and AGBP water-related features.

Prior Water Assessment Techniques

Previous studies have employed a variety of techniques to assess features or conditions that significantly affect water consumption. Engineering models have been used to predict how much water items or processes will use (Baumann, Boland, & Hanemann, 1998). Technological advances have enabled researchers the ability to monitor water usage directly as it occurs. While flow-trace devices do provide accurate data, cost and obtrusiveness can be a problem, and thus are limited to small case studies (Mayer, et al., 1999).

Although few studies have been conducted on water saving features, more substantial research has been completed on other conditions or items that affect residential water consumption. In regards to weather for example, rainfall and temperature have proven to be significant variables affecting water use in a number of studies that utilized multiple regression techniques (Anderson, Miller, & Washburn, 1980; Morgan & Smolen, 1976; Hansen & Narayanan, 1981). For example, a study conducted by Fourt (1958) in 1955 found that rainfall days, average number of people per meter and cost of water were significant factors affecting consumption (R^2 of .839) when 21 large cities were surveyed (Grima, 1972). However, in studies conducted by Linaweaver, Gyer, and Wolff (1967) and Haver and Winter, (1963) climatic factors were not found to be highly significant (Grima, 1972). Evapotranspiration (ET) has also been found to affect outdoor water consumption in a variety of studies (Danielson, Feldhake & Hart, 1980; Duble, 1997; Mayer, 1995; Stadjuhar, 1997; Aquacraft, Inc., 1997).

Aside from weather-related findings, homes with pools were found to use more than twice the exterior water as those without. Findings have also indicated that outdoor water use was positively correlated with home and lot square footage (Mayer, et al., 1999). Income or economic level has also been held as a significant factor influencing water consumption because it is generally assumed that those with higher incomes have more water-utilizing appliances or features (such as pools) and often have larger lots for irrigating (Grima, 1972). These items, as well as the AGBP conservation-related items will be tested to determine the effect each has on residential water use by Austin residents in 1998-2002.

Data

The first data required included monthly temperature, rainfall and evaporation data for the two-year period of March 2001 to March 2003. The second data consisted of monthly water consumption records (gallons per month) for each home registered in the Green Builder database on record at the Travis County Appraisal District. The span of the monthly records was from March 2001 to March 2003, corresponding with weather information gathered. The third data needed was the square footage of each home and yard, the appraised value and the existence of a pool for each home registered with the Green Builder Program that had a record at the Appraisal District. Finally, records of the green features included in each home along with information on the builder and star-rating were required.

The Location of the Data

Monthly temperature and rainfall information was gathered from the National Weather Service's Southern Regional Headquarters website. Evaporation data was gathered from the Ft. Worth District's Reservoir Control Office of the US Army Corps of Engineers website for Lake Travis/Marshall Ford Dam. Monthly water consumption records were obtained from the Austin Energy department. Information on the square footage of the homes and yards, appraised value and the existence of a pool for the green residences were then obtained by typing in each address at the Travis County Appraisal District and recording the information on site. Finally, records on green water-related features, builder and star rating information for each home were obtained from Austin Energy's Green Building Program database zip disk received in person from Austin Energy. The list of water-related green features is included in Appendix G.
Identifying information was deleted prior to obtaining the data except for address that was used to merge the diverse data sets. Once merged, address information was deleted. All findings are reported in aggregate figures only to ensure anonymity of residences. Builder information was considered public information by the AGBP.

Data Analysis

Temperature and evaporation were averaged monthly, while rainfall was totaled for each month. Home square footage, land square footage, appraised value, pool information, green features, builder, star-rating and household monthly gallons consumed were entered according to each residence built between 1998 and 2001. Stepwise linear regression was used to analyze significant relationships associated with monthly water use. Only those models with p-values less than .05 were considered further. Standardized residuals were saved for the model and then, to control for equal variance, only those cases in which the absolute value of the residuals was +/-4 were retained. This reduced the number of cases by less than 1% (N=16,477 from 16,605). Multicollinearity of the independent variables was analyzed using the Variance Inflation Factor (VIF) with values over 10 considered problematic. Therefore, models were only selected if VIF's for all variables were under 10.

Of the thirty-three builders participating in the Austin Green Building Program during the study period with corresponding available home water consumption records, there were 5 strata constructed based on the number of green homes, (1) Builder 1 with twenty-nine small builders with 24 or fewer homes totaling 169 homes, (2) Builder 2 with 65 homes, (3) Builder 3 with 79 homes, (4) Builder 4 with 115 homes, and (5) Builder 5 with 402.

Results

Descriptive statistics were first calculated for the data and are summarized in Table 15.

Table 15

Descriptive statistics for weather and home-related variables

	Water Use in Gallons per House per Month	Monthly Average Temp. ^{0}F	Monthly Rainfall Inches	Monthly Average Evap. Inches	Appraised Value $	Home S.F.	Lot S.F.	Star Rating
Mean	10,149	68.57	3.32	0.19	223,987	2,186	8,277	1.94
Median	7,900	69.50	2.46	0.16	225,000	2,279	7,680	2.00
Std. Deviation	7,877	12.91	2.63	0.10	106,632	774	2,653	0.57
Minimum	100	49.60	0.34	0.07	42,365	451	3,300	1.00
Maximum	57,700	87.20	10.00	0.39	952,004	4,853	30,056	4.00

The large variance in monthly water consumption was evidenced in the spread from a minimum of 100 gallons monthly per household to a maximum of 57,700 gallons. Half of the green-built households used 7,900 gallons/month or less. Approximately 20% of households consumed 4,000 gallons or less a month and approximately 20% used 15,000 or more. Less than 1% of households used over 38,000 gallons in a month.

Climatic conditions experienced during the study period were then compared to average Austin conditions to determine if the two year study period was indicative of normal weather patterns. Using Pearson correlation coefficients, temperature for the two year study period correlated over 98% with historic Austin levels and evaporation correlated almost 93%. However, rainfall was negatively correlated (-.14) for the study period's rainfall vs. historic Austin rainfall. The differences are illustrated in Figure 4 below. Thus, the inverse relationship between rainfall and water consumption found in prior studies may vary with respect to this particular study.

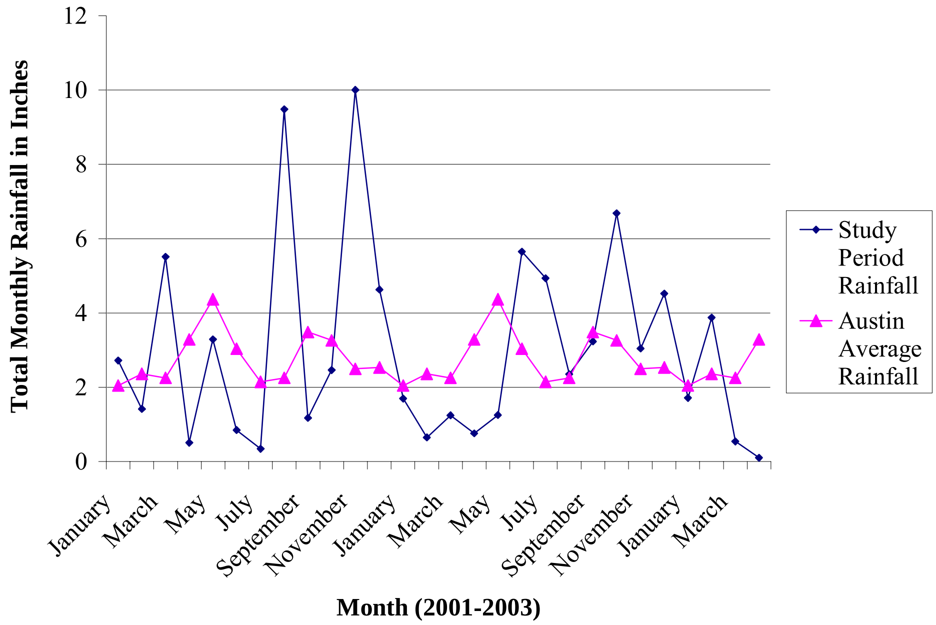

Figure 4: Study period monthly rainfall totals vs. Austin historic average monthly rainfall totals

Appraised values of the green-built homes ranged from $42,365 to $952,004 per home. When frequencies were analyzed, just over 12% of homes were valued at or below $100,000. Almost 50% were between $200,000 and $300,000, which is illustrated by the large spike in Figure 5. Finally, just over 11% of homes were appraised at or above $350,000. This distribution includes 47% of all green homes in the greater Austin area built between 1998 and 2001, however, it is not known how these values compare to non-green builder residences.

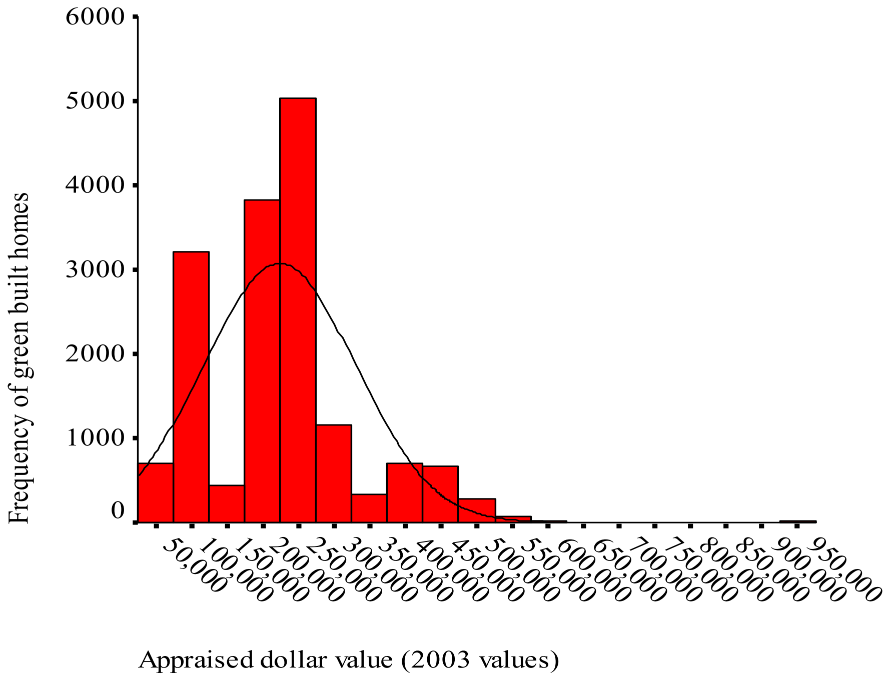

Figure 5: Frequency distribution for appraised value in Austin green-built homes, 1998-2001

Only 2% of study homes had square foot areas of 1,000s.f. or less and less than 2% were at or above 3,450s.f. The mean home square footage was 2,186. Lot square footages ranged from 3,300 to 30,056 with almost 60% between 6,000 and 9,000s.f.. Figure 6 illustrates this distribution. While the maximum sized lot was 30,056s.f., only 1% of lots were above 17,500s.f.

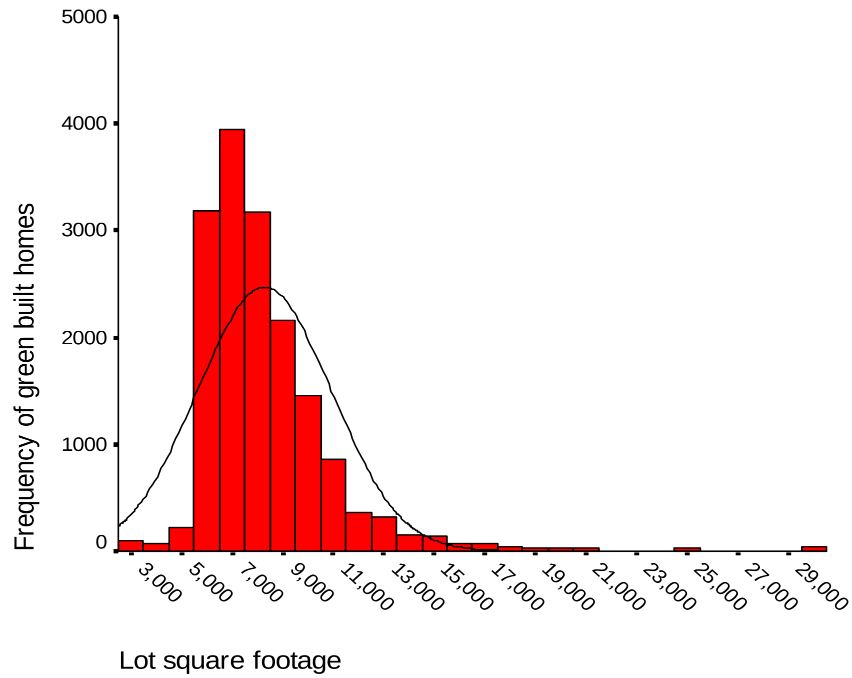

Figure 6: Frequency distribution for lot square footage in Austin green-built homes, 1998-2001

The distribution of star-ratings ranged from 1 to 4 stars for homes registered by the Austin Green Building Program from the period of 1998-2001 (a 5-star rating was available, but for all 7 homes registered with the rating, residuals were higher than 4). Findings show that almost 75% of homes registered achieved the two-star rating which requires point totals of 60 to 89. Less than 10% achieved a higher rating, with no 5-star homes. This distribution is reflected in Table 16.

Table 16

Star-rating distribution, Austin, 1998-2001

Star-Rating	Frequency	Percent
1	2,820	17.1%
2	12,099	73.5%
3	1,190	7.2%
4	346	2.1%
5	0	0

The frequency of using water-conservation features listed as builder options in the Austin Green Building Program home rating sheet was then investigated. A few items were very popular, including utilization of site trees (81.7% of the homes), Xeriscape (66% of homes) and efficient dishwashers, (65% of study homes) other features were used less than 25% of the time. For example, less than 1% of homes included solar heating, efficient clotheswashers, rainwater catchment systems, efficient irrigation systems, drip irrigation and graywater systems. While other options were incorporated more, their inclusion was still minimal. Table 17 below provides frequency percentages for inclusion for each of the AGBP water-related options.

Table 17

Frequency percentages for Austin rating system water-related options

% of Homes Containing	Shaded	Porch	Light Color	Solar Heat	Utilize Site Trees	Low Flow Showerhead	Efficient Clotheswash
Percentage	8.3	13.4	91.2	<1	81.7	20.9	<1
	Remodel	**Large Porch**	**Multiple Dwellings**	**15+ year Utilities**	**Mixed Use Subdivision**	**Save Site Trees**	**Pool**
Percentage	<1	12.9	2.6	23.3	5.4	10.5	1.9
	Efficient Dishwash	**Limited Area Waterheat**	**Natural Vegetation**	**Minimal Turf Use**	**Low-Water Turf**	**Xeriscape**	**Pervious Pavement**
Percentage	64.9	24.7	8.2	15.3	18.3	65.5	6.4
	Dillo Dirt	**Topsoil Amendment**	**Directed Gutters**	**Rainwater Catchment**	**Efficient Irrigation**	**Drip Irrigation**	**Graywater System**
Percentage	5.3	15.2	10.2	<1	<1	<1	<1

Next, SPSS was employed to calculate the most effective model describing the factors affecting water consumption using stepwise regression. The following formula was chosen as that with the highest R^2 value without any variance inflation factors over 10. The resulting R^2 was 0.224 and all variables were significant below the .05 level.

$$Y = -12445.996B_0 + 170.476B_1 + .0104B_2 + 351.521B_3 + .209B_4 + 3660.119B_5 + 1.428B_6 + 1021.443B_7 + 1884.920B_8 + 487.716B_9 -4954.909B_{10} + 2648.481B_{11} + 7113.801B_{12} -3288.587B_{13} + 6884.856B_{14} -1454.845B_{15} -2248.672B_{16} -1424.801B_{17} + 1498.224B_{18} -1630.345B_{19}$$

Where:
B_0 = Constant
B_1 = Temperature
B_2 = Value
B_3 = Rainfall
B_4 = Lot Square Footage
B_5 = Pool
B_6 = Home Square Footage
B_7 = Water Heather
B_8 = Low Water Turf
B_9 = Builder
B_{10} = Efficient Irrigation
B_{11} = Save Trees
B_{12} = Evaporation
B_{13} = Remodel
B_{14} = Efficient Clotheswasher
B_{15} = Minimal Turf
B_{16} = Gutters Directed at Vegetation
B_{17} = Dillo Dirt Amendment
B_{18} = Natural Vegetation Retained
B_{19} = Efficient Dishwasher

Negative relationships were of considerable interest, with the following green builder variables found to decrease consumption: an efficient irrigation system, a remodel, minimal use of turf, gutters directed towards vegetation, Dillo Dirt amendment (EPA-certified soil conditioner comprised of wastewater sludge that is anaerobically digested and composted) (Water and Wastewater Utility, 2001) and an efficient dishwasher. Unexpectedly, the following Program variables were found to increase water use: a water heater located close to distribution sources, low-water turf varieties, saving site trees, use of an efficient clothes washer, and retaining natural vegetation. As found in several previous studies, temperature, value, home and lot square footage, evaporation and the existence of a pool were directly related to water consumption as well. However, rainfall also increased consumption which is counterintuitive and in opposition to prior findings. The builder variable was also found to significantly affect water consumption, but further investigation is needed on which builders in particular are positively and negatively associated with water consumption.

Therefore, regression analysis was utilized to develop formulas for each builder group to determine if the same variables were significant for each. Table 18 illustrates the findings for and between each builder.

Extreme differences between home builder groups are evident in the above table. One observation is that the small builder group incorporated a wider variety of water-conserving features into its homes. It is unclear, however, if this relates to the greater variety of builders and styles in the small builder (Builder 1) group or if small builders actually incorporate more water saving features. Findings for the group however, do vary substantially from prior study population findings as a whole. For instance, ensuring shade, installing a porch, using site trees, creating a light colored exterior, installing pervious paving and topsoil amendment all proved to significantly reduce water consumption where these items had not in the general grouping. As before however, the use of Dillo Dirt amendment, an efficient dishwasher, a remodel, minimal use of turf, and gutters directed towards vegetation, decreased water usage. Also of interest were the findings that solar heating, multiple dwellings, and 15 year old + utilities increased consumption, although upon consideration, this may seem reasonable. Finally, within the small builder group, it appears that two-star homes have the greatest impact in reducing water consumption.

Table 18

Univariate analysis coefficients for each of five green builder groups

Intercept	Builder 1	Builder 2	Builder 3	Builder 4	Builder 5
Avg. Monthly Temperature	-5,320.63	-2,478.07	-1,279.90	-4,298.03	-15,972.28
Total Monthly Rainfall	99.93	48.50	53.75	228.13	234.12
Avg. Monthly Evaporation	212.81	243.00	222.03	551.66	424.53
Value	2,076.07	29,187.61	10,721.24	15,103.84	3,633.54
Home Square Footage	-0.01	-0.03	0.03	-0.10	0.02
Lot Square Footage	4.82	2.62	-0.18	8.15	0.48
Shaded	0.05	0.15	0.08	-0.17	0.32
Porch	-1,592.68	0.00	0.00	0.00	0.00
Light Color	-287.31	-1,159.74	0.00	0.00	0.00
Solar Heating	-835.08	908.56	0.00	0.00	0.00
Use Trees	803.56	0.00	0.00	0.00	0.00
Low-Flow Showerhead	-978.69	0.00	0.00	5,012.85	0.00
Efficient Clotheswasher	1,153.27	0.00	0.00	0.00	0.00
Efficient Dishwasher	6,452.19	0.00	0.00	0.00	0.00
Water Heater	-875.26	0.00	0.00	0.00	0.00
Natural Vegetation	636.55	0.00	0.00	0.00	0.00
Minimal Turf	2,652.60	0.00	0.00	0.00	0.00
Low Water Turf	-2,164.31	0.00	0.00	0.00	0.00
Xersiscape	1,469.73	0.00	0.00	0.00	0.00
Pervious Paving	2,435.30	0.00	0.00	0.00	0.00
Dillo Dirt	-697.39	0.00	0.00	0.00	0.00
Topsoil	-2,451.41	0.00	0.00	0.00	0.00
Directed Gutters	-1,366.06	0.00	0.00	0.00	0.00
Rain Catchment	-4,573.30	0.00	0.00	0.00	0.00
Efficient Irrigation	0.00	0.00	0.00	0.00	0.00
Remodel	4,254.80	0.00	0.00	0.00	0.00
Large Porch	-242.98	0.00	0.00	0.00	0.00
2+ Dwellings	1,558.88	0.00	0.00	0.00	0.00
Old Utilities	3,201.68	0.00	-880.85	0.00	0.00
Mixed Use	950.08	0.00	0.00	0.00	0.00
Save Trees	2,156.38	0.00	0.00	0.00	0.00
Pool	3,241.94	1,827.30	0.00	0.00	0.00
Star Rating 1	4,709.73	1,572.47	0.00	0.00	3,778.44
Star Rating 2	-690.73	0.00	0.00	0.00	0.00
Star Rating 3	-2,691.48	0.00	0.00	0.00	0.00
Star Rating 4	-1,798.68	0.00	0.00	0.00	0.00

Among the other builders, few variables stood out as significantly affecting water consumption. This may be because some builders include certain variables in every one of their homes and thus within group comparisons can not be made to determine if the item is effective. Regardless, in Builder Group 2, homes with porches consumed less water, while light colored homes and saving trees resulted in increased water use. For Builder Group 3, multiple dwellings were the only item found to reduce consumption and utilizing trees on site increased consumption for Builder Group 4.

Between group findings were also of interest. For groups one, two and four, value was found to negatively relate to consumption. This is in contrast to previous findings from other studies and to the findings for the groups as a whole. Also, weather had significantly different magnitudes of effect between builders such that each degree in temperature rise increased water use by 48.5 gallons for builder 2 and over 234 gallons for builder 5. However, each inch of evaporation increased water consumption for Builder 2's homes by over 29,000 gallons, while Builder 5's homes only increase 3,634 gallons per inch. Only for Builder 3, did home square footage and consumption have a negative relationship and for Builder 4, lot square footage and consumption had a negative relationship. A summary of descriptive statistics for all five builder groups is included in Appendix C to aid in possible explanation of these variances.

Finally, in an attempt to explain a greater portion of the variance in the dependent variable, interaction terms were analyzed as well as the difference between small and large builders. The following formula resulted as that with the highest R^2 and no VIF's over 10 to control for multicollinearity.

$$Y = -8969.48B_0 + 197.31B_1 + 382.14B_2 + 7167.53B_3 + 0.01B_4 + 1.21B_5 + 0.28B_6 - 607.96B_7 + 506.81B_8 + 4241.97B_9 + 2477.20B_{10} - 2213.01B_{11} + 1993.56B_{12} - 2397.63B_{13} - 4021.38B_{14} + 5922.87B_{15} + 2245.34B_{16} + 1394.05B_{17} + 2477.37B_{18} + 3449.60B_{19} + 5156.70B_{20} - 132.62B_{21} - 149.63B_{22} - .03B_{23} + 2.61B_{24} - .27B_{25} - 3163.43B_{26} + 3688.63B_{27}$$

Where:
B_0 = Constant
B_1 = Temperature
B_2 = Rainfall
B_3 = Evaporation

B_4 = Value
B_5 = Home Square Footage
B_6 = Lot Square Footage
B_7 = Porch
B_8 = Use Trees
B_9 = Efficient Clothes washer
B_{10} = Natural Vegetation
B_{11} = Minimum Turf
B_{12} = Low-Water Use Turf
B_{13} = Dillo Dirt
B_{14} = Directed Gutters
B_{15} = Efficient Irrigation
B_{16} = Multiple Dwellings
B_{17} = Mixed Use
B_{18} = Save Site Trees
B_{19} = Pool
B_{20} = Builder
B_{21} = Temperature x Small Builder
B_{22} = Rainfall x Small Builder
B_{23} = Value x Small Builder
B_{24} = Home Square Footage x Small Builder
B_{25} = Lot Square Footage x Small Builder
B_{26} = Star Rating
B_{27} = Star Rating x Small Builder

The adjusted R^2 for the above group of variables was .241 with all variables significant below the .05 level. To verify that the above model would be applicable to future data, correlations were conducted to see if the model could be applied to a sample of 80% of the data and a sample of 20% of the data. When the model was compared to the 80% sample, Pearson's coefficient was over 99.5%. When the proposed model was compared to the 20% sample, a correlation coefficient of 96% was reached. Finally, when the 80% group was compared to the 20% group, a coefficient of 94% was realized. It is therefore believed, since the correlation coefficients were fairly similar, that the formula should be effective for future data.

The interaction terms can be interpreted as the reaction of small builders' homes to either temperature, rainfall or evaporation as opposed to large builders or how increases in builder's home value, lot and home size affect water consumption. For example, water consumption in small builders' homes increases less than large builders with temperature and rainfall. Also, as value increases in small builders' homes, water consumption increases less relative to large builders and as home square footage increases for small builders, water consumption increases more than large builders. Finally, as lot square footage increases in the yards of small builders, water usage does not increase as much as that in large builder yards.

Like the prior formula without interactions, the use of minimal amounts of turf, Dillo Dirt amendment and directed gutters reduced water consumption. In contrast however, porches also decreases consumption, but efficient irrigation systems, remodels and efficient dishwashers instead increased use.

Unlike the other formula and of particular interest is the finding that small builder's homes increase usage in a general sense, however, if temperature, rainfall and value increase significantly, these homes would actually use less water than large builder's homes.

Discussion

Several significant findings resulted from this study. One of the most important is the fact that different conditions and green features have distinct effects depending on the builder. This may be due to the manner builders install features, what types of products they install, their overall designs or other characteristics of their homes. Whatever the cause, it means that the assumption should not be made that certain green features are ineffective in all cases, for it may just depend on who is installing the item and what other features are included.

Overall, however, it was found that Dillo Dirt amendment, minimal use of turf and gutters directed towards vegetation decreased water consumption in both formulas. Consistently increasing water consumption were the green variables of low-water turf, saving site trees, use of an efficient clothes washer, and retaining natural vegetation. Conclusive results regarding clothes washers should not be made however, because less than 1% of homes incorporate these fixtures. As far as non-green variables, temperature, rainfall, evaporation, appraised value, home square footage, lot square footage and pools all had a positive relationship with water consumption. Rainfall's positive affect was a surprise as most prior research has found it to have a negative relationship to water consumption. In this study, the reason may be due to the abnormal rainfall during the study period, which correlated only slightly and also negatively with Austin historic averages.

Finally of interest is the relatively small effect green features had overall in reducing the total variability in monthly water consumption. The R^2 of the regression model with temperature, rainfall, size, value and pool characteristics included and no green features was .207. The highest R^2 without interactions was .224. Thus, only .017 of the water consumption variability was described by the green features. Thus, some variables not investigated in this study or purely homeowner use habits must account for the largest portion of water variability.

Recommendations

To determine the true effects of more green water-related features, a sample population that incorporated a greater number of these items would be beneficial. For instance, less than 1% of study population homes included such items as rainwater catchment systems, graywater reclamation systems, and drip irrigation systems. These however, may significantly reduce water consumption. Even though the total number of homes included in the study was quite large, either a population with greater variety or a study of homes that are known to include these items versus homes that do not would be more beneficial.

Also, a comparison of green to non-green homes could provide additional information on the effectiveness of these features. These homes may have owners that are more highly concerned with water conservation or may all have better plumbing or fixtures than the general population. Thus, a comparison with non-rated homes would allow the total story to be told.

Finally, a study of an area that did not include one dominant builder would also be beneficial. Because one builder constructed approximately 50% of the homes rated by the Program, their homes and features included may have had an undue influence on the findings for the group as a whole. With a more evenly distributed builder population, one builder's effects would be dissipated.

CONSERVING RESIDENTIAL WATER CONSUMPTION: AN ANALYSIS OF BUILDER EFFECTS ON THE AUSTIN GREEN BUILDING PROGRAM

Water conservation is taking on increased importance in Texas as populations explode and water resources dwindle. Several areas of the state have already developed methods to prevent future water crisis. One of the oldest and most well-known programs not only for water conservation, but overall sustainable practices, is the Austin Green Building Program. It was the first program in the county developed to rate homes based on the number and type of environmental features or design considerations included. It has and continues to serve as a model for programs around the country. While it is generally accepted that the Program results in better performing, more environmentally friendly homes, little research has been conducted except in energy conservation to support this. Therefore, this study investigates those factors that affect water consumption and conservation and the results that occur from the participation of various builders. Findings show that actually very few water-reducing features are included in the homes of most large builders, but of those incorporated, some are positively and some negatively related to water consumption. Additionally, results show that variables outside the program such as weather, value and size contribute to increased water consumption but at varying degrees by builder. Finally, yearly water use averages of Green Building homes compared to Austin area average home water consumption shows that the homes of smaller green builders fall below local use averages, while homes of the two largest builders fall above.

The Importance of the Study

The purpose of this paper is to describe and assess one of the first comprehensive residential green-builder programs in the U.S., comparing the effects participating green builders have on the water consumed in registered homes. Over 30 builders constructed homes in the Austin Green Building Program between 1998 and 2002. This study will assess the level of commitment (determined by the number of green water-conserving features included) and success in reducing water consumption between the homes of AGBP builders. If significant differences are noted between builders, those with more successful results could help educate others on their methods and materials. Also, if it is found that certain water-conserving features used by different builders have a greater effect in reducing water, than this information could be shared and these features promoted or required among other builders so that all homes registered with the Program realize substantial water savings.

By the year 2050, Texas' population is expected to double, and with it, municipal water demand is projected to increase from 4.23 to 7.06 million acre-feet/year (National Wildlife Federation, Environmental Defense, and Lone Star Chapter of the Sierra Club, 2001). Presently, conventional fresh water supplies in Texas are 75%-80% developed (Texas Water Development Board, 1995). This means that to be capable of meeting future water demands, new sources will have to be found or developed which will cost either governments or consumers greatly. This study proposes to identify the effectiveness of water conservation features among various builders participating in the Austin Green Building Program. If all or certain builders are saving considerable amounts, then these builders and their practices should be investigated and either promoted or required of other builders so that the state's dire water future can improve.

In response to these projections and to hypothesized solutions, polls have been taken with results indicating that residents favor conservation efforts as opposed to costly supply side initiatives (National Wildlife et al., 2001). If conservation was achieved in lieu of expansion, numerous benefits could result. For example, the cost of pumping and treating water could be reduced. Also, the expansion of existing facilities could be postponed or avoided resulting in both financial and environmental benefits. Energy required for pumping, treating and heating water would also be reduced (Prasifka, 1994). Finally, philanthropic benefits could result from the knowledge that one is contributing to the continued availability of Earth's most precious natural resource.

Far less data has been collected on water use than on supply and availability (Gleick, Burns, Chalecki, Cohen, Cushing, Mann, Reyes, Wolff, & Wong, 2002). Scientific results are available for a limited number of water-saving features, and of these, many are limited in scope or applicability. Additionally, the effectiveness of many water conservation measures as stated in various literature sources, have one or more of the following three faults (Baumann, Boland, & Hanemann, 1998): (1) the information is based on a priori engineering estimates instead of actual application, (2) other contributing factors are not included in the analysis and claims and (3) results are stated in aggregate form although affects differ by use groups (residential, commercial…). For example, many low flow toilets were engineered with less water required per flush; however, in actual application, two or three flushes were required to dispose of all waste (Baumann, Boland, & Hanemann, 1998). Additionally, if factors such as weather or price changes were not included in an analysis of the effects of drip-irrigation systems or some other conservation feature, an abnormally cool, wet year or increased prices might actually be accounting for changes in water use (Baumann, Boland, & Hanemann, 1998). Finally, if water prices were raised and the effects only tested on high-income single-family households, the results could not be generalized for other demographic groups or use groups because the effects would probably vary (Baumann, Boland, & Hanemann, 1998). Thus, scientific evidence on conservation effort effectiveness that addresses these problems would assist in improving existing programs or in developing new approaches (Mayer, DeOreo, Opitz, Kiefer, Davis, Dziegielewski, & Nelson, 1999).

The Review of the Related Literature

The Need for Reduced Water Consumption in New Construction

Sufficient future water supply is a concern for the entire world. Since 1960, the per capita supply of fresh water has dropped approximately 60% (Power, 2000). Water projections estimate that 3 billion people will live in areas classified as under water scarcity or stress by the year 2025. This is more than a six fold increase from year 2000 levels (Gleick, et al., 2002).

Texas consumes more water than any state in the U.S (Wagner & Kreuter, 2002). The Governor's Task Force recently identified Texas' tremendous consumption and limited water supply as one of the most serious natural resource issues facing the state (Wagner & Kreuter, 2002). While most of this consumption has traditionally been tied to heavy agricultural use, municipal use is on the rise and projected to account for over 1/3 of the State's water usage by 2050 (Texas Water Development Board, 2002). This means that water used in businesses and residences will become increasingly important for conservation efforts.

The Texas State Water Plan, created in 1997, recommends a range of actions, from conservation to dam construction, to ensure an adequate water supply for the future. Revised in 2002, the Plan includes water management plans until the year 2050. Demand projections were made for approximately 900 water use groups within 16 Texas water planning regions (including cities of 500+, use sectors such as residential, commercial, and industrial and county aggregations) along with any needs for additional water if existing resources are insufficient for the future. If additional water was needed, strategies were presented to meet this projected need. The work was accomplished by a combination of regional representatives, almost 900 public meetings, and Texas' natural resource management agencies. The plan also put water planning in the hands of the public on a more local basis (Texas Water Development Board, 2001). Unfortunately, conservation has been addressed minimally in the Plan. Only 21% of water use groups have included water conservation to any extent. (National Wildlife et al., 2001).

Texas spends approximately $1 billion a year on new water treatment, sewage and drainage facilities. From 1995 to 2050, it is estimated that $65 million will be needed for water treatment, supply and drainage infrastructure (Texas Environmental Profiles, 2003). Also, over 600,000 acres of forested wetlands have been replaced with deep-water aquatic habitats as a result of reservoir construction. The 1997 Texas Water Plan proposes the conversion of an additional 52,000+ acres of wetlands to deep water habitats. Opponents argue that this harms existing wildlife and penalizes users downstream with decreased water flow. It also increases costs for water treatment as discharged water must meet higher standards because it is flowing into more diluted rivers and streams (Texas Environmental Profiles, 2003).

It is hypothesized however, that year-round conservation efforts could result in huge savings for Texas. A National Wildlife Federation report found that water savings from even just municipal sector conservation could result in such water savings, that many financially and environmentally damaging projects could be avoided (National Wildlife et al., 2001). Thus, there are significant benefits, both financial and environmental, to develop and use methodologies that conserve water. However, further testing is required to ensure that products and programs claiming to conserve water actually do.

Methods Used to Determine What Is Affecting Water Usage

A variety of methods have been utilized in past studies to determine the effects of conservation measures on water use. The major methods used include retrospective regression analysis or monitoring devices with before and after results compared. Both techniques have advantages and disadvantages.

Multiple coefficient regression methods use statistical formulas with variables either hypothesized to effect water consumption or variables found to influence consumption in past studies. The number and type of independent variables included in these models varies with local conditions, the choice of variables deemed as potentially important, the availability of data and the desired accuracy (Prasifka, 1994).

Econometric forecasting uses multiple regression to analyze the relationships between independent variables and the dependent variable of water consumption with the assumption that the relationships will not change in the future. An example of an econometric model would correlate demand to variables such as price, income and weather. These models can be either linear or mathematically converted to a linear relationship. One must be cautious when developing econometric models to test for multicollinearity, equal variance, and autocorrelation which would invalidate the findings (Prasifka, 1994).

“Flow trace analysis” and the use of “micro-meters” are relatively new technologies (DeOreo, Mayer, and Lander, 1996) that have been employed in several recent water conservation studies (Aquacraft Inc., 2003). These devices can record and identify the source of water use in a residence to determine the effects of conservation programs (DeOreo, Mayer, & Lander, 1996). While initial costs for this type of study were very high (almost $10,000 per home in some studies), equipment and software advances have significantly reduced this amount (Mayer, et al., 1999).

A majority of studies concerning residential water demand utilize either cross-sectional or time-series data. Cross-sectional studies utilize information on water usage from different locations during one time period. Time-series studies focus on one location over different or extended time periods (Griffin & Chang, 1989). Time series data are considered superior by some in creating forecast models because trends can be identified and possibly assumed to continue in the future. Cross-sectional studies require greater assumptions as it is difficult to make generalizations about one period of time which may be abnormal from usual conditions. However, time series data are only valid in the short term because the variables that affect use can significantly change (Prasifka, 1994).

For larger, more economical studies, statistical models that use historic billing data are the most common. In one of the earliest of these studies, conducted in 1940 by Roy Hunter, typical water demands for fixtures were determined using a probability function. The results of this study were used for almost 60 years to size water meters and service lines (Mayer, et al., 1999). More recent studies include a 1993 study in Pasadena in which billing records and socioeconomic data were analyzed to measure the effects of a conservation program (Kiefer, Dziegielewski & Opitz, 1993). A similar study was conducted in 1994 using a sample of 494 homes in the Phoenix area. Recommendations from this study included the use of metering devices to verify modeling results (Mayer, et al., 1999).

Findings Related to Factors Influencing Residential Water Usage

Numerous studies have been conducted to determine which variables reliably affect residential water use. Although results of the studies have varied with time and place, most researchers hypothesized that climatic factors affect residential water usage. Fourt (1958) found that rainfall days, average number of people per meter and cost of water were significant factors (R^2 of .839) when 21 large transcontinental U.S. cities were surveyed (Grima, 1972). Evapotranspiration (ET) has also been found to affect outdoor water usage (Danielson et al., 1980, Duble, 1997; Mayer, 1995; Stadjuhar, 1997; Aquacraft, Inc., 1997). When homes in a 14-city 1999 study were analyzed and averaged by city, the effect of ET yielded an R^2 value of .17 when outdoor use was assumed as the amount above a winter baseload in which it is assumed that no exterior watering occurs. Alternately, when outdoor use was calculated as the amount above the indoor baseload calculated from a data logger, an R^2 of .59 was yielded which suggests that over 50% of outdoor water use was explained solely by ET when compared to average exterior city usage. Amazingly, when one study location with the highest average lot sizes was deleted, Las Virgenes, California, the R^2 value jumped to .78. However, when ET was compared to individual residences throughout each city, an R^2 of only .1645 was derived (Mayer, et al., 1999). This occurrence is speculated to be caused by large variation in water use habits among homeowners which will be discussed more in-depth below. When water use was averaged by city, much of the individual variation was removed and hence led to higher correlation values. In other studies however,(Linaweaver, Gyer, & Wolff, 1967) climatic factors were not found to be highly significant (Grima, 1972).

Income or economic level have also been held as significant factors influencing water consumption. It is generally assumed that those with higher incomes have more water-utilizing appliances or features (such as pools) and often have larger lots. This is evidenced in high levels of collinearity shown to exist between lawn size and residence value (Grima, 1972). However, while many studies report this finding, few have shown that income was significantly associated with increased water usage aside from a study by J.D. Headley (1963) which found a correlation coefficient of .81 between water usage and median family income (Grima, 1972).

Many other factors have also been evaluated in regards to their influence on water consumption such as metering, water cost and the number of people in a residence, but no conclusive evidence has been produced from prior studies that these factors significantly affected water use consistently (Grima, 1972). However, Mayer and others (1999) found in their 12-city nation-wide study of indoor water consumption, that the greatest predictor of use was the number of people per household. In fact, a regression formula with the number of occupants per household as the only independent variable and indoor water consumption as the dependent variable yielded an R^2 value of .9944.

Regardless of the method used or variables included, consistently low correlation values among water use studies are thought to be the result of inconsistent homeowner behavior. In a 1990 Southern California study it was found that just 11% of households irrigated within +/-10% of what the landscape required, 39% over-irrigated and 50% under-irrigated (Baumann, Boland, & Hanemann, 1998). In another study, findings showed that approximately 22% of homeowners used less than 10% of a theoretical required water amount, and approximately 17% applied more than the required amount (Mayer, et al., 1999). Thus a great deal of water use can not be explained simply from a collection of significant independent variables because unexplained water use amounts varied so widely.

Green Construction and Water Conservation

Without a doubt, green construction is not merely a component-by-component substitution for traditional building products. Instead, it is a "whole-building" approach to design (Bynum & Rubino, 1999), taking into effect not only construction techniques, but also reduced energy and water consumption, protection of ecosystems and occupant health (Environmental Building News, 2001). Finally, the definition by the U.S. Green Building Council, creators of the Leadership in Energy and Environmental Design commercial building program is "design and construction practices that significantly reduce or eliminate the negative impact of buildings on the environment and occupants in five broad areas: sustainable site planning, safeguarding water and water efficiency, energy efficiency and renewable energy, conservation of materials and resources, and indoor environmental quality" (United States Green Building Council, 2003).

The trend in green construction is growing by leaps and bounds throughout the United States and the world. The United States Green Building Council now has over 2,000 members, up from approximately 250 just three years ago (Freemantle, 2002). Figure 7 below illustrates this growth, with particularly high acceleration among constructor memberships which have tripled in the last year.

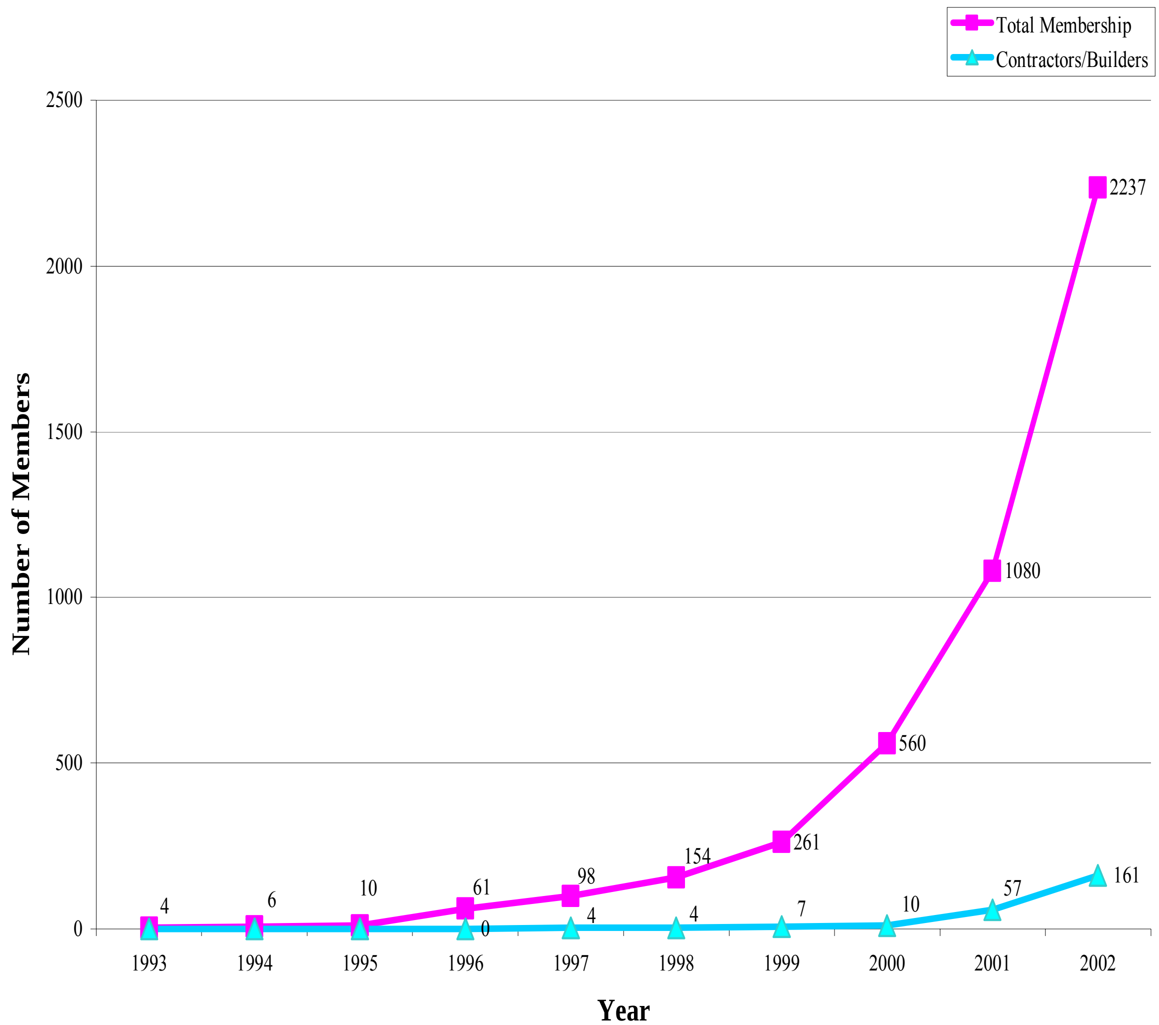

Figure 7: USGBC total membership and construction membership

Residential initiatives in green construction are growing particularly fast. The first green rating system in the country was developed as the Austin Green Builder Program in 1990, which at that time was purely residential. As of July of 2002, 19 programs were functioning nationwide with an additional 7 in the development stages. While the functions of these programs vary, the primary goals of all are to increase education and thus acceptance of green building as a necessary technique for future growth. The number of homes registered within these programs varies substantially, with almost 10,000 registered in the Built Green Colorado program to very few homes registered in the newer programs, such as the Green Built Program of Grand Rapids (4 homes) (NAHB, 2002b).

Austin's Green Builder Program

Austin has been ahead of the sustainability curve since the 1980's. The city launched its first green program in 1985, the Austin Energy Star Program, which gave marketing assistance to builders that exceeded the City's Energy Code. Over 6,000 homes were rated under this program. However, the city decided more could be done to stop the damage caused by development and construction. With the assistance of several green movement leaders in the Austin area, the City's Green Builder Program was created and has continued to grow and thrive ever since (Green Building Program, 2001).

The Austin Green Building Program(AGBP) evaluates new homes and remodels on a scale of one-to-five stars, with more stars indicating a greater number of green features. These features are subdivided into to five main categories: energy efficiency, water efficiency, materials efficiency, health and safety and community (City of Austin, 2001). Point requirements can be met by incorporating items from a few or all of the five categories. Besides rating homes, the AGBP also provides consultation services and marketing support for members, technical seminars for designers, a directory of Green Building professionals and a resource library. The Program is considered comprehensive and as a long term success which led to its being named the National Association of Home Builders' 2002 Program of the Year (NAHB, 2002a).

Analysis of the Program

The purpose of this study was to investigate a performance-based standard which would indicate the actual effects of the ABGP. Testing the performance of water saving features as well as other considerations could help reinforce the benefits of Program participation. Additionally, the findings should be of aid to homebuilders who are interested in what techniques or combination of techniques were most associated with reduced water consumption.

Builder Study Population

Thirty-three builders participated in the Austin Green Building Program between 1998 to 2002. Data on each of their homes and its water consumption records were analyzed. The builders were divided into five major groups, one with 402 homes, a second with 115, a third with 79 and a fourth with 65 and the fifth group, of the remaining twenty-nine builders, each having constructed less than 25 homes during the period of 1998-2001.

Each of the four large builders was investigated to determine their green focus and characteristics. The largest builder in the AGBP builds in a variety of price and size ranges, from the low $100's to over $700 thousand. They pride themselves as having one of the "most extensive energy and resource efficiency programs in the nation" and now have committed to constructing only green homes in the Austin market. The fourth largest builder advertised specifically it's commitment to energy efficiency, however, there was no mention of water-saving features. While this company built a large number of green homes in 2000 and 2001, no green homes were constructed after 2001. The second largest builders constructed green homes ranging in size and cost as well, from $60,000 to $300,000. Their advertisements purport that they build energy efficient and environmentally responsible homes. (Austin Green Building Program, 2003). Austin's largest local home builder, and third largest green home builder emphasizes affordability and energy efficiency in their advertisements (Main Street Homes, 2003).

General Procedure

In order to determine if differences in use of water conservation features exist between builders participating in the Austin Green Builder Program, both Program and non-Program features/conditions must be assessed to determine their effect on residential water consumption. Non-Program variables include such items as weather (temperature, rainfall and evaporation), home size, lot size, cost and the existence of a pool. Additionally, all items under the AGBP "Water Conservation" category will be assessed along with several others that might affect water usage such as saving trees on site and connecting to 15+ year old utility lines. In all, a total of 36 independent variables were analyzed. A list of these is included in Appendix G.

Collection Procedures

The first data required included monthly temperature, rainfall and evaporation data for the two-year period of March 2001 to March 2003. Temperature and rainfall information was gathered from the National Weather Service's Southern Regional Headquarters website. Evaporation data was gathered from the Ft. Worth District's Reservoir Control Office of the US Army Corps of Engineers website for Lake Travis/Marshall Ford Dam. The second data consisted of monthly water consumption records (gallons per month) for each home registered in the Green Builder database that is on record at the Travis County Appraisal District. The span of the monthly records was from March 2001 to March 2003, corresponding with weather information gathered. Water consumption data was provided by the Austin Energy Department. The third data included the square footage of each home and yard, whether a pool existed, and the appraised value for each home registered with the Green Builder Program that has a record at the Appraisal District. Finally, information on green features (specifically water reducing) included in each builder's homes was acquired from AGBP database records provided by the Austin Energy office.

Treating the Data

All factors that may have an affect on water usage including: monthly average temperature, monthly total rainfall, monthly average evaporation, home square footage, land square footage, appraised value, existence of a pool, green features, builder, and star-rating data were compared to the household gallons consumed per monthly billing period using multivariate linear regression in SPSS to determine if significant relationships existed. Variables with p-values of 0.05 or less were determined to be significant. Coefficients of significant variables were then analyzed to determine whether the variable positively or negatively affected water usage and to what extent. These findings were then compared between the four largest builders, each with over 60 homes constructed in the 1998-2001 period and the fifth grouping which included the smaller builders with registered green homes. Descriptive statistics were also analyzed to compare each of the builder groups.

Results

Significant differences were found to exist between the items the five builder groups chose to include in their homes and their effect on water consumption. Table 19 illustrates these differences. Cases refer to each month of billing information for each home in which information on all variables was available.

Table 19

Descriptive statistics comparison of builders

Builder	**Water Use (Gallons)**	**Appraised Value**	**Home S.F.**	**Lot S.F.**
Builder 1				
N=3,343				
Minimum	100	42,365	451	3,300
Maximum	51,200	952,004	4,853	30,056
Median	6,800	109,252	1,152	7,555
Mean	8,616	156,051	1,475	8,187
Std. Deviation	6,632	123,910	685	3,271
Builder 2				
N=1443				
Minimum	100	54,000	1,425	5,750
Maximum	47,600	250,000	2,438	19,529
Median	6,700	200,000	1,845	6,941
Mean	8,763	198,693	1,911	7,904
Std. Deviation	6,688	25,377	319	2,759
Builder 3				
N= 1851				
Minimum	100	82,509	1,008	5,750
Maximum	43,700	130,000	1,497	12,377
Median	7,200	101,539	1,226	6,815
Mean	8,597	99,301	1,257	7,164
Std. Deviation	5,935	8,805	146	1,232
Builder 4				
N=1231				
Minimum	100	200,000	1,572	6,999
Maximum	55,000	339,799	3,580	12,898
Median	9,600	273,920	2,314	8,125
Mean	11,756	271,014	2,400	8,337
Std. Deviation	8,922	35,039	558	1,120
Builder 5				
N=8591				
Minimum	100	166,000	1,570	5,609
Maximum	57,700	561,216	3,885	29,748
Median	8,600	245,045	2,730	8,096
Mean	11,081	274,785	2,679	8,606
Std. Deviation	8,501	85,762	503	2,671

From the above table it is apparent that households in builder groups one, two and three use approximately the same amount of water when monthly averages are compared. In all three instances as well, the median value is over 1,000 gallons different from the mean, indicating that the distribution is skewed by a small number of homes with large variances in water consumption. Mean usage values for builders four and five are over

2,000 gallons higher per month than the other three groupings. This could be due to the fact that average home and lot areas and appraisal values for these two builders are higher than for the other three groups. Later, multivariate analysis will control for the influence of these factors.

A chi-square analysis was conducted to determine if builder groups used all features equally. This analysis is included in Appendix D. These findings show that the small builder group (group 1) used the widest majority of green features and used them to a greater extent than large builders except for using trees from the site, using a light colored exterior, using water efficient dishwashers, and multiple dwellings on the site. The chi-square matrix also illustrates that big builders used few of the water-conserving features in their homes overall.

A regression model was then analyzed to determine the affects of both the green features and non-program related variables such as weather and appraisal data on water use. Also included were the effects that individual builders' homes displayed regarding water usage. Only those variables shown to be significant at the 0.05 level were included (Table 20 and Appendix E).

Table 20

Coefficients and p-values for all significant (.05) water-related variables with builders broken out individually

Category	Variable	Coefficient	P-Value
	Intercept	-21344.14	0.000
Homebuilder	Builder 5	-13384.53	0.008
	Builder 6	16586.15	0.000
	Builder 10	11456.86	0.008
	Builder 11	24155.27	0.000
	Builder 13	23419.95	0.000
	Builder 14	16366.41	0.000
	Builder 15	10058.60	0.000
	Builder 17	8839.44	0.012
	Builder 20	23088.50	0.000
	Builder 21	14594.52	0.000
	Builder 22	9507.10	0.000
	Builder 25	22896.68	0.000
	Builder 28	13932.56	0.000
	Builder 29	16026.86	0.000
Star Rating	Star Rating 1	-8689.45	0.003
	Star Rating 2	-7553.78	0.003
	Star Rating 3	-5038.54	0.014
Non-Program	Temperature	185.06	0.000
	Rainfall	403.34	0.000
	Evaporation	7317.80	0.000
	Value	0.02	0.000
	Home S.F.	1.32	0.000
	Lot S.F.	0.36	0.000
	Pool	3218.66	0.000
Exterior	Shaded	-2963.48	0.019
	Light Color	1271.86	0.011
	Use Trees	-5900.58	0.000
	Natural Vegetation	3448.86	0.010
	Minimal Turf	3569.89	0.036
	Xersicape	5865.34	0.001
	Pervious Pavement	-4022.48	0.024
	Dillo Dirt	-3336.51	0.010
	Large Porch	3658.39	0.000
Interior	Efficient Clotheswasher	7810.27	0.040
	Efficient Dishwasher	-10788.36	0.001
Development	Remodel	6945.43	0.013
	Mixed Use Area	2852.76	0.005

From this analysis, it is apparent which factors and builders lead to decreased water consumption and which actually increase water use. While a majority of factors appear to increase water usage, having a shaded home, using existing trees, using efficient dishwashers, installing pervious paving and installing Dillo Dirt amendment were shown to decrease water consumption. Also, builder 5 was shown to build homes that consume less water. Finally, homes rated with one, two and three star ratings exhibit decreased water usage, although one-star homes seemed to reduce consumption to a greater extent.

Finally, Pearson correlation procedures were used to determine if relationships existed between the five builder groups (small builders were grouped together) and numerical independent variables such as weather, appraisal information and star rating (Table 21). Each weather factor was positively correlated with water use for all builders. Value, home and lot square footage are also positively correlated with water use in each instance where they are significant. Star-ratings were only significant for builders 3 and displayed an inverse effect with water consumption.

Table 21

Pearson correlation coefficients of water use by builder

Water Use	**Star Rating**	**Value**	**Home SF**	**Lot SF**	**Rainfall**	**Temperature**	**Evaporation**
Builder 1	.	0.09	0.13	0.06	0.08	0.20	0.17
Builder 2	.	.	0.10	0.08	0.05	0.47	0.48
Builder 3	-0.07	0.07	.	.	0.09	0.26	0.25
Builder 4	.	0.16	0.20	.	0.16	0.41	0.37
Builder 5	.	0.27	0.22	0.23	0.13	0.35	0.32

. =not significant at .05

Summary

Two green features used by large builders of AGBP homes were shown to reduce water usage significantly, these were porches for builder 2 and multiple dwellings for builder 3 (Appendix D). No large builders included rainwater catchment systems or DilloDirt amendment, and only one of the four large builders included low-water use turf or pervious paving – the other four features shown to reduce water consumption. Also of interest is the finding that three of the four largest water increasing builders from the regression analysis (highest regression coefficients) are three of the four highest volume builders (builder 5 = 25, builder 4 = 11 and builder 2 = 20 from Table 2) which could indicate that the majority of homes are not conserving much water. The average Austin family uses 120,000 gallons of water a year although newer homes, built under the requirements of the current plumbing code use approximately 100,000 gallons per year. It was projected that green builder homes could reduce water use to 36,000 gallons per year (City of Austin Environmental and Conservation Services, 2003). What this study found was that compared to the Austin average, by taking the median monthly water consumption value of each builder and multiplying it by twelve months, builder 5's (the largest builder) homes use 121,200 gallons/year, which is more than the city average. Builder 4's homes use 103,200, which is less than the city average, but not as good as expectations under the new plumbing code. Homes of builders 1-3, however, use 86,400 or less gallons of water per year, which is an improvement over city averages. Some of the consumption values may be influenced by size and cost as well, but for this study it appears that at least some of the green homes are having a positive effect, however not as significant as the City had hoped for.

The lowest water consuming group on average was builder 3 who also had the lowest average appraised value, home and lot square footage. This correlates with the finding that water use is positively related to value, home and lot square footage from the Pearson correlation analysis here and with prior studies. Also of interest from the Pearson correlation analysis was the finding that all weather-related variables, including rain, were positively related to water consumption for each builder group. This finding is contrary to what would be expected which is decreased water usage with more precipitation.

Star-ratings of 1, 2, and 3 were significant from the multivariate analysis, but only for builder 3 from the Pearson correlation analysis. They each displayed an inverse effect with water consumption, however, since all homes in the study were rated and one-star homes appear to decrease water usage the most, this finding is inconsistent with what would be expected.

For the most part, the large builders seemed to be consistent in the number of items they included and in the fact that they included very few of the water conserving features into their homes. The smaller builder group included a much wider range of water-reducing features, but this might be expected considering that some 29 builders comprised this group. While several of these small builders actually did include greater numbers of water related green items, others did not and therefore it is difficult to make generalizations about small builders as a whole.

When descriptive statistics were analyzed, standard deviations were very high. This is probably due to the great discrepancy in watering habits that have been shown to exist in prior studies for the large builders and for the small builder group (group 1), it may be due to the large variation in green water-conservation features included.

Conclusions

This study illustrated the wide variation in green features residential builders choose to incorporate into their homes and the affects that builders can have in creating a water-conserving home. Definitely there are some builders that have a greater impact than others on water consumption among the Austin Green Builders. However, it appears that overall, the smaller AGBP builders create homes that use less water than their non-green counterparts, while homes of larger builders use more than expected.

Also of interest was the finding that certain green water-related items displayed a significant affect in reducing consumption while others did not. Further testing is necessary to confirm these results, but if they are confirmed, these water-reducing items should be considered first in future homes so that even greater reductions in water consumption can be realized.

Differences not only in the items that green builders include, but possibly in their installation methods or materials can have a substantial affect on which items actually performed as expected. Thus in future studies of green building programs, it is important to disaggregate home information by builder so that incorrect generalizations are avoided. For instance, from the multivariate analysis of all builders, it appeared that home appraised value positively correlated with water consumption. However, when builders were analyzed individually, the homes of three of the five groups actually showed reduced water consumption as value increased. Therefore, the specific practices of each builder should be analyzed to determine why or why not their methods actually result in water use reductions.

Recommendations

In future studies, it would be beneficial to compare both non-green and green homes between builders and in general. This way, the entire effect of the features could be determined instead of comparing affects to an already higher standard. One problem with this however is that several of the builders only construct green homes. Still, for those that construct a variety of both rated and non-rated homes the comparison would be beneficial. Additionally, homeowner effects should be taken into consideration. Surveys could be developed and completed that would assess the number of occupants per household, watering habits and other factors so that all possible water-affecting variables would be included.

CONCLUSIONS

In each of the four studies, new and sometimes unexpected findings resulted. Overall, one of the most important findings appears to be that the success of the Program and of the green water-related features depends to a great extent on the builder and possibly what other practices or features they employ. Other findings, applicable to each separate study are explored below.

Builder Survey

Information was gained about builder characteristics and tendencies in this study. Of interest in regards to the database information on trends and popularity was the fact that builders seem to choose checklist items more on the basis of cost than on the basis of point value. This fact was reinforced by survey results where 80% of builders indicated that the consideration of cost was somewhat to very important and only 33% indicated that point value was somewhat to very important.

Trends were also observed in regards to air quality and possibly mold-related items (primarily mechanical related). This probably stems from the recent onslaught of court cases against builders in Texas regarding toxic mold syndrome. Builders may be implementing changes in relation to mold problems regardless of involvement in the Green Building Program, but decide they might as well get points if those items are listed.

In regards to the survey, the researcher found participants for the most part were more than willing to help and offer additional valuable advice about green construction and even philosophical advice on the environment. Many interesting comments and discussions arose including the comment that the greatest improvements in green participation would be found if suppliers were convinced that manufacturing green products could be beneficial to their business and then started offering more options and better prices for their environmental goods. Many of the builders interviewed stated that they had been building green all along and that it was simply the “right thing to do” regardless if their homes were rated.

There were a variety of answers in regards to whether green building was more profitable than non-green construction. Those that felt it was not had strong feelings either that it was morally wrong to receive a higher profit or that the time outlay was considerably greater than conventional construction which in turn reduced profits. Many simply said that green building was still not a high priority for most buyers and that if it cost more, they were not interested. Others stated that green homes were more profitable when clients were educated thoroughly on their benefits or when cost-plus work was performed because construction costs were higher, resulting in a higher profit. Builders repeatedly concurred that the real benefits were gained by the homeowners that would have lower bills, better health and higher resale value.

For the most part, builders were very supportive of the Austin Green Builder Program and the efforts of those working there. Some disagreed slightly with some of the rating items – either that there were not enough to cover all aspects that might be incorporated or that some items were included just for political reasons. However, even these comments were followed with overall satisfaction with the Program and its administrators. Survey results also indicated that builders felt checklist item point values were at least somewhat based on their environmental impact (80%). Only 32% indicated they believe that point values are at least somewhat based on their cost to include in or on the property. This corresponds with database comparisons indicating that few checklist item cost estimates relate to their allotted point value.

Finally, in regards to the correlation analysis it appears that more large builders are qualifying homes at the 2-star level and that those at this level choose checklist items more for their environmental impact. Few large builders actually take part in the Program however, and not all of them could be reached. Therefore, this finding could be the result of the answers of a very few samples and thus be skewed. Among custom home builders, there was a negative correlation with choosing checklist items for their environmental impact. This could be because owners are often driving or at least influencing the process and they do not give builders free reign to make their homes as green as possible.

Weather, Size, Value and Pool Effects on Residential Water Consumption

In the second study, which investigated the effects of non-green features on residential water consumption, results demonstrated that only a fraction of residential water consumption can be explained by the water-increasing variables of temperature, rainfall, evaporation, appraised value, home square footage, lot square footage and the existence of a pool. However, each is significant (at $p=.05$) in explaining monthly water use. Findings here also gave light to the magnitude many of these factors have in regards to water consumption. For instance, if one compared the minimum sized home (451sf) to the maximum size home (4853sf) in this study, based solely on the square footage coefficient (1.31), there would be a difference of 5,767 gallons per month between the two homes. Additionally, if the lowest ($42,365) cost home were compared to the highest cost home ($952,004) in the survey, the difference in water usage based on the regression coefficient (.0048) would be a difference of 4,366 gallons per month when only value was considered. Temperature is also highly significant as each degree in average temperature raises consumption by 168 gallons. Rainfall's positive affect was a surprise as most prior research has found a negative correlation to water consumption. In this study, the reason may be due to the abnormal rainfall during the study period, which correlated only slightly and also negatively with Austin historic averages.

While the fairly low correlation coefficient was disappointing, previous studies have had similar results. One factor that was not investigated in this study was the number of occupants per household. This has been shown to be a substantial variable in explaining water consumption in several past studies. Unfortunately, use of the Austin Green Building Program database was contingent on the agreement that no homeowners would be contacted. Low correlation coefficients may also be the result of the great disparity in water use habits that exist among residential consumers as evidenced in prior research. Regardless, efforts should still be made to determine those variables that effect residential water consumption so that either future predictions regarding water needs can be made with these findings in mind or changes can be made in relation to these factors, thus reducing their attributed water effects. For example, if temperature is found to significantly affect residential water consumption, then the sources of temperature-related water use can be investigated and changes made. Turf might be replaced with native vegetation or more shade trees might be planted just to name a few alternatives. Hence, even with fairly low predictive power, regression models that attempt to explain residential water use are still of benefit even though generalizations made based on the formulas should be made with caution.

The Effect of Austin Green Building Features on Residential Water Consumption

Several significant findings resulted from this study of water-related green features. One of the most important was the fact that different conditions and green features have distinct effects depending on the homebuilder. This may be due to the manner builders install features, what types of products they install, their overall designs or other characteristics of their homes. Whatever the cause, it means that the assumption should not be made that certain green features are ineffective in all cases, for results may just depend on who is installing the item and what other features are included.

Overall, however, it was found that Dillo Dirt amendment, minimal use of turf, and gutters directed towards vegetation decreased water consumption in both formulas. Consistently increasing water consumption were the green variables of low-water turf, saving site trees, use of an efficient clothes washer, and retaining natural vegetation. Conclusive results regarding clothes washers should not be made however, because less than 1% of homes incorporated these fixtures.

Finally of interest is the relatively small effect green features had overall in reducing the total variability in monthly water consumption. The R^2 of the regression model with temperature, rainfall, size, value and pool characteristics included and no green features was .207. The highest R^2 with green features included and no interactions was .224. Thus, only .017 of the water consumption variability was described by the green features. Thus, as concluded in the prior study, some variables not investigated or purely homeowner use habits must account for the largest portion of water variability.

Differing Effects of Green Builders

This fourth and final study illustrated the wide disparity in green features various builders chose to incorporate into their homes and the great influence builders have in creating a water-conserving home. It appears that large builders integrate only a small number of water-related green features into their homes, while results are unclear for the majority of small builders. This may explain why the builder variable for some small builders was negatively correlated with water consumption and positively affected consumption for all large builders.

Positive relationships with water consumption for large builders and some small builders may be a result of not only the number of green items included, but possibly in their installation methods or materials used. Thus, in future studies of green building programs, it is important to disaggregate home information by builder so that incorrect generalizations are avoided. Then, the specific practices of each builder should be analyzed to determine why or why not their methods result in water use reductions.

Also of interest was the finding that certain green water-related items displayed a significant affect in reducing consumption while others did not. Therefore, these water-reducing items should be considered first for incorporation in future homes so that even greater reductions in water consumption can be realized.

Summary

The Austin Green Building Program, while successful in number of homes included, energy reductions and possibly other environmental benefits, has done little to assess water conservation amongst its homes as well as builder attitudes towards the Program and features overall. While Program organizers assume that rated homes consume considerably less water than non-rated homes, without assessment, these generalizations should not be made. This series of studies has demonstrated that more must be done in regards to water-related features to reduce consumption levels in rated homes and to ensure consistent results among builders. While a few features appear to be working as desired, others have little effect or actually seem to increase usage. Thus, changes should be made so that claims regarding water reductions can actually be met.

In an assessment of builders, what was found was that most choose to incorporate less expensive features into their homes. This does not mean that inexpensive items are not as effective as those that cost more, but in the case of water conservation, better results might actually arise if more expensive items were used. For example, rainwater collection systems and graywater systems have had great success in testing, but their cost seems to be prohibiting their incorporation in these homes. If greater point values were assigned to these items or point minimums were increased, then these types of items might start finding their way into more green homes and water savings might be improved.

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APPENDIX A

Austin Green Builder Program Homebuilder Survey

Company Name ___________________________ Phone Number ________________

What is your name? ____
What is your position/title? ____________________________________

1. How many properties did you build in the last two years? ___________________
   If you do not know exactly, what range would you approximate?
   10 or less ________
   11 – 25 ________
   25 – 100 ________
   100+ ________

2. Which percent are custom? __________ Which percent are spec.? ___________

3. Approximately what percentage of your Austin homes built in the past two years qualify as "Austin Green Builder Program homes"? _________

4. Which level(s) of green homes have you built?*
   1 ____
   2 ____
   3 ____
   4 ____
   5 ____

5. On a scale of 1- 5 with 1 indicating strong agreement, 2 indicating agreement, 3 indicating neutrality, 4 indicating disagreement and 5, strong disagreement please rate the following two statements:

In general, I feel checklist item point values are related to the cost of incorporating them in a home. _____

In general, I feel checklist item point values are related to their environmental impact. __

Please explain your response. ____
____

6. Does your company or the buyer decide which items to include in custom homes?
   ___Buyer ____Company ____Both Options

7. When making decisions about which checklist items to include in a home, how important is each of the following on a scale of 1 to 5 with 1 as very important and 5 as not important at all?
   _____ Expected environmental impact

_____ Cost
_____ Point value
_____ Familiarity with process or products
_____Public perception
_____Other ___________________________________

8. How much do you agree with the statement that green homes are more profitable than non-green homes on a scale of 1 to 5 with 1 indicating strong agreement and 5 indicating strong disagreement? _______

Thank you so much for your time.

*Point Ranges:

One Star	40-59 pts.
Two Star	60-89 pts.
Three Star	90-129 pts.
Four Star	130-179 pts. Including E11, E18, E38 (or E10), and H20
Five Star	180 or more pts. Including E11, E18, E38 (or E10), and H20

This research study has been reviewed and approved by the Institutional Review Board – Human Subjects in Research, Texas A&M University. For research-related problems or questions regarding subjects' rights, the Institutional Review Board may be contacted through Dr. Michael W. Buckley, Director of Research Compliance, Office of the Vice President for Research at (979) 845-8585 (mwbuckley@tamu.edu).

APPENDIX B

Austin Green Building Program Single-Family Home Rating Checklist

Category		Pts.		Designation and Descriptions
ENERGY				High quality mechanical systems, efficient equipment, reduced need for mechanical systems
Design		3	E1	Home designer and builder is are full Members of the Green Building Program
		2	E2	Design created by design team, including designer, builder and mechanical contractor
		3	E3	A detailed mechanical plan has been made concurrently with, and is part of, the construction plans and specs
		4	E4	Size: maximum 1200 sq. ft. for 2 bedroom home + 250 sq. ft. maximum for each additional bedroom
		3	E5	House shaded on east and west (e.g. shade trees, overhangs, covered porches)
		2	E6	50% of west wall interior space protected by buffer spaces (e.g. garage, closets)
		2	E7	Operable thermal chimney / cupola / clerestory / monitor designed for stack effect ventilation
		3	E8	Glazing on east and west sides combined is limited to 25% of total glass area
			E9	
		4	E10	All duct work is located within the thermal envelope (insulated space)
		5	E11	Home design allows for a minimum of 600 sq. ft. of living space per ton of cooling;
		6	E12	**Or** home design allows for a minimum of 700 sq. ft. of living space per ton of cooling
		1	E13	Raised-heel roof truss construction to allow for increased insulation and ventilation
		2	E14	Fireplace is glass-door-sealed unit with outside combustion air; or house has no fireplace
		2	E15	Washer and dryer are located outside the home's heated and cooled space
		2	E16	Covered outdoor area such as porch or patio (minimum of 100 sq. ft.)
Thermal Envelope		2	E17	"Total fill" insulation in walls (e.g. wet-blown cellulose, BIBS, open-cell foam, cementitious foam), or wall is integrally insulated or requires no added insulation (e.g. ICF, SIPS, straw, earth)
		4	E18	Blower door test performed by qualified technician results in range of 0.35-0.45 Air Changes per Hour
		3	E19	Continuous ridge and soffit vents; or attic space is within thermal envelope
		4	E20	Roof radiant barrier; or radiant barrier is not needed (e.g. unvented attic w/ complete insulation at the roof deck)
		2	E21	No skylights
		2	E22	Double pane windows
		3	E23	Tile or metal roof or roofing material from Cool Roofs list
		2	E24	Light colored exterior walls
Heating, Cooling, Water Heating		3	E25	Ceiling fans in all main rooms and bedrooms (not required in dining/breakfast rooms)
		1	E26	Whole-house fan with insulated cover
		1	E27	13.0 SEER cooling equipment efficiency
		2	E28	**Or** 14.0 SEER cooling equipment efficiency
		3	E29	**Or** 15.0 SEER cooling equipment efficiency
		1	E30	Programmable thermostat
			*	***We recommend that items E31--E37 be included in mechanical system specifications.***
		2	E31	No main HVAC trunk lines made of flex duct and no flex duct take-offs over 10' long
		1	E32	Ducts cut to exact length and supported to manufacturer's specs, original diameter maintained
		2	E33	No turns in ductwork greater than 90 degrees
		2	E34	90 degree angles in rigid duct have turning vanes; take-offs have air-grabbers
		2	E35	Air-balancing dampers installed at each start collar
		2	E36	Supply system air flow tested by qualified technician (attach test form)
		2	E37	Main bedroom has dedicated return air duct or pressure balancing mechanism (door undercut does not qualify)
		5	E38	Direct "duct blaster" pressure test by qualified technician results in 10% or less air leakage (attach test form)
		3	E39	Energy recovery ventilator installed
		2	E40	Gas water heater has Energy Factor of 0.59 or higher; or 0.57 plus heat-trap nipples
		2	E41	Gas combo space / water heating system with minimum 76% Recovery Efficiency
		4	E42	Solar domestic hot water or swimming pool heating system
Lighting, Appliances		3	E43	All recessed can lights are ICAT type (insulatable and sealed); or no recessed cans are installed
		3	E44	Minimum of 3 light fixtures are installed with fluorescent lamps/bulbs (compact or tube)
		1	E45	Outdoor lights are installed with fluorescents, motion detectors, or photovoltaics
		4	E46	Photovoltaics installed on home (garden pathway lights excluded)
		1	E47	Installed appliance is Energy Star-certified (refrigerator, dishwasher, or clotheswasher)
Additions				

MATERIALS			Durable, low-maintenance, engineered, certified, reused, recycled, recyclable, local, natural
Design, Structure		4	M1 Size: maximum 1200 sq. ft. for 2 bedroom home + 250 sq. ft. maximum for each additional bedroom
		2	M2 No solid lumber 2x10's or larger used for floor or roof framing
		1	M3 Engineered roof trusses
		2	M4 **Or** alternate roof structure (e.g. I-beams, LVL, SIPS, steel)
			M5
		2	M6 Wall stud framing is on 24" centers (as Code allows);
		3	M7 **Or** wall framing is by the "Optimum Value Engineering" method (as Code allows);
		3	M8 **Or** "solid" exterior wall system (e.g. SIPS, ICF, AAC, straw, earth)
		4	M9 Built-in recycling center in kitchen, pantry, or utility room
Finish Materials		2	M10 Tile or metal roof
		2	M11 Porch/deck/patio floor: reused/reclaimed lumber; alternative (wood composite, plastic lumber); or masonry
		2	M12 Doors or cabinet wood is reused or local species (e.g. pecan, mesquite, Texas juniper)
		2	M13 Entire trim package is finger-jointed/engineered/MDF/reused or local species
		1	M14 Another recycled-content (50% or more content) or reused material (Enter others in Additions section below.) Material: ____________
		3	M15 Floor is durable material for minimum of 1/2 of all flooring (e.g. concrete, stone, brick, wood, ceramic tile)
		2	M16 Structural floor is finish floor for minimum 1/3 of all floor (e.g. exposed concrete, single-layer wood)
		2	M17 Flooring: natural fiber carpet (e.g. wool, jute, grass); linoleum (not vinyl); cork; bamboo; local-species, or reused wood; or there is no carpet in the house
Excess Jobsite Resources		2	M18 Trees removed from site are used (e.g. mulched); or house is designed to avoid tree removal
		2	M19 Wood scraps longer than 2 feet are reused/recycled
		2	M20 Paper / cardboard packaging and aluminum cans are recycled (receptacles provided on jobsite)
		2	M21 Metals are reused/recycled
		2	M22 Excess building materials are reused, given/sold to salvage, or donated to Habitat for Humanity RE-store
Additions			

WATER			Conservation of all water; protection of water quality
Indoor			W1
		3	W2 Horizontal axis clothes washer or Energy Star rated clotheswasher
		1	W3 Dishwasher uses no more than 7 gallons of water per load on normal cycle or is Energy Star labeled
		2	W4 Water heater is located within 20' of dishwasher, clothes washer and baths it serves; or demand-type hot water recirculator is installed
Outdoor		2	W5 Existing natural vegetation is essentially retained on at least 50% of pervious cover area
		2	W6 Turf grass/lawn does not exceed 50% of pervious cover area
		2	W7 Turf grass/lawn in sunny areas is low-water variety (buffalo or common bermuda); or there is no turfgrass
		2	W8 At least 90% of plants, shrubs and trees are selected from the City of Austin Xeriscape brochure list
		2	W9 Pervious paving (check with GBP staff for approval of type used)
		2	W10 Dillo Dirt is used for soil amendment (6 cubic yards minimum per site)
		4	W11 Landscape requiring watering has a minimum 6" of organic top soil (includes turfgrass areas)
		2	W12 Gutters and downspouts installed and directed away from foundation to landscaping or catchment system
		4	W13 Rainwater catchment system installed
		1	W14 Irrigation system has a) a controller for 5-day programming, b) multiple start times, c) 2 or more independent programs, d) manual flow control valves, e) rain shut-off device, f) matched precipitation heads with head-to-head spacing, g) check valves for heads on slopes, and h) an "as-installed" plan provided to homeowner.
		1	W15 Drip irrigation system for non-turf areas *Take both irrigation points if you have no turf and only natural vegetation/native plantings.*
		4	W16 Landscape irrigated with reclaimed water (e.g. greywater system, stormwater catchment)
Additions			

HEALTH, SAFETY			Improved air quality: reduced humidity, dust mites, and harmful chemicals
Molds, Mites, Fibers		3	H1 HVAC filter is electronic (not electrostatic); or 4" or thicker pleated-media type; easily accessed
		3	H2 No fiberglass fibers are exposed to the air stream in duct work. (Use only metal or lined duct material.)
		2	H3 Hygrometer installed in home
		3	H4 Central humidity control system in addition to cooling system (ERV with enthalpy qualifies)
		4	H5 Exhaust fans installed and vented to outside for cooktop/stove and any room with tub or shower
		2	H6 Laundry room exhaust fan installed, vented to outside (whether or not room has an operable window) or washer/dryer located outside of thermal envelope
		2	H7 Bathroom fan connected to timer or humidistat
		2	H8 50% or more of finish flooring is hard surface material (not carpet)
Chemical Outgassing		1	H9 Interior paint is super-low VOC (under 100 grams per liter);
		3	H10 **Or** interior paint has no VOC's (under 10 grams per liter); or is plant-based
		2	H11 All finish flooring installed with no-VOC-adhesives; or no adhesives are required
		2	H12 Cabinet, paneling, moulding and floor finishes are water-based
		3	H13 Construction adhesives have no VOC's
		3	H14 All insulation is formaldehyde-free--check Material Safety Data Sheet (MSDS)
		3	H15 Interior cabinetry and millwork are formaldehyde-free (Check MSDS)
		2	H16 Lockable hazardous-material cabinet, sealed off from living space and attached garage, vented outside
			H17
Combustion Gases		3	H18 Garage has exhaust fan with timer; or is separate structure from house; or there is no garage
		1	H19 No unvented gas logs (venting must be to outside of building shell)
		2	H20 House passes combustion safety/backdraft test as performed by qualified technician or there is no fireplace
		1	H21 Carbon monoxide detector installed
EMF's		1	H22 EMF-reducing wiring methods (See instructions)
		1	H23 Electrical main panel set ten feet or more away from bedrooms and areas of frequent occupancy
Integrated Pest Management		1	H24 Any wood used (e.g. siding, trim, structure) is at least 1 foot above soil
		1	H25 Fill dirt at foundation beams in plastic sand bags (not paper); no wood, cardboard or paper left in soil under or near foundation; "sono-tube" forms removed
		1	H26 Exterior wood-to-concrete connections are separated by metal or plastic; or there are no wood-concrete connections
		4	H27 Wood framing treated with a borate product to a minimum of 3 feet above foundation; or sand or diatomaceous earth or steel mesh barrier termite control system; or wall structure is not made of wood
Additions			

COMMUNITY			Improved quality of life; improved community ties; reduced urban sprawl
General		3	C1 Remodeling of an existing structure
		2	C2 Home has a front porch large enough for family to use (100 sq. ft. minimum)
		4	C3 Site has more than one dwelling unit (e.g. duplex, condo, "granny flat")
		3	C4 Street, electricity, water, wastewater have been in place for a minimum of 15 years
		4	C5 Home is located in a high-density or mixed use subdivision (e.g. Traditional Neighborhood Develop., Small Lot)
		2	C6 Public transit is within a 10-minute walk
		2	C7 A shopping area is within a 15-minute walk
		2	C8 Subdivision is adjacent to, or has a hike and bike trail or green belt or park
		2	C9 Backyard compost bin specified and provided (site-built or off-the-shelf)
		2	C10 Trees to be saved are protected with fencing at the drip line during construction activity (or no trees removed)
			C11
Additions			

Taken directly from the Austin Green Building Program Single Family Rating system

APPENDIX C

Home Builder Group Descriptive Statistics

Builder 1	**Water Use (Gallons)**	**Appraised Value**	**Home S.F.**	**Lot S.F.**
N=3343				
Minimum	100.00	42,365.00	451.00	3,300.00
Maximum	51,00.00	952,004.00	4,853.00	30,056.00
Median	6,800.00	109,252.00	1,152.00	7,555.00
Mean	8,616.06	156,050.95	1,475.41	8,186.97
Std. Deviation	6,632.29	123,910.13	685.33	3,271.28
Builder 2	**Water Use**	**Value**	**Home S.F.**	**Lot S.F.**
N=1443				
Minimum	100.00	54,000.00	1,425.00	5,750.00
Maximum	47,600.00	250,000.00	2,438.00	19,529.00
Median	6,700.00	200,000.00	1,845.00	6,941.00
Mean	8,762.96	198,692.64	1,911.23	7,904.49
Std. Deviation	6,688.01	25,376.94	319.30	2,759.40
Builder 3	**Water Use**	**Value**	**Home S.F.**	**Lot S.F.**
N= 1851				
Minimum	100.00	82,509.00	1,008.00	5,750.00
Maximum	43,700.00	130,000.00	1,497.00	12,377.00
Median	7,200.00	101,539.00	1,226.00	6,815.00
Mean	8,597.19	99,301.25	1,256.85	7,163.85
Std. Deviation	5,934.65	8,804.58	145.77	1,231.98
Builder 4	**Water Use**	**Value**	**Home S.F.**	**Lot S.F.**
N=1231				
Minimum	100.00	200,000.00	1,572.00	6,999.00
Maximum	55,000.00	339,799.00	3,580.00	12,898.00
Median	9,600.00	273,920.00	2,314.00	8,125.00
Mean	11,755.56	271,013.51	2,400.08	8,336.94
Std. Deviation	8,922.04	35,039.43	558.22	1,120.32
Builder 5	**Water Use**	**Value**	**Home S.F.**	**Lot S.F.**
N=8591				
Minimum	100.00	166,000.00	1,570.00	5,609.00
Maximum	57,700.00	561,216.00	3,885.00	29,748.00
Median	8,600.00	245,045.00	2,730.00	8,096.00
Mean	11,081.05	274,784.96	2,678.82	8,605.88
Std. Deviation	8,500.66	85,762.38	502.83	2,671.40

APPENDIX D

Variable Correlation Analysis

	Star Rating 1	Star Rating 2	Star Rating 3	Star Rating 4	Shaded
Builder 1	total:17.2%star1 total:20.4%bld1 p=.000	total:73.5%star2 total:20.4%bld1 total: p=.000	total:7.2%star3 total:20.4%bld1total: p=.000	total:2.1%star4 total:20.4%bld1 total: p=.000	total: 8.4%shd total:20.4%bld1 p=.000
Builder 2	total:17.2%star1 total:8.7%bld2 p=.000	total:73.5%star2 total:8.7%bld2 p=.000	total:7.2%star3 total:8.7%bld2 p=.000	total:2.1%star4 total:8.7%bld2 p=.000	total: 8.4%shd total:8.7%bld2 p=.000
Builder 3	total:17.2%star1 total:11.2%bld3 p=.000	total:73.5%star2 total:11.2%bld3 p=.000	total:7.2%star3 total:11.2%bld3 p=.000	total:2.1%star4 total:11.2%bld3 p=.000	total: 8.4%shd total:11.2%bld3 p=.000
Builder 4	total:17.2%star1 total:7.5%bld4 p=.000	total:73.5%star2 total:7.5%bld4 p=.000	total:7.2%star3 total:7.5%bld4 p=.000	total:2.1%star4 total:7.5%bld4 p=.000	total: 8.4%shd total:7.5%bld4 p=.000
Builder 5	total:17.2%star1 total:52.3%bld5 p=.000	total:73.5%star2 total:52.3%bld5 p=.000	total:7.2%star3 total:52.3%bld5 p=.000	total:2.1%star4 total:52.3%bld5p=.000	total: 8.4%shd total:52.3%bld5 p=.000

	Porch	LightColor	Solar	UseTrees	Blank
Builder 1	total:13.3%prch total:20.4%bld1p=.000	total:91.1%lght total:20.4%bld1 p=.000	total:.3%solar total:20.4%bld1p=.000	total:81.%tree total:20.4%bld1 p=.000	total:20.7%blk total:20.4%bld1p=.000
Builder 2	total:13.3%prch total:8.7%bld2 p=.000	total:91.1%lght total:8.7%bld2 p=.000	total:.3%solar total:8.7%bld2 p=.034	total:81.%tree total:8.7%bld2 p=.000	total:20.7%blk total:8.7%bld2 p=.000
Builder 3	total:13.3%prch total:11.2%bld3 p=.000	total:91.1%lght total:11.2%bld3 p=.000	total:.3%solar total:11.2%bld3 p=.015	total:81.%tree total:11.2%bld3 p=.000	total:20.7%blk total:11.2%bld3 p=.000
Builder 4	total:13.3%prch total:7.5%bld4 p=.000	total:91.1%lght total:7.5%bld4 p=.000	total:.3%solar total:7.5%bld4 p=.051	total:81.%tree total:7.5%bld4 p=.000	total:20.7%blk total:7.5%bld4 p=.000
Builder 5	total:13.3%prch total:52.3%bld5 p=.000	total:91.1%lght total:52.3%bld5 p=.000	total:.3%solar total:52.3%bld5 p=.000	total:81.%tree total:52.3%bld5 p=.000	total:20.7%blk total:52.3%bld5 p=.000

	Clotheswasher	Dishwasher	WaterHtr	Natl. Veg.	Min. Turf
Builder 1	total:.1%cloth total:20.4%bld1p=.000	total:64.9%dish total:20.4%bld1 p=.000	total:24.5%wtr total:20.4%bld1 p=.000	total:8.1%natl total:20.4%bld1 p=.000	total:15.2%min total:20.4%bld1 p=.000
Builder 2	total:.1%cloth total:8.7%bld2 p=.13	total:64.9%dish total:8.7%bld2 p=.000	total:24.5%wtr total:8.7%bld2 p=.000	total:8.1%natl total:8.7%bld2 p=.000	total:15.2%min total:8.7%bld2 p=.000
Builder 3	total:.1%cloth total:11.2%bld3p=.082	total:64.9%dish total:11.2%bld3 p=.000	total:24.5%wtr total:11.2%bld3 p=.000	total:8.1%natl total:11.2%bld3 p=.000	total:15.2%min total:11.2%bld3 p=.000
Builder 4	total:.1%cloth total:7.5%bld4 p=.163	total:64.9%dish total:7.5%bld4 p=.000	total:24.5%wtr total:7.5%bld4 p=.000	total:8.1%natl total:7.5%bld4 p=.000	total:15.2%min total:7.5%bld4 p=.000
Builder 5	total:.1%cloth total:52.3%bld5 p=.000	total:64.9%dish total:52.3%bld5 p=.000	total:24.5%wtr total:52.3%bld5 p=.000	total:8.1%natl total:52.3%bld5 p=.000	total:15.2%min total:52.3%bld5 p=.000

	Low Turf	Xeriscape	Pervious	Dillo Dirt	Topsoil
Builder 1	total:18.3%low total:20.4%bld1 p=.000	total:65.6%xer total:20.4%bld1 p=.654	total:6.3%perv total:20.4%bld1 p=.000	total:5.2%dill total:20.4%bld1 p=.000	total:15.1%top total:20.4%bld1 p=.000
Builder 2	total:18.3%low total:8.7%bld2 p=.000	total:65.6%xer total:8.7%bld2 p=.000	total:6.3%perv total:8.7%bld2 p=.000	total:5.2%dill total:8.7%bld2 p=.000	total:15.1%top total:8.7%bld2 p=.000
Builder 3	total:18.3%low total:11.2%bld3 p=.000	total:65.6%xer total:11.2%bld3 p=.000	total:6.3%perv total:11.2%bld3 p=.000	total:5.2%dill total:11.2%bld3 p=.000	total:15.1%top total:11.2%bld3 p=.000
Builder 4	total:18.3%low total:7.5%bld4 p=.000	total:65.6%xer total:7.5%bld4 p=.000	total:6.3%perv total:7.5%bld4 p=.293	total:5.2%dill total:7.5%bld4 p=.000	total:15.1%top total:7.5%bld4 p=.000
Builder 5	total:18.3%low total:52.3%bld5 p=.000	total:65.6%xer total:52.3%bld5 p=.000	total:6.3%perv total:52.3%bld5 p=.000	total:5.2%dill total:52.3%bld5 p=.000	total:15.1%top total:52.3%bld5 p=.000

	Gutter	Raincatch	Irrigate	Remodel	Big Porch
Builder 1	total:10.2%gutt total:20.4%bld1 p=.000	total:.1%rain total:20.4%bld1 p=.000	total:.3%irr total:20.4%bld1 p=.000	total:1%reml total:20.4%bld1 p=.000	total:12.8%big total:20.4%bld1 p=.000
Builder 2	total:10.2%gutt total:8.7%bld2 p=.000	total:.1%rain total:8.7%bld2 p=.13	total:.3%irr total:8.7%bld2 p=.032	total:1%reml total:8.7%bld2 p=.000	total:12.8%big total:8.7%bld2 p=.000
Builder 3	total:10.2%gutt total:11.2%bld3 p=.000	total:.1%rain total:11.2%bld3 p=.082	total:.3%irr total:11.2%bld3p=.014	total:1%reml total:11.2%bld3 p=.000	total:12.8%big total:11.2%bld3 p=.000
Builder 4	total:10.2%gutt total:7.5%bld4 p=.000	total:.1%rain total:7.5%bld4 p=.163	total:.3%irr total:7.5%bld4 p=.049	total:1%reml total:7.5%bld4 p=.000	total:12.8%big total:7.5%bld4 p=.000
Builder 5	total:10.2%gutt total:52.3%bld5 p=.000	total:.1%rain total:52.3%bld5 p=.000	total:.3%irr total:52.3%bld5 p=.000	total:1%reml total:52.3%bld5 p=.000	total:12.8%big total:52.3%bld5 p=.000

	Dwellings	Old Util	Mixed Use	Save Tree	Pool
Builder 1	total:2.6%dwll total:20.4%bld1 p=.000	total:23.3%old total:20.4%bld1 p=.000	total:5.4%mix total:20.4%bld1 p=.000	total:10.5%save total:20.4%bld1 p=.005	total:1.9%pool total:20.4%bld1 p=.000
Builder 2	total:2.6%dwll total:8.7%bld2 p=.000	total:23.3%old total:8.7%bld2 p=.000	total:5.4%mix total:8.7%bld2 p=.000	total:10.5%save total:8.7%bld2 p=.000	total:1.9%pool total:8.7%bld2 p=.000
Builder 3	total:2.6%dwll total:11.2%bld3 p=.000	total:23.3%old total:11.2%bld3 p=.000	total:5.4%mix total:11.2%bld3 p=.000	total:10.5%save total:11.2%bld3 p=.000	total:1.9%pool total:11.2%bld3 p=.000
Builder 4	total:2.6%dwll total:7.5%bld4 p=.000	total:23.3%old total:7.5%bld4 p=.000	total:5.4%mix total:7.5%bld4 p=.000	total:10.5%save total:7.5%bld4 p=.000	total:1.9%pool total:7.5%bld4 p=.000
Builder 5	total:2.6%dwll total:52.3%bld5 p=.000	total:23.3%old total:52.3%bld5 p=.000	total:5.4%mix total:52.3%bld5 p=.000	total:10.5%save total:52.3%bld5 p=.000	total:1.9%pool total:52.3%bld5 p=.000

if ___(row), then its' ___(color) that they have __(column)	
	less likely than expected
	more likely than expected
	no cases
	very close to expected (w/in 1 pt.)
	not significant

APPENDIX E

Variable Parameter Estimates

Dependent Variable: WATERUSE

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	-3416.292	326.342	-10.468	.000	-4055.957	-2776.628
TEMP	18.479	1.417	13.039	.000	15.701	21.256
RAINFALL	40.310	2.615	15.412	.000	35.184	45.437
EVAPORAT	732.515	190.237	3.851	.000	359.629	1105.401
SF_FILLD	.130	.023	5.550	.000	8.436E-02	.176
LOTSF	3.551E-02	.003	10.629	.000	2.896E-02	4.206E-02
VALUE	1.856E-03	.000	11.740	.000	1.546E-03	2.166E-03
STAR_RAT	262.537	91.371	2.873	.004	83.439	441.634
SHADED	-341.997	120.794	-2.831	.005	-578.766	-105.228
PORCH	-33.471	62.991	-.531	.595	-156.940	89.999
LIGHTCLR	129.103	49.949	2.585	.010	31.199	227.008
SOLAR	1608.111	271.434	5.924	.000	1076.071	2140.152
USETREES	-632.959	99.884	-6.337	.000	-828.742	-437.176
BLANK	267.357	134.518	1.988	.047	3.688	531.026
CLOTHES	775.835	369.584	2.099	.036	51.411	1500.259
DISHWSH	-1215.930	241.588	-5.033	.000	-1689.469	-742.392
WATERHTR	-175.146	142.982	-1.225	.221	-455.407	105.115
NATLVEG	299.798	120.221	2.494	.013	64.152	535.443
MIN_TURF	415.749	141.296	2.942	.003	138.794	692.704
LOW_TURF	-190.607	84.772	-2.248	.025	-356.769	-24.445
XERISCAP	539.314	156.515	3.446	.001	232.527	846.100
PERVIOUS	-426.017	177.717	-2.397	.017	-774.361	-77.672
DILLODRT	-390.088	116.820	-3.339	.001	-619.067	-161.109
TOPSOIL	89.838	158.203	.568	.570	-220.256	399.933
GUTTERS	-171.979	235.718	-.730	.466	-634.012	290.054
RAINCTCH	-2158.817	482.278	-4.476	.000	-3104.133	-1213.500
IRRIGATE	340.612	338.461	1.006	.314	-322.807	1004.031
REMODEL	691.846	278.393	2.485	.013	146.166	1237.527
BIGPORCH	349.772	85.038	4.113	.000	183.087	516.456

DWELLNGS	139.899	135.176	1.035	.301	-125.060	404.858
OLD_UTIL	470.873	151.120	3.116	.002	174.661	767.086
MIXEDUSE	267.636	101.491	2.637	.008	68.704	466.569
SAVETREE	59.258	73.330	.808	.419	-84.477	202.993
POOL#	321.768	49.562	6.492	.000	224.620	418.915
[BUILDER#=1]	435.632	265.486	1.641	.101	-84.750	956.013
[BUILDER#=2]	548.896	290.290	1.891	.059	-20.102	1117.895
[BUILDER#=3]	0[a]	.	.	.	.	.
[BUILDER#=4]	856.743	535.374	1.600	.110	-192.648	1906.134
[BUILDER#=5]	-1511.533	453.334	-3.334	.001	-2400.117	-622.949
[BUILDER#=6]	1839.401	316.382	5.814	.000	1219.257	2459.544
[BUILDER#=8]	441.272	362.126	1.219	.223	-268.534	1151.077
[BUILDER#=9]	-262.084	336.357	-.779	.436	-921.379	397.211
[BUILDER#=10]	1121.624	358.998	3.124	.002	417.949	1825.300
[BUILDER#=11]	2627.828	348.102	7.549	.000	1945.510	3310.146
[BUILDER#=12]	99.496	336.210	.296	.767	-559.511	758.503
[BUILDER#=13]	2573.903	310.897	8.279	.000	1964.512	3183.294
[BUILDER#=14]	1670.760	296.351	5.638	.000	1089.880	2251.640
[BUILDER#=15]	928.346	279.627	3.320	.001	380.247	1476.444
[BUILDER#=16]	732.109	292.395	2.504	.012	158.984	1305.234
[BUILDER#=17]	721.952	280.691	2.572	.010	171.767	1272.137
[BUILDER#=18]	353.452	270.642	1.306	.192	-177.036	883.941
[BUILDER#=19]	-663.246	355.290	-1.867	.062	-1359.653	33.162
[BUILDER#=20]	2287.405	385.103	5.940	.000	1532.562	3042.247
[BUILDER#=21]	1474.192	271.991	5.420	.000	941.060	2007.323
[BUILDER#=22]	947.479	237.347	3.992	.000	482.254	1412.703
[BUILDER#=23]	-161.396	310.634	-.520	.603	-770.272	447.479
[BUILDER#=24]	642.799	547.309	1.174	.240	-429.985	1715.583
[BUILDER#=25]	2519.868	310.306	8.121	.000	1911.634	3128.102
[BUILDER#=26]	565.348	297.580	1.900	.057	-17.941	1148.636
[BUILDER#=27]	969.338	404.015	2.399	.016	177.425	1761.252
[BUILDER#=28]	1404.249	263.018	5.339	.000	888.705	1919.792
[BUILDER#=29]	1769.054	331.166	5.342	.000	1119.933	2418.175
[BUILDER#=30]	485.793	322.294	1.507	.132	-145.939	1117.524
[BUILDER#=31]	112.492	315.841	.356	.722	-506.589	731.574
[BUILDER#=32]	0[a]	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

APPENDIX F

Regression Analysis Coefficients for Each of Five Green Builder Groups

	Builder 1	Builder 2	Builder 3	Builder 4	Builder 5
Intercept	**-5320.63**	-2478.07	-1279.90	-4298.03	**-15972.28**
Temperature	**99.93**	48.50	53.75	**228.13**	**234.12**
Rainfall	**212.81**	**243.00**	**222.03**	**551.66**	**424.53**
Evaporation	2076.07	**29187.61**	**10721.24**	**15103.84**	3633.54
Value	**-0.01**	**-0.03**	0.03	**-0.10**	**0.02**
Home S.F.	**4.82**	**2.62**	-0.18	**8.15**	**0.48**
Lot S.F.	0.05	**0.15**	0.08	-0.17	**0.32**
Shaded	**-1592.68**	0.00	0.00	0.00	0.00
Porch	-287.31	**-1159.74**	0.00	0.00	0.00
Light Color	-835.08	**908.56**	0.00	0.00	0.00
Solar Heating	803.56	0.00	0.00	0.00	0.00
Use Trees	**-978.69**	0.00	0.00	**5012.85**	0.00
Low Flow Shower	**1153.27**	0.00	0.00	0.00	0.00
Clotheswash	**6452.19**	0.00	0.00	0.00	0.00
Dishwasher	-875.26	0.00	0.00	0.00	0.00
Water Heater	636.55	0.00	0.00	0.00	0.00
Natural Veg.	**2652.60**	0.00	0.00	0.00	0.00
Minimal Turf	**-2164.31**	0.00	0.00	0.00	0.00
Low Water Turf	**1469.73**	0.00	0.00	0.00	0.00
Xersiscape	**2435.30**	0.00	0.00	0.00	0.00
Pervious Paving	-697.39	0.00	0.00	0.00	0.00
Dillo Dirt	**-2451.41**	0.00	0.00	0.00	0.00
Topsoil	**-1366.06**	0.00	0.00	0.00	0.00
Directed Gutters	**-4573.30**	0.00	0.00	0.00	0.00
Efficient Irrigation	**4254.80**	0.00	0.00	0.00	0.00
Remodel	-242.98	0.00	0.00	0.00	0.00
Large Porch	**1558.88**	0.00	0.00	0.00	0.00
2+ Dwellings	**3201.68**	0.00	**-880.85**	0.00	0.00
Old Utilities	950.08	0.00	0.00	0.00	0.00
Mixed Use	**2156.38**	0.00	0.00	0.00	0.00
Save Trees	**3241.94**	**1827.30**	0.00	0.00	0.00
Pool	**4709.73**	1572.47	0.00	0.00	**3778.44**
Star Rating 1	-690.73	0.00	0.00	0.00	0.00
Star Rating 2	**-2691.48**	0.00	0.00	0.00	0.00
Star Rating 3	**-1798.68**	0.00	0.00	0.00	0.00
Star Rating 4	0.00	0.00	0.00	0.00	0.00

Bold indicates significant at .05

APPENDIX G

List of water-related features under investigation

Category	Item
AGBP Energy Category	House shaded on east and west (e.g. shade trees, overhangs, covered porches)
	Light colored exterior walls
	Solar domestic hot water or swimming pool heating system
	Trees removed from site are used (e.g. mulched); or house is designed to avoid tree removal
AGBP Water Category	Low flow shower heads
	Horizontal axis clothes washer or Energy Star rated clotheswasher
	Dishwasher uses no more than 7 gallons of water per load on normal cycle or is Energy Star labeled
	Water heater is located within 20' of dishwasher, clothes washer and baths it serves; or demand-type hot water recirculator is installed
	Existing natural vegetation is essentially retained on at least 50% of pervious cover area
	Turf grass/lawn does not exceed 50% of pervious cover area
	Turf grass/lawn in sunny areas is low-water variety (buffalo or common bermuda); or there is no turfgrass
	At least 90% of plants, shrubs and trees are selected from the City of Austin Xeriscape brochure list
	Pervious paving (check with GBP staff for approval of type used)
	Dillo Dirt is used for soil amendment (6 cubic yards minimum per site)
	Landscape requiring watering has a minimum 6" of organic top soil (includes turfgrass areas)
	Gutters and downspouts installed and directed away from foundation to landscaping or catchment system
	Rainwater catchment system installed
	Irrigation system has a) a controller for 5-day programming, b) multiple start times, c) 2 or more independent programs, d) manual flow control valves, e) rain shut-off device, f) matched precipitation heads with head-to-head spacing, g) check valves for heads on slopes, and h) an "as-installed" plan provided to homeowner.
	Drip irrigation system for non-turf areas Take both irrigation points if you have no turf and only natural vegetation/native plantings.
	Landscape irrigated with reclaimed water (e.g. graywater system, stormwater catchment)
AGBP Community Category	Remodeling of an existing structure
	Home has a front porch large enough for family to use (100 sq. ft. minimum)
	Site has more than one dwelling unit (e.g. duplex, condo, "granny flat")

	Street, electricity, water, wastewater have been in place for a minimum of 15 years
	Home is located in a high-density or mixed use subdivision (e.g. Traditional Neighborhood Develop., Small Lot)
	Trees to be saved are protected with fencing at the drip line during construction activity (or no trees removed)
AGBP Related	Star Rating
	Builder
Weather	Average monthly temperature
	Total monthly rainfall
	Average monthly evaporation
Non-Green Features	Appraised value
	Home square footage
	Lot square footage
	Existence of a pool

VITA

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Teaching Assistant, January 1997 to May 1997.

Professional Experience

Vratsinas Construction Co., Little Rock, Arkansas (June 1997-May 1999)

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R. C. Hope, Inc., Construction, Irving, Texas (May 1996-August 1996)

Construction Intern

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