Energy Use And Greenhouse Gas Emissions In Residential Neighborhoods In The Southwest: A Built Environment Life-Cycle Assessment

by

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ABSTRACT

In recent years environmental life-cycle assessments (LCA) have been increasingly used to support planning and development of sustainable infrastructure. This study demonstrates the application of LCA to estimate embedded energy use and greenhouse gas (GHG) emissions related to materials manufacturing and construction processes for low and high density single-family neighborhoods typically found in the Southwest.

The LCA analysis presented in this study includes the assessment of more than 8,500 single family detached units, and 130 miles of related roadway infrastructure. The study estimates embedded and GHG emissions as a function of building size (1,500 – 3000 square feet), number of stories (1 or 2), and exterior wall material composition (stucco, brick, block, wood), roof material composition (clay tile, cement tile, asphalt shingles, built up), and as a function of roadway typology per mile (asphalt local residential roads, collectors, arterials).

While a hybrid economic input-out life-cycle assessment is applied to estimate the energy and GHG emissions impacts of the residential units, the PaLATE tool is applied to determine the environmental effects of pavements and roads. The results indicate that low density single family neighborhoods are 2 – 2.5 X more energy

and GHG intensive, per residential dwelling (unit) built, than high density residential neighborhoods. This relationship holds regardless of whether the functional unit is per acre or per capita. The results also indicate that a typical low density neighborhood (less than 2 dwellings per acre) requires 78 percent more energy and resource in roadway infrastructure per residential unit than a traditional small lot high density (more than 6 dwelling per acre). Also, this study shows that new master planned communities tend to be more energy intensive than traditional non master planned residential developments.

DEDICATION

This personal accomplishment is dedicated to the love of my life, my wife Anita, to my mom and dad, and to my grandfather, Pasquale Gallo, for the help he gave me to become the man I am today.

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I wish to thank my wife Anita, for all the love, kindness, and unwavering support she has given me. Thank you for never stopping in believing in me and for all your encouragement during this long journey. I wish to thank my mom and dad for all their love and support, despite all the personal struggles.

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CHAPTER 1

INTRODUCTION

Residential building construction is an important part of U.S. economy. In 2007 it represented 2.7 percent of the entire U.S. Gross Domestic Product (BEA 2011). Since 2002, about 10 million new residential single-family building permits have been issued. According to the U.S. Department for Housing and Urban Development (HUD) 1.8 million of these units were built in five southwestern states: Arizona, Colorado, Nevada, New Mexico, and Utah (HUD 2011). In recent years, due its impacts and ramifications throughout the U.S. economy, this sector has received much attention from economists, academics, legislators, media, and the public at large. Most of the attention has been devoted at looking at this sector from a financial and economic prospective. However, little has been done to understand the impacts of this sector from an energy and environmental prospective.

In this study we specifically take up the question of energy use and greenhouse gas (GHG) emissions in housing, to show how they are related to size of the livable space, characteristics of housing unit, and to neighborhood urban form. The objective is to map the embedded energy and GHG impacts of the construction phase of a wide range of single-family detached units' by type and size, and of the

transportation infrastructure (local residential, collector, and arterial roads) typically found in residential neighborhoods of the Southwest. This is accomplished through the use of life-cycle assessment (LCA) tools.

Also, this study provides a longitudinal comparative analysis of low density and high density neighborhoods, built near or at the urban core, and at the fringes of a metropolitan area. The intent is to explore whether there are differences in energy and GHG emissions between old and new neighborhood developments, and between master planned and simple lot split subdivision developments.

In the U.S. there are more than 79 million single-family detached units. These represent 62 percent of the entire housing stock available. Yet, there is a lack of sufficient understanding of the specific influences of this type of urban form on the production of energy use and GHG emissions (Norman et al 2006; Anderson et al 1996).

Most of previous life-cycle studies have focused on specific building design issues such as: insulation, window panels, exterior wall material, water heaters, etc. The focus of these studies was to find ways to reduce the energy use in the operational phase of the life-cycle of the building. There are only a few studies that quantifiably identify the links between energy, environmental impact, and planning policies applicable to single-family residential developments. By examining the

energy use and GHG emission impacts of entire neighborhoods, it will be possible to understand the effects of planning, zoning, and design policies. Thus, there is a need to holistically analyze and compare single-family neighborhoods, with various building densities and typology, to achieve an understanding of the relationship between this type of urban form and the energy required and GHG emissions emitted in the process to build it.

This is of particular importance because residential environments use a large amount of energy and are responsible for significant GHG emissions. In 2008, the U.S. residential sector consumed about 21.2 quadrillion British Thermal Units of energy (BTU) from all sources and produced 1,159 million metric tons of carbon dioxide (Energy Information Administration [EIA] 2009). The amount of energy consumed in the residential sector is anticipated to increase by 16 percent, to 22.8 quadrillion Btu in 2035 (AEO2011 reference case). While the per capita delivered energy use per capita declines 17 percent the amount of energy delivered will stay relatively constant, according to the EIA. This is due to the growth in the number of new homes and in average square footage leading to increased demand for energy services which offset in part the energy efficiency savings in space heating, water heating, and lighting equipment. (EIA 2011-DOE/EIA-0383(2011).

As such, the emissions from the residential sector, accounting for 21 percent of all CO_2 emissions in the U.S., are expected to increase, resisting the downward trajectory observed in transportation and industrial sectors (DOE/EIA-0573(2008).

During the past two decades, concern over energy security, fossil fuel use, air quality and climate changes amid academic, policy, and media circles, has led to changes in energy production technologies, energy use, and efficiency, . Moreover, the further understanding of climate change triggered by GHG emissions from fossil fuels have also signaled an urgent need to dramatically reduce global non renewable fuel based energy use. While the transportation sector has received considerable attention in GHG reduction policies, strategies for reducing residential energy use have not been addressed systematically (Ewing and Rong 2008; NRC 2010).

Although the U.S. government has not adopted Kyoto-like targets for reducing GHG emissions, many U.S. cities and several States have instituted their own programs and policies. The most significant of these state led programs have been California's Assembly Bill 32 (AB32 – California Global Warming Solutions Act of 2006), and Senate Bill 375 (SB375 – Regional Planning Coordination Pursuant to AB32), that sets intermediate and long term targets for GHG reductions in California. Under AB32 the California Air Resource

Board established resolution 10-42 – Cap and Trade Program – a reduction target of273 million tons of CO2 equivalent. The initial application of this legislation is targeted towards energy production sectors (hydrogen production, oil and gas production and refineries, electricity generation, etc.) and other GHG emission intensive sectors (like cement production, glass production, iron and steel production, etc.). Additional strategies to achieve the reduction targets have been aimed at transportation, housing, and land use sectors (ARB 2011).

Using a real world case study approach, this study offers an empirical assessment of the energy use and GHG emissions, associated with existing neighborhoods. The number of material required to build a typical single-family is in the hundreds. However, because there is tremendous variability in the products and materials available it is very difficult to create an accurate inventory of all the material and processes involved with just a single unit. Repeating this process for thousands of unit becomes extremely cumbersome, unrealistic and unnecessary since ultimately only neighborhood aggregate values are sought. Thus, it is required to make some assumptions, and to simplify the analysis, in order to achieve usable results within reasonable time and resources. All the simplifications and assumption are further discussed in Chapter 4 of this document.

The next part of this document is organized in five chapters. In Chapter 2, a brief review of previous similar LCA studies is presented. The details about the case study, along with detailed information about the study area selected for analysis are presented in Chapter 3. A review of the use of LCA for this type of analysis and the overall theoretical methodology used is presented and discussed in Chapter 4. Details about the multiple data sources and the parameters used are presented in Chapter 5. The results and findings are then presented in Chapter 6 followed by a discussion of various planning implication in Chapter 7. Supporting data are included in the appendices.

CHAPTER 2

LITTERATURE REVIEW

Life Cycle Assessment is a set of methods, tools and data constructed in order to estimate materials flows and assess environmental impacts over the life-cycle of a product or service (Baumann and Tillman 2004 , Hendrickson et al 2006). In recent years LCA has been used to assess urban systems at different scales in order to inform design and policy issues. A review of previous LCA studies reveals that a few have focused on residential dwellings, but the issues of environmental impacts related to development density have been largely unexplored, especially for single-family units.

Most previous studies are focused on life-cycle energy analyses of specific building design issues or material technologies.

Cole (1996; 1998) studied the embodied energy of alternative wall assemblies' construction, roof insulation, and other components. He found that, while upgrading certain components of the residential unit increases the embodied energy in the materials production and construction, significant savings can be achieved in the use phase. He also determined that onsite construction accounted for 6% to 16% of the total embodied energy for wood assemblies relative to total initial embodied energy associated with materials production and assembly.

Debnath et al (1995) determined the energy requirements for building materials of residential buildings in India. Energy intensity varied from 3 to 5 GJ/m2 of floor area for single, double, and multistory dwellings.

Fay et al (2000) using LCA estimated that adding higher levels of insulation to single-family units would have paid back its initial embodied energy investment in around 12 years, and that the saving represented less than 6% of the total embodied energy and operational energy.

Keoleian et al (2001) compared differences in embedded energy in the construction phase, use phase, and disposal phase between a standard 2,450 square feet single-family unit and a high energy-efficient single-family unit in Michigan. He concluded that the use phase accounted for 91 percent of the total lice-cycle energy consumption over 50 years, but that significant saving can be achieved by implementing a series of seventeen, of energy-efficiency strategies, such as increasing wall and ceiling insulation, installing high performance windows, using energy-efficient appliances and lighting, etc.

Ochoa et al (2002) analyzed the economic input-output of residential building sector in the U.S, and as part of his doctoral dissertation he conducted three case studies on single-family units. He

concluded that from the standpoint of the entire U.S. economy the residential construction phase represent 26 percent of the total energy use and 24 percent of total greenhouse gas emission, 26 percent of hazardous waste , and 12 percent of toxic air emissions.

Kahhat et al (2009) analyzed the environmental impacts of a single-story residential building using different exterior wall systems. They concluded that in the construction phase the insulated concrete buildings produce the greatest impact on the environment and traditional wood frames had the fewest environmental impacts. However, in the use phase the results were reversed, the insulated concrete buildings had the lowest impacts and the other material had progressively larger environmental impacts.

Norman et al (2006) compared high and low density residential structures, namely a 15 story condominium and a typical single family unit in Toronto. The purpose of the study was to use economic input-output LCA to effectively quantify the energy and GHG emission impacts of buildings and transportation, both in the operational and construction phase, from a density prospective. They concluded that the embodied energy and GHG emission from the materials production were about 2.5 times higher for low density building than for high density on a per capita basis, and that the high density building was

1.25 times more energy and GHG emission intensive than low-density on a unit of area basis (square meter).

Frijia et al (2011) explored the life-cycle energy of materials and constructions for single family detached units of sizes 1,500-3,500 square feet located in Phoenix, Arizona. They concluded that changing the functional unit and accounting for technological progress implies that approximately 30% of a building's life cycle energy can be attributed to materials and construction, compared to 5-10% in previous studies.

Other studies have made a substantial contribution to the advancement to the LCA of urban buildings. Adabeth et at (1996) focused on four multifamily buildings. Guggemos and Horvath (2005) compared environmental effects of steel and concrete frame in two five-story residential buildings. Thormark (2002) focused of the embodied energy of four low energy two-story row houses. These studies quantified the share of annual operational energy and GHG emissions impacts in relation to the total life-cycle of the unit as well as the importance of material selection and embodied energy in high rise structures.

LCA has also been used to assess the energy and emission impacts of urban transportation systems.

Chester and Horvath (2009) developed a comprehensive life-cycle assessment (LCA) models to quantify the energy inputs and emissions from multiple transportation modes (i.e., autos, buses, rail, etc) associated with the entire life cycle including the design, raw materials extraction, manufacturing, construction, operation, maintenance, end-of-life) of the vehicles, infrastructures, and fuels involved in these systems.

Overall, all the above mentioned studies indicate that different structural materials significantly influence the life-cycle energy profile of a home. Thus, when estimating life-cycle energy and GHG emission for an entire residential neighborhood, the material assemblies used in each building within the study area must be considered and accounted for. Treating all single-family units as being uniform in material composition, size, and height (number of stories) would cause to either underestimate or overestimate the total energy and GHG emissions.

The link between transportation, energy use, and urban density has been explored extensively (Newman and Kenwordy 1989; Cooper 2001; Bartholomew 2007; Brownstone 2008; Hankey and Marshall 2009). However, as noted by Norman et al (2006) the relationship between residential density, energy and GHG emissions impact, together with the required transportation infrastructure has not been holistically quantified.

The purpose of this study in to advance knowledge related to the understanding and environmental impacts of single-family detached residential land use at different densities in relation to the environmental impacts for building and maintaining the required roadway infrastructure.

CHAPTER 3

STUDY AREA

Previous Life-Cycle Assessment (LCA) studies have explored the impacts of selected construction materials and construction processes on energy use and GHG emissions. These studies were limited to a small a number building types. Their primary focus was to indentify materials that would reduce energy use during the operational phase of the building. In this study these same relationships are revisited and explored from a holistic point of view. Here, rather than comparing an individual building type against another, or one technology against another, the objective is to compare energy use and GHG emission profiles for entire existing single-family residential neighborhoods.

The goals are to provide comparable profiles for entire neighborhoods of various types and densities, commonly found in the Southwest, and to explore the impacts of land use planning and zoning on overall life cycle energy use and GHG emissions during the construction phase. Therefore, building typology, characteristics and layouts of existing real single-family neighborhoods are used for this analysis.

The characteristics of the study areas selected and the criteria used in the selection process are presented in the following sections.

Study Area

An LCA analysis of construction materials and construction processes can be executed virtually for any type of residential development in any geographical location. The analysis is limited only by data quality and availability.

The Phoenix Metropolitan Area (MSA) was chosen due to its pattern of rapid population growth that spurred fast, extensive, and high density single-family residential developments; as well as for the availability of sufficiently detailed data to complete the intended analysis.

The 2010 U.S. Census indicates that during the last ten years the Phoenix MSA grew 28.9 percent, from 3.2 to 4.2 million residents. However, some communities grew at a much faster pace. For example, the population of the Town of Buckeye, Town of Surprise, and Town of Gilbert grew 678 percent, 281 percent, and 90 percent respectively (Census 2010a). The demand for new housing units, supported by the high population growth, was met in part by large scale tract developments of master planned single–family housing units. Specifically, in the period between 2000 and 2010 more than 327,000 new single–family building permits were issued in the Phoenix MSA (U.S. Census, 2010b).

Another important period of intense development occurred post World War II, between 1945-1960, during which the City of Phoenix incorporated most of its current land mass and quadrupled in size (Konig 1982). It was towards the end of this period, in the late '50s that the first modern master planned communities appeared in Arizona (i.e., the J.F. Long residential developments in Maryvale in the late '50s, and the development of the "McCormick Ranch" in the mid '60s, in the heart of Scottsdale).

For this study it was important to capture some of the difference in planning, development styles, street layout and characteristics (i.e., cul-de-sacs, offset alignments) that have shaped the Phoenix MSA urban environment during the past housing booms. This was done by using four selection criteria:

1. The study area should include both new large master planned communities developed by a single builder, over short periods of time; as well as dwellings build by private owners and by small developers.
2. The study area should include residential dwellings built before 1965 and after 1999 using the median construction years of the units in the neighborhood.
3. The study area should include both low density developments with large parcels (larger than 20,000 square feet) and high density

developments with small parcels (smaller than 8,712 square feet), based on the size of the residential parcel recorded in the 2011 Maricopa County Assessor parcel database.

4. The boundaries of the study area should be delineated by the boundaries of Traffic Analysis Zone (TAZ)[1] as in year 2000. For this study TAZ boundaries are used in this instance mainly because this analysis includes a transportation infrastructure component and the use of TAZ would facilitate linking the results of this study with future transportation related analyses.

Based on these above listed criteria, the resulting study area selected for this parametric LCA analysis included 8,543 single-family units located in the City of Phoenix and Town of Gilbert. The study area covers over 3,000 acres of urban area, with various mixes of commercial, vacant and agricultural land uses, and it is divided in ten TAZs of various sizes. To facilitate the analysis, the ten TAZs are organized in four groups, according to their respective built environment similarities. Each study area group reflects a specific density, median construction year, street layout and development type. A summary of the main characteristics of the study area is provided in Table 1. Figure 1 is a location map indicating the respective location of each study area group in relation to each other, and to the Phoenix

[1] A TAZ is a unit of geography commonly used in transportation planning models. Their size varies, but typically they are built from census block information.

MSA. The figure illustrates that the TAZ belonging to study Group One and Two are in the center (core) of the metropolitan urban development while study area Group Three and Four are newer, at the fringe of the MSA, and with still much agricultural land around them.

Table 1

Study Area Main Characteristics Summary

Characteristic Type	Unit	Value
Total TAZ	N	10
Total Residential Parcels [a]	N	8,543
Total Net S.F. Residential Land Use [b]	Acres	1,793
Total Population [c]	N	25,652
Total roadway miles	Miles	130.45

[a] 2010 Maricopa County Assessor, 2010

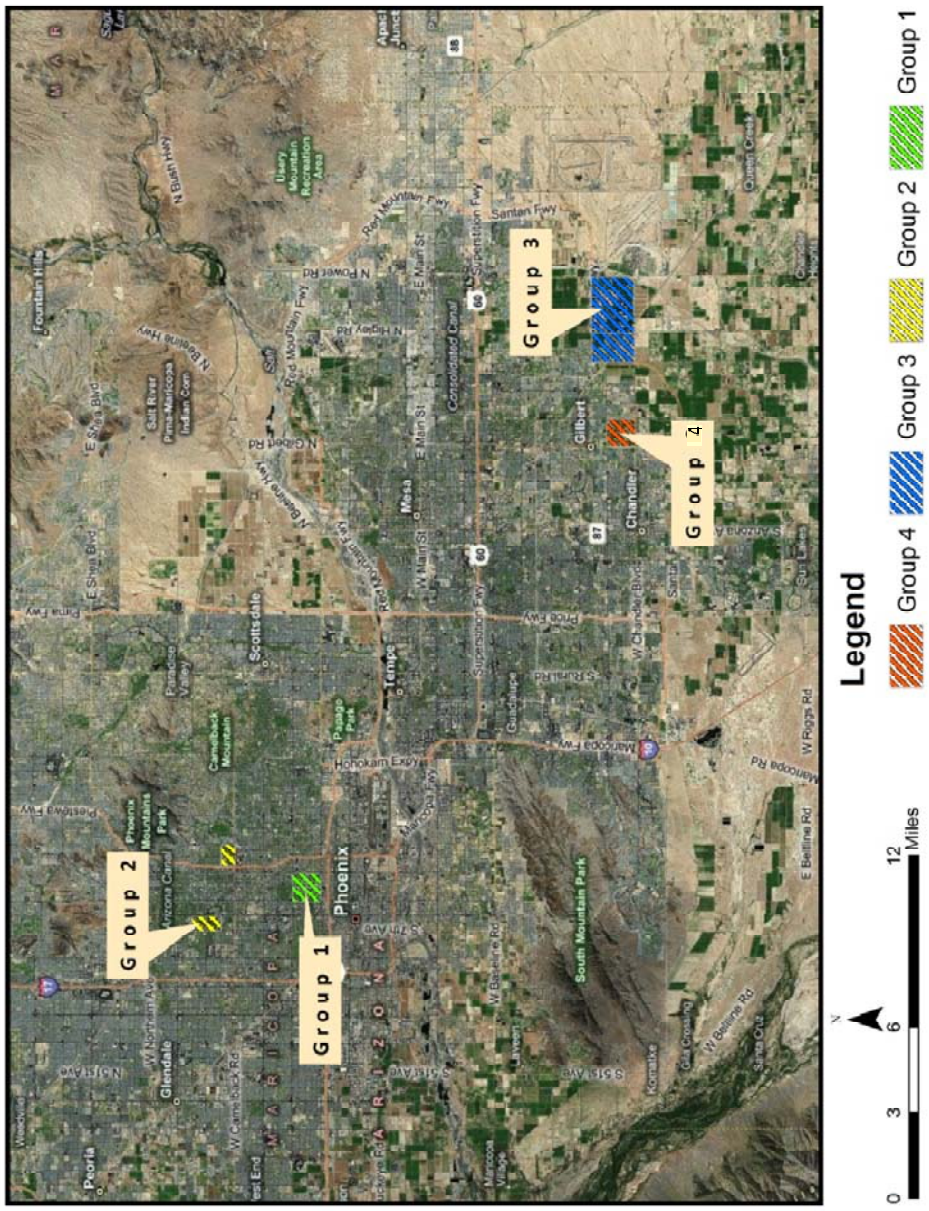
[b] The net residential is the sum of only single-family residential parcels, which include single family homes as well as other ancillary uses (Property Use Codes: 131-134; 141-144; 181-184; See Appendix A for Property Use Code descriptions)

[c] 2010U.S. Census

Additional details for each area selected TAZ are presented in the following sections.

Figure 1

Study Area Location Map



Study Area: Group One.

The first area selected, as illustrated in Figure 2, is composed of four adjacent TAZs (numbers: 786, 787, 791 and 792). It is located between 7th Street and 16th Street, south of West Thomas Road and North of West McDowell Road. It corresponds to the "Coronado" and the "Country Club Park" historic districts, which comprises 469.57 acres of high density urban area located in the City of Phoenix.

The residential units, accounting for 67 percent of the total land use in the study area group one, were built, prior 1960, over several years and not by a single builder/developer. The architectural style of these neighborhood units is a mix of mainly single story bungalows, English Tudor, Spanish Colonial Revival, Pueblo Revival, Southwest, and Transitional/Early Ranch styles (Coronado N.A. 2011).

Most of the commercial developments (31 percent of the total land use) are located along the arterial roads.

The local streets are laid in a tight perpendicular grid that creates small rectangular blocks of less than four acres. In this area there is only one cul-de-sac.

A summary of study area Group One primary characteristic is presented in Table 2.

Figure 2

High Density Neighborhood in Phoenix, AZ

Table 2

Study Area: Group One Characteristics Summary

Characteristic Type	Unit	Value
Density	du/acre	6.03
Median construction year [b]	years	1940
Population [a]	people	5647
Total residential parcels [b]	.	1899
Total single story dwelling [b]		1851
Total two story dwellings [b]		35
Total net residential area [b]	acres	312.34
Single Story average dwelling size [b]	sq. feet	1186
Two story average dwelling size [b]	sq. feet	1726
Total commercial parcels [b]		373
Total net commercial area [b]	acres	147.32
Total net vacant area [b]	acres	7.34
Total agricultural area	acres	0
Principal arterial roads [c]	miles	4
Collector roads [c]	miles	2
Local roads [c]	miles	18.05

[a] 2010 U.S. Census
[b] 2010 Maricopa County Assessor, 2010
[c] U.S. TIGER

Study Area: Group Two

The second area selected, illustrated in Figure 3, is composed of three TAZ (number: 685, 686, and portion of 711). It corresponds to neighborhood just north of the Phoenix "Central Corridor" located between 7th Avenue and Central Avenue, south of West Maryland Avenue and north of West Missouri Avenue. Also included in this selection is the neighborhood adjacent to the Biltmore Fashion Park, located between 20th street and 24th Street, south of Missouri Avenue and North of Camelback Road. The total area is over 391 acres, of which 78percent are for residential land use.

Most of the dwellings in these neighborhoods were built over several years and not by a single builder/developer. These are mostly custom homes of various architectural styles.

Commercial developments are concentrated along the arterial roads.

The street layout is characterized by an irregular layout which creates large irregular size blocks. It allows only limited through traffic, mainly due to the 18 cul-de-sacs.

A summary of study area Group Two primary characteristic is presented in Table 3.

Figure 3

Low Density Neighborhood in Phoenix, AZ

Table 3

Study Area: Group Two Characteristics Summary

Characteristic Type	Unit	Value
Density	du/acre	1.90
Median construction year [b]	years	1962
Population [a]	people	1550
Total residential parcels [b]		587
Total of single story dwelling [b]		521
Total two story dwellings [b]		46
Total net residential area [b]	acres	308.4
Single Story average dwelling size [b]	sq. feet	2913
Two story average dwelling size [b]	sq. feet	3555
Total commercial parcels [b]		87
Total net commercial area [b]	acres	60.75
Total net vacant area [b]	acres	22.42
Total agricultural area [b]	acres	0
Principal arterial roads [c]	miles	5.02
Collector roads [c]	miles	1
Local roads [c]	miles	9.38

[a] 2010 U.S. Census
[b] 2010 Maricopa County Assessor
[c] U.S. TIGER

Study Area: Group Three

The third area selected, as illustrated in Figure 4, is composed of two TAZs (number:1557, 1562). These are located south of the Loop 202 between South Greenfield Road and Power Road. The combined area is over 1,552 acres, of which 29 percent is for residential use. However, there are still large numbers of vacant residential tracts.

In this area are located a variety of high density and recently built residential communities: Agritopia, Ashley Heights, Crossing at Crossroads, Crossroads, Gardens, Gateway Village, Gateway Ranch, Higley Park, Ray Ranch, Willows.

These neighborhoods were built as part of master planned communities and include single and two storied bungalows, Craftsman/California Bungalow, Spanish Eclectic, Northern European Revival, and Arizona Territorial.

While from the land use map it appears that there may be sufficient commercial land, most of it is not fully developed, with the exception of parcels along Power Rd and some parcels on Higley Rd.

The local street layout in these master planned communities is irregular grid pattern, designed to provide access only to local residents and maximize the developable land. Cul-de-sacs and loops are frequently used by the developers. Access to the principal arterial and collector road is restricted to specific community entrance point

that can be occasionally gated. A summary of study area Group Three primary characteristic is presented in Table 4.

Figure 4

High Density Neighborhood in Gilbert, AZ

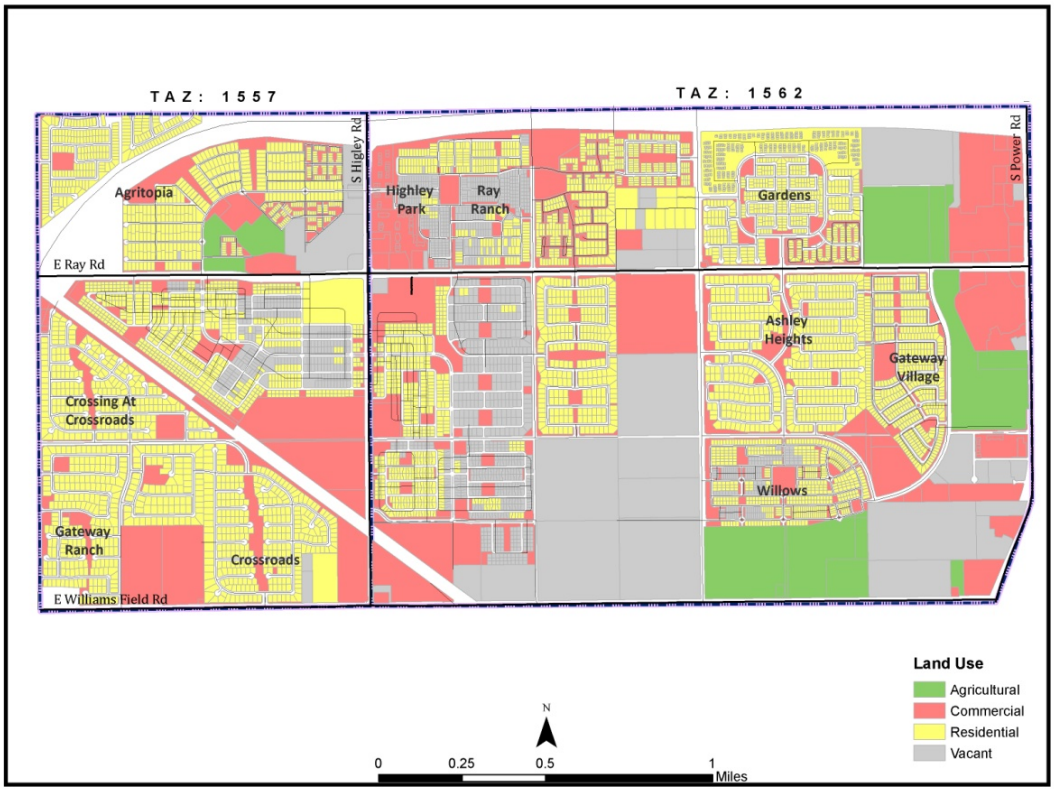


Table 4

Study Area: Group Three Characteristics Summary

Characteristic Type	Unit	Value
Density	du/acre	8.1
Median construction year [b]	years	2004
Population [a]	people	17451[d]
Total residential parcels [b]		3618
Total single story dwelling [b]		1048
Total two story dwellings [b]		2569
Total net residential area [b]	acres	449.0
Single Story average dwelling size [b]	sq. feet	1829
Two story average dwelling size [b]	sq. feet	1946
Total commercial parcels [b]		414
Total net commercial area [b]	acres	450
Total net vacant area [b]	acres	498.3
Total agricultural area	acres	155.3
Principal arterial roads [c]	miles	10.5
Collector roads [c]	miles	1.5
Local roads [c]	miles	66.1

[a] 2010 U.S. Census
[b] 2010 Maricopa County Assessor
[c] U.S. TIGER
[d]This value was adjusted because one of the census blocks extends beyond the TAZ boundary.

Study Area: Group Four

The fourth area selected, as illustrated in Figure 5, is composed of a single TAZ (number:1543). It is located South of East Ray Road and North of East Williams Field Road, between South Gilbert Road and South Lindsay Road.

This includes the Ranchos Del Sol and Tierra Madre community. This area is not a master planned community, but an ensemble of traditional minor land divisions. The architectural style found in this area include a mix of single and two stories bungalows, Craftsman/California Bungalow, Spanish Eclectic, English Tudor, Northern European Revival, and Arizona Territorial. Overall the area has limited commercial/retail developments.

The street layout follows the land division lines, in a regular grid pattern with only few cul-de-sacs due to some lots not being yet developed.

A summary of study area Group Four primary characteristic is presented in Table 5.

Figure 5

Low Density Neighborhood in Gilbert, AZ

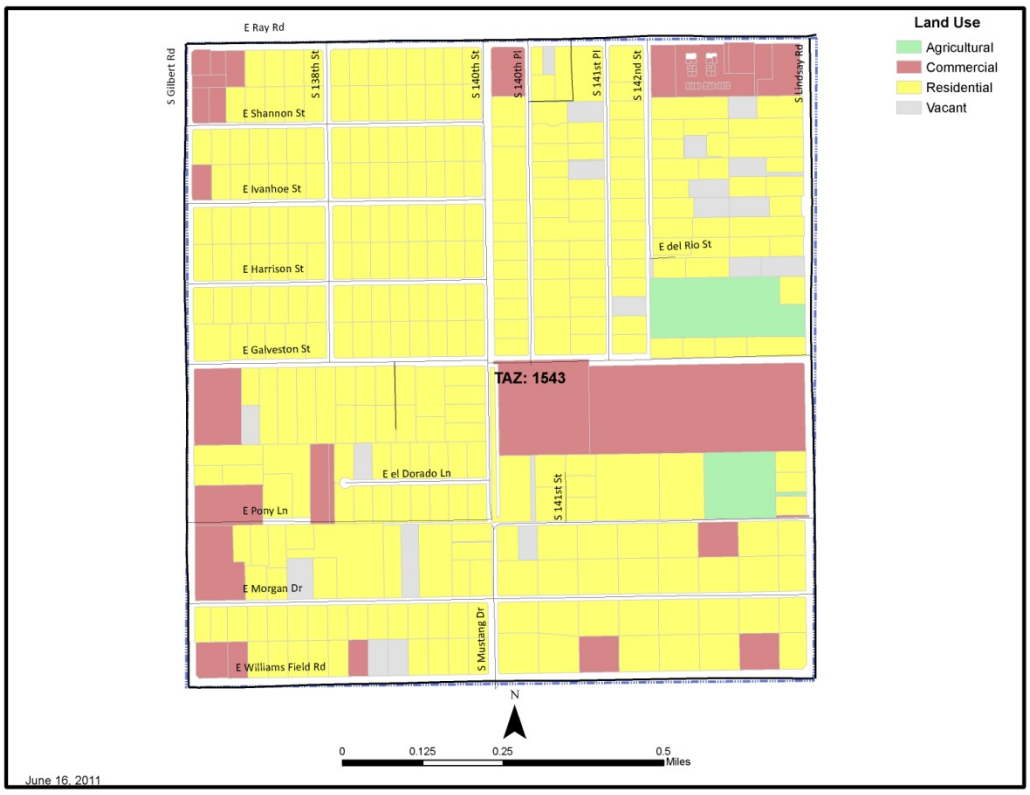


Table 5

Study Area: Group Four Characteristics Summary

Characteristic Type	Unit	Value
Density	du/acre	0.75
Median construction year [b]	years	1976
Population [a]	people	1004
Total residential parcels [b]		310
Total single story dwelling [b]		288
Total two story dwellings [b]		16
Total net residential area [b]	acres	411.6
Single Story average dwelling size [b]	sq. feet	2336.5
Two story average dwelling size [b]	sq. feet	3377.5
Total commercial parcels [b]		61
Total net commercial area [b]	acres	92.5
Total net vacant area [b]	acres	22.4
Total agricultural area	acres	20.86
Principal arterial roads [c]	miles	4
Collector roads [c]	miles	0
Local roads [c]	miles	8.9

[a] 2010 U.S. Census
[b] 2010 Maricopa County Assessor
[c] U.S. TIGER

CHAPTER 4

METHODOLOGY

This chapter provides the details of the LCA methodological framework used in this study. The chapter is organized in three sections:

- Overview of Life Cycle Assessment history and processes;
- Life Cycle Assessment: Scope & Boundaries Phase; and
- Life Cycle Inventory.

In the following sections a description of how LCA has being applied to the context of this study is provided. Details of the various components of this LCA for single-family detached dwellings and of the street networks that connects them are also provided.

Life Cycle Assessment Overview

Life Cycle Assessment emerged as a tool to quantify environmental impacts of industrial processes in the mid 1970s. Initially, it was used by the U.S. Dept. of Energy to quantify energy, raw material requirements, air emissions, and various environmental impacts in fuel cycle specific studies (Bullard and Herendeen 1975). Later it was expanded to allow the manufacturing industry to improve the environmental profile of manufactured products (Curran 1996).

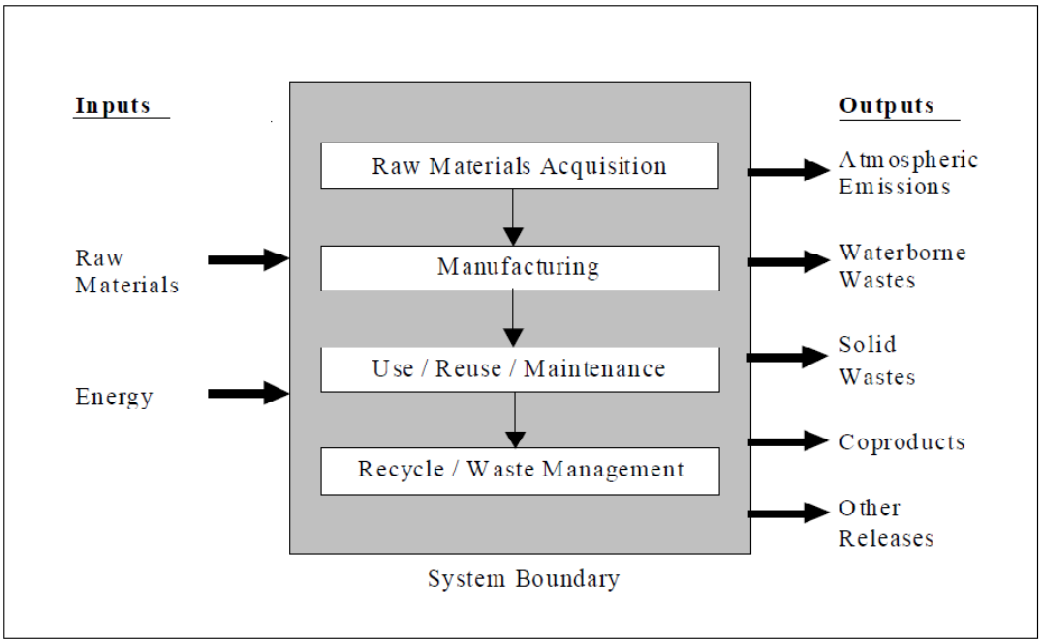
In the early 1990s the U.S. Environmental Protection Agency (EPA) took interest in LCA and developed a comprehensive guideline document to help "incorporate environmental performance based on the life cycle concept into their decision-making processes" (EPA, 2006, iv). The EPA describes LCA as a tool that "provides a comprehensive view of the environmental aspects of the product or process and a more accurate picture of the true environmental trade-offs in product and process selection" (EPA, 2006, pp 1).

As such, LCA is a comprehensive "cradle-to-grave" quantitative method designed to assess the cumulative environmental impacts of products and services. These are expressed in terms of inputs and outputs for each specific process that is part the overall manufacturing or production process of the product or service considered.

LCA starts with an inventory of inputs that are utilized during all the processes included within the system boundary. Inputs include raw materials (e.g., ore, water, etc.) and energy. As illustrated in Figure 6, the processes included in the system boundary may include raw material extraction or acquisition processes, manufacturing, assembly, use, distribution, maintenance, recycle and disposal processes. The outputs for each process are also inventoried. Outputs may include: air emission, waste, energy use and other releases.

Figure 6

Life Cycle Assessment Stages and Boundaries. (Source: EPA, 2006)



The LCA framework can be conceptually divided into four phases: scope and boundaries, life cycle inventory (LCI), impact assessment, and interpretation. In the first phase the following aspects of the LCA are defined: the purpose of the study, the functional unit, the boundary condition, the assumption and omissions. In the second phase, LCI, the materials and energy use, and environmental releases (e.g., air emissions, solid waste disposal, waste water discharges) are quantified though the use of a model over the life cycle of the system. For this study emissions are defined as "the direct release of greenhouse gases to the atmosphere from any anthropogenic source and certain indirect emissions" (DOE, 2006).

In the third phase, impact assessment, the impacts to human health and environment are measured and inventoried. In the fourth phase the results are interpreted and combined to estimate impacts on one or more environmental issues.

In the following section the first two LCA's phases are presented and discussed: scoping & boundaries, and life cycle inventory for both single-family units and for their street networks. The third phase, impact assessment, will be discussed in the Chapter 5: Results. The fourth phase, interpretation, will be discussed in Chapter 6: Discussion.

Life Cycle Assessment: Scope & Boundaries Phase

The scope of this LCA is to provide policy makers, urban and transportation planners better information for energy efficient and low-carbon residential communities in the U.S. This is accomplished by mapping the life cycle embedded energy and GHG emissions of a variety of single-family detached building, together with the transportation infrastructure (local residential, collector, and arterial roadways).

This LCA will provide quantifiable and comparable energy and environmental impacts of single-family detached units and their supporting roadway infrastructure built before 1965 (1900-1965) and

after 1999 (1999-2010). This will highlight the effects of development of future residential neighborhoods in the Phoenix MSA cities on energy use and GHG emissions.

In order to perform an LCA it is important to properly define a functional unit and reference flow. To best provide quantifiable and comparable energy and environmental impacts of single-family detached units and their supporting roadway infrastructure, two separate LCA models are required. Therefore, two distinctive definitions for functional unit and reference flow are used.

Single-Family Units Functional Unit

The functional unit for single-family detached dwellings LCA buildings is defined as the energy and GHG impacts for climate controlled livable spaces over a 50 years life-cycle (Frijia et al 2011). Detailed information about all the exact materials and processes used in each of the residence in the study area is not available nor would such a detailed analysis be feasible. Thus the analysis is simplified by developing a parametric approach based on size, building envelops, and materials, as reported in the Maricopa County Assessor Residential Master (Frijia et al 2011). The analysis is limited to five unit sizes: 1,500, 2,000, 2,450, 3,000, and 3,500 square feet of livable space because the energy and GHG emission embedded in the material

and in the construction processes for the single-family residential units scales linearly with size of the unit after controlling for the number of stories (Frijia et al 2011). Details about the various material envelop combination used in this analysis are presented in Chapter 4.

It is understood that there are more than a dozen different architectural styles in the study area, some units are very modest while other are elaborate and are built with premium materials. However, since the objective of this study is to compare neighborhoods and not individual structures, all the results are aggregated at neighborhood level, and all the units are assumed to be of average construction quality, with no basement, on a cement slab foundation and with basic architectural components. Site work, utility infrastructure and access related developments (i.e., driveways, etc) are not included.

Single-Family Units Reference Flow

The reference flows for the functional unit, previously described, include the energy and GHG emission associated with material manufacture, construction of buildings, and heating cooling and ventilation (HVAC). In the Unites States HVAC related energy use accounts for 52.2% of the total residential energy end-use (DOE 2009). HVAC was included in the function unit primarily because associated

energy use is strongly correlated with building design and material used in the construction the of building envelop. Other appliances and equipment found in a typical home were not included since their use is more dependent on household behavior than building design and materials.

Single-Family Units System Boundary

The system boundary for the single-family building includes the energy and GHG emission related to the following phase: raw material extraction, material manufacturing, material assembly, building construction, maintenance. Since the end-life of the building accounts for only a small fraction of the total energy use and GHG emissions, it is omitted from the system boundaries (Keolian et al 2001). Since the residential units where built in a period spanning from the early 1900s to 2010 there are differences in the material quality, construction quality, and technologies used. For the purpose of this analysis it is assumed that all the buildings are built at the same time and are all of equivalent quality.

Infrastructure Functional Unit

The functional unit for the roadway infrastructure LCA is defined as energy and GHG impacts for one mile of built asphalt

roadway for three functional class types, over 40 years life cycle[2]. The three main roadway types being considered are described below:

• Principal Arterial – A divided four or six-lane road with posted speed less or equal to 45 mph on which traffic movements in urban areas consists of through movement and major circulation.

• Collector – An undivided two-lane road were traffic movement consist of both land access and circulation.

• Local – An undivided short distance two-lane road with frequent driveway access.

Infrastructure Reference Flow

The reference flow for this functional unit is organized in two categories: initial construction and maintenance (wearing layer repaving). Each category includes the following processes: material manufacture, material transportation, and construction processes (equipment) (Chester and Horvath, 2009).

Infrastructure System Boundary

The system boundary for the roadway infrastructure LCA includes the energy and GHG emission related initial construction and repaving of two wearing layers and one sub-base layer (Chester and

[2] Note that Maricopa County Depart of Transportation considers the "design life" pavement to be 20 years or less (MCDOT, 2004)

Horvath, 2009). Material and processes associated with street lighting, underlying utilities, sidewalk[3] and other ancillary's structure are omitted. For this analysis it is also assumed that roadways are built at the same time and in accordance with specifications set by the American Association of State Highway and Transportation Officials (AASHTO) for roadway design.

It is acknowledged that the travel needs of the residents of each area are not confined within the study area. Nevertheless, the issue addressed here is not about how much or how far do the resident travel but about whether building and maintaining miles of pavement to accommodate the living preference of private property owners is consistent with energy use and GHG emission reductions goals.

Life cycle inventory

There are three main methods for estimating life cycle inventories of material, energy used, and GHG emission. They are: process-sum, economic input-output, and hybrid analysis.

Most LCI are based upon a bottom up process-sum model (Baumann and Tillmann 2004). This method involves developing a flow diagram of all the processes being evaluated. Following the flow diagram, input and output data for each material or element included

[3] The LCA of sidewalks has being omitted do to the lack of sufficient inventory data.

in the network diagram are collected. Typically the flows between processes are described in material terms (e.g. kg of emissions per unit mass of product output). LCI are very data, and time intensive. Inputs and outputs data must be identified for each process identified in the flow diagram. Data are then normalized and/or partitioned before being compiled in the model. However, data may be limited, confidential, proprietary, available only as site-specific, or aggregated for the whole industry. As such, truncation error due to data availability and quality is the main issues with using a process-sum as some processes in the flow may need to be excluded.

Economic input-output life cycle assessment (EIO-LCA) is a top down linear model. It is based on Wassily Leontief's formulation of an economy as a matrix describing economic transactions between each producer or commodities sectors of the economy. This matrix uses sales and purchases data to map all inputs and output in each sector, both direct and indirect (Hendrickson et. al 2006). Since its inception the model has being supplemented with environmental information to estimate supply chain materials use and emissions for products by dividing the total external output of the sector being considered by the total dollar output for that sector (Bullard et. Al 1975; Hendrickson et. al 1998). Researchers at Carnegie Mellon University Green design Initiative (GDI) have developed and maintained a public use model

comprised of 491-aggregated industry sectors based on the North American Industry Classification System (NAICS). The economic data that links each sector with the corresponding energy and environmental impacts matrix is based on the 2002 Benchmark U.S. input-output tables (GDI 2009).

As with the process-sum model, there are issues and limitations with the EIO-LCA. It is a coarse grain model often combining many different processes into economic sectors, leading to aggregation error Also it must deal with the issues associated with linking dollar values with physical units, and with the fact that the input-output tables are almost ten years old (Hendrickson et. al 2006).

For this analysis two hybrid methods are used, one for the single-family building LCA and one for roadway infrastructure.

The hybrid LCA model can be an additive or economic balance method that combined the process-sum model EIO-LCA (Engelenburg et al 1994, Suh et al 2004, Williams 2004, Zhai and Williams 2010). The goal, in a hybrid model, is to reduce truncation error in the process-sum and aggregation in the EIO-LCA (Williams et al 2009). Here a variant of the additive method is used. This method relies entirely on the EIO model to model supply chains for manufacturing. This cost-breakdown EIO-LCA method is based on economic analysis to account for the full cost of a product such as the costs of different

materials and basic manufacturing processes (Bullard et al 1978, Frijia et al., 2011).

The basic model to estimate the total energy to manufacture a residence for this study is given by:

$$E_{production} = \sum_{i} C_i \cdot E_{sc,i} \quad (1)$$

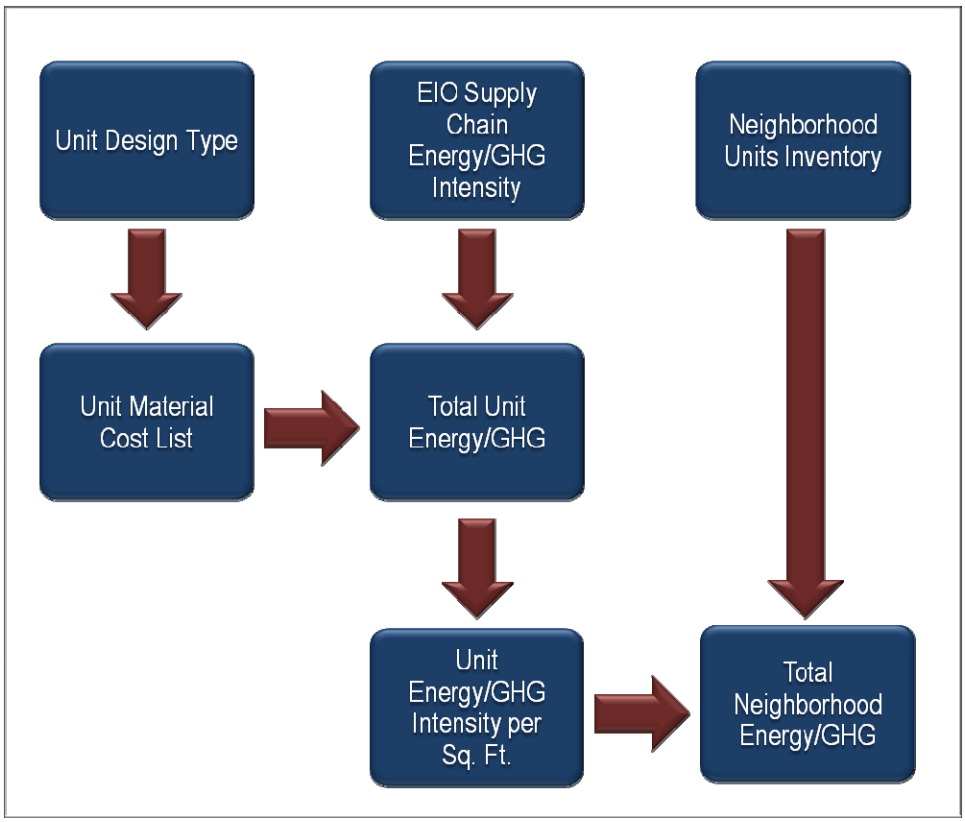
Where the subscript i refers to the ith line item in the cost model, Ci ($) refers to the cost of line item i, and Esc,i (MJ/$) refers to the corresponding supply chain energy intensity from EIO-LCA (GDI 2009). The sum of the energy for each line item corresponds to the total energy to manufacture a single residence. The model required to estimate the total GHG emission, is the same as in equation (1), the Esc,i is substituted with a the corresponding supply chain GHG emission intensity from the EIO-LCA (GDI 2009).

Each line item in the cost model is determined by the design characteristics of the unit, such as size, construction materials, and number of stories. Since there are more than eight thousands different units in the study area, the process is repeated for selected major representative unit types found in each study area group. This allows to estimate both the total energy and GHG emission for each representative unit type and to estimate the respective intensities per unit of square foot.

The resulting energy and GHG emission intensities are used to estimate the total energy use and GHG emission for each study area group. These are estimated by multiplying the appropriate square foot intensity value by the size of the matching units in the study area and then summing the results for all the units within the study area. The overall approach is illustrated in Figure 7.

Figure 7

Neighborhood Life Cycle Assessment Process Flow

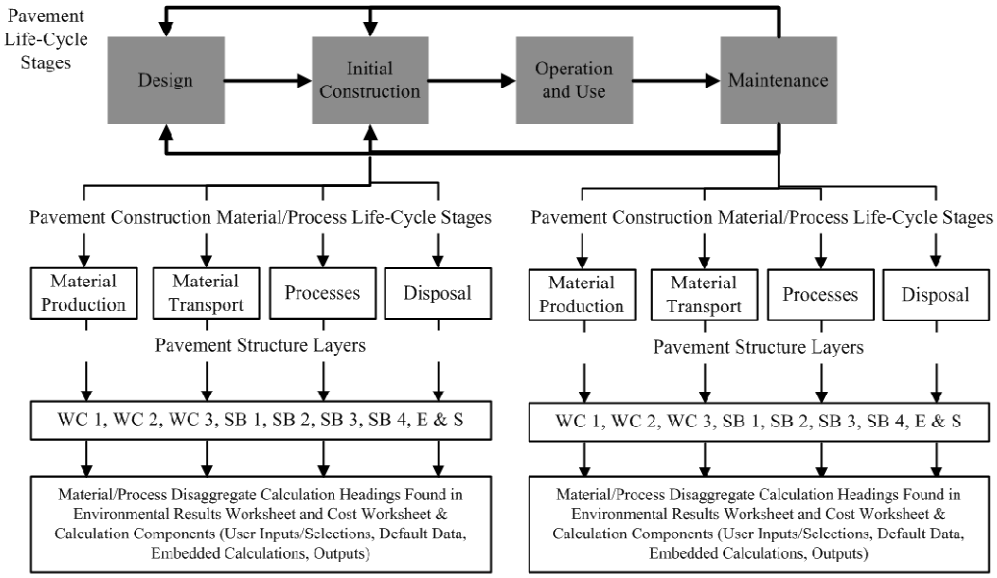


With regards to the roadway infrastructure, the LCA method used here is a streamlined additive hybrid economic input-output tool developed specifically to model the environmental effects of initial road

construction and maintenance. The tool Pavement Life-cycle Assessment Tool for Environmental and Economic Effects (PaLATE) was developed by the Consortium on Green Design and Manufacturing at the University of California at Berkeley (Horvath, 2004). It was later updated by Mikhail Chester (Chester and Horvath, 2009). The Excel based tool can be used to model specific roadway pavement designs, materials, wearing layers, sub-bases, and various construction activities (Horvath, 2004). The output of the model includes energy, water, and GHG emission. Figure 8 illustrates the PaLATE levels of disaggregated calculations for the process.

Figure 8

PaLATE Levels of Disaggregate Process Flow



(Source: Nathman, 2008, p.21)

CHAPTER 5

DATA AND PARAMETERS

In this chapter are the data requirements, parameters used to perform the life cycle inventory, and assumptions made in the analysis. The chapter is organized in two sections: a) Single-Family Residential Inventory and Analysis; and b) Roadway Infrastructure Inventory.

Single-Family Residential Inventory and Analysis

To perform this type of LCA, as discussed in chapter 3, it is necessary to gather specific information about the buildings, including size of the unit, the materials used in construction, and the cost of such materials. A comprehensive database listing all the materials used and their cost for each one of the 8,543 existing units in the study area does not exist, nor would it be possible to account for all the modifications, remodels and upgrades done over the years. Therefore, to simplify the analysis all the units in the study area are assumed to match the description of the functional unit previously defined in Chapter 3.

Construction materials and labor costs are affected by a number of variables. Typically, these include building design, quality, size, materials type, project location, market conditions, and other variables. Rather than acquiring the specific building blueprints and

deriving individual bill of material and labor estimates, the economic data associated with material quantities, and labor and equipment costs for a standard building design of average construction quality is estimated using a construction estimating software – CostWorks 2011, by RSMeans[4].

The produced output includes an itemized up-to-date bill of material and unit costs for about 56 to 65 typical material assemblies used for the residential structures considered (e.g. foundation, framing, roofing, etc.) (See Appendix B for a sample of the software outputs). The output data are adjusted quarterly to reflect local area material costs and labor rates. Adjustments used include material price index and cities cost index (RSMeans 2010). The data used in this analysis reflect material and labor cost for the Phoenix area in the first quarter of 2011.

The primary input parameters used in this software are: unit size, number of stories, construction quality, exterior wall finish, and roof material type. All the other material assemblies are automatically included. The source of these input parameters was the 2011 Maricopa County Assessor Residential Master file.

[4] RSMeans is a North America's supplier of material, labor and equipment construction cost information for both new building construction and renovation projects (RSMeans 2010).

Table 6 is a list of the main attributes used that were gathered from the Assessor database.

Table 6

Assessor Parameters for the LCA Model

Attributes	Parameter/Unit
Parcel Area	Square feet
Livable Space	Square feet
Number of Stories	1,2
Exterior Wall Composition	Frame Wood
	8" Painted Block
	8" Stucco
	Brick
	Stone
	Slump Block
	Adobe
	Other
Roof Composition	Wood
	Asphalt Shingle
	Asbestos Shingle
	Built Up
	Tile
	Slate
	Metal
	Roll
	Concrete Tile
	Other

To perform a parametric LCA analysis of the five unit sizes for all possible attribute combinations listed above, would require 720 model runs. However, some of the material listed are seldom used or no longer used in new construction (i.e., asbestos). Therefore, only the most recurrent combinations were used which, when combined, recurred in more than 90 percent of the units. Table 7 is a list of the materials considered at this time -- five types of roof material and four types of exterior wall material. This reduces the number of required model runs to 200.

Table 7

Single-Family Units Roof and Exterior Wall Materials

Attributes	Parameter/Unit
Exterior Wall Composition	Frame Wood
	8" Painted Block
	8" Stucco
	Brick
Roof Composition	Wood
	Asphalt Shingle
	Built Up
	Concrete Tile
	Clay Tile

For the remaining units, proxy values were used. The “slump block” exterior was treated as : “8 painted blocks”; “stone” and “adobe” was treated as “brick”; and the “other” was substituted by “frame wood”, the most common wall structure.

In addition to material and labor cost, the economic value of tools and equipments required in the construction phase are also included in the LCA analysis. A line item for the manufacturing of tools and equipment used during the construction phase was added to the standard material list provided in the output. Typically, tools and equipment are not purchased and completely consumed during the construction of just a single unit, but are used in multiple projects. Thus, the economic value associated with the manufacturing of the tools is estimated according to industry standards -- 1.5 percent of total material cost plus 5.9 percent of total labor cost of each project. These factors are derived from industry surveys for certain overhead cost and gross revenues (RSMeans 2010).

Since the Economic Input / Output model is based on the 2002 Benchmark U.S. producer sector tables, each material assembly in the output element, is adjusted to reflect only the producer prices in 2002 real dollar. The adjustment is done by multiplying each material assembly in the output by a US Producer Price Index (PPI) and by a producer/purchaser ratio. Architectural fees, permits fees, profits,

overhead costs, and markups are removed from each cost element prior to the adjustment.

The formula used to calculate the net energy use in materials manufacturing associated with a unit of economic output for economic sectors is derived from the formula (1) in Chapter 3 and is given by:

$$E_{material} = \sum_{i} (C_i - OPM_i) \cdot (PPI_{2002/2010} \cdot PPR_i) \cdot E_{sc,i} \quad (2)$$

Where the subscript i refers to the ith line item in the cost model, C_i (\$) refers to the cost of line item i, OPM_i refers to overhead, profits and markups for line item i, PPI refers to the U.S. producer price index ratio between 2002 and 2010, PPRi refers to the producer/purchaser ratio for the corresponding material producing industry and $E_{sc,i}$ (MJ/\$) refers to the corresponding supply chain energy intensity from EIO-LCA (GDI 2009). (See Appendix C for details on the producer/purchaser ratio). Table 8 provides a list of the main material producers sectors used for this LCA and their respective E_{sc} values derived from the Carnegie Mellon model.

Table 8

NAICS Producer Sector Codes and Matching EIO Sector Energy Intensities

Code	NAICS producer sector	EIO code/name	E_{sc} MJ/$
313111	Yarn spinning mills	Fiber, yarn, & thread mills	4.16
313230	Nonwoven fabric mills	Nonwoven fabric mills	3.98
321113	Sawmills	Sawmills & wood preservation	5.37
321211	Hardwood veneer & plywood mfg.	Veneer & plywood mfg.	8.07
321214	Truss mfg.	Engineered wood member & truss mfg.	5.19
321911	Wood window/door mfg.	Wood windows/doors & millwork	1.68
321918	Other Millwork		
325510	Paint & Coating mfg.	Paint & Coating mfg.	3.07
326192	Resilient Floor Covering mfg.	Other plastics product mfg.	1.57
326199	All other plastics product mfg.		
327121	Brick & Structural Clay Tile mfg.	Brick, tile, other structural clay product mfg.	23.3
327122	Ceramic wall/floor tile mfg.		
327310	Cement & Concrete Product mfg.	Cement mfg.	59.7
327121	Brick and Structural Clay Tile Manufacturing	Brick and Structural Clay Tile Manufacturing	31.4
327331	Concrete block/brick mfg.	Concrete pipe, brick & block mfg.	2.25
327420	Gypsum product mfg.	Lime & gypsum product mfg.	26.4
327993	Mineral wool mfg.	Mineral Wool mfg.	10.8
332321	Metal window/door mfg.	Ornamental & arch. metal products mfg.	0.86
332998	Enameled iron/metal sanitary ware mfg.	Other fabricated metal mfg.	1.64
333415	A/C & warm air heating equip. mfg.	A/C, refrigeration, warm air heating equip. mfg.	0.62

Code	NAICS producer sector	EIO code/name	E_{sc} MJ/$
335228	Other major household appliance mfg.	Other major household appliance mfg.	1.57
335931	Current-carrying Wiring device mfg.	Wiring device mfg.	0.92
337110	Wood kitchen cabinet & countertop mfg.	Wood kitchen cabinet & countertop mfg.	0.87

To calculate the total GHG emission a similar equation to (2) is used.

$$GHG_{material} = \sum_{i} (C_i - OPM_i) \cdot (PPI_{2002/2010} \cdot PPR_i) \cdot GHG_{sc,i} \quad (3)$$

Where $GHG_{sc,i}$ refers to the corresponding supply chain environmental coefficients of emissions for dollar of input. These include six air pollutants: sulfur dioxide (SO_2), carbon monoxide (CO), nitrous oxides (N_2O), volatile organic compounds (VOC), methane (CH_4), perfluorocompounds (PFC) which include trifluoromethane (CHF_3), nitrogen trifluoride (NF_3), and sulfur hexafluoride (SF6). (See Appendix D for a detailed table with specific GHG emission per dollar of input).

The energy used in the actual construction process of the residence is also estimated using a hybrid EIO. This process includes gasoline, diesel fuel, lubricants, and electric energy purchased by NAICS sector 236115 – New Single Family General Contractors Businesses – from other companies or received from other

establishments. Also included are costs for natural gas, manufactured gas, fuel oil, and coal and coke products. Aggregate data on energy and resources used in the construction phase by this sector are available from the 2002 Economic Census report (DOC 2005).

According to the Census data the New Single Family General Contractors Businesses reported $62.2 billion in value of business done and $673 million were spent in energy purchases (DOC 2005). Using 2002 average industrial prices and EIA's energy conversion factors (EIA, 2002, 2005), Table 9 show that total energy used in this sector is equivalent to 112 petajoules (PJ) which is equal to one 1.81 mega joules of primary energy per dollar of business done. (Frijia et al., 2011)

Table 9

Energy Expenditures and Total Energy for the US New Single Family Construction Sector

Energy Type	Cost ($1,000) [a]	Unit Prices [b]	Energy (TJ)
Purchased electricity	170,735	$0.0491 /kWh	38,006
Natural/mfg gas	74,983	$4.02/1000 ft^3	20,071
Gas/diesel fuel	400,549	$1.03/gallon	54,155
Total power/fuels/lubricants	673,393	-	112,233

Sources:
[a] DOC 2002
[b] EIA 2002, 2005

To estimate the energy used in the construction processes of the residential buildings the following equation is used:

$$E_{constr.process} = BV_{house} * (BV_{sector} / \sum_{i} F_{i,sector} * k_i) \quad (3)$$

Where the subscript i refers to a specific fuel type used in construction sector, BV_{house} ($) refers to the business value of the home, BV_{sector} ($) refers to the entire business value the new single-family general contractors businesses, $F_{i,sector}$ ($) refers to total fuel purchased by the sector, and k_i refers to the energy contents and GHG emissions value, per unit cost, of a given fuel type.

Roadway Infrastructure Inventory and Analysis

Roads vary according to function, design speeds, adjacent land uses, access controls, local terrain, and many other roadway engineering factors. Each municipality typically develops their own design standards and typology definitions to best suit their local needs. For this study the following design specification were reviewed: City of Phoenix Street Planning and Design Guidelines Street Transportation and Town of Gilbert Public Works and Engineering Standards and Details (City of Phoenix, 2009; City of Gilbert, 2009). However, the transportation departments of both municipalities do not maintain an electronic database with the exact dimensions of each segment of their

own roadway infrastructure. They maintain, in electronic format only, centerline data and general classifications, which does not always reflect the actual built condition. Instead, such information can be found only in the "as-built" design drawings. Therefore, the inventory roadway lane-miles per zone by type were based solely on centerline and matching classification data.

The cross-section dimensions of the streets found in the study area are estimated based on the design standards provided by the City of Phoenix and Town of Gilbert. Table 10 is a summary of the roadway classifications used and the respective curb-to-curb dimensions used.

Table 10

Roadway Classification and Curb-to-Curb Width

Road Type	City/Town	Design Type	Curb-to- Curb [ft]
Arterial	Phoenix	D	62
Arterial	Gilbert	#21	94.5
Collector	Phoenix	E	50
Collector	Gilbert	#23	45.5
Local	Phoenix	H	32
Local	Gilbert	#27	31.5

While these roads differ in the curb-to-curb dimensions, the base and sub-base characteristics follow the Maricopa County Department of Transportation (MCDOT) design standards and meet or exceed

AASHTO standards. To simplify the process, as discussed in Chapter 3, this LCA analysis is first modeled in PaLATE using the AASHTO roadway design standards.. The results are adjusted to reflect the actual design dimensions[5]. Like the EIO model, the PaLATE tool is also matrix based. It estimates the total energy of GHG impacts based on the volume of the material used in the wearing courses and sub-base. Table 11 summarizes the inputs used.

For each wearing courses and sub base and subsequent maintenance, the output provides data on the energy and GHG emission in the material production phase, material transport phase, and installation process (equipment) phase. Table 12 is a summary of the materials and processes considered as part of this LCA.

[5] The PaLATE output data was prepared Dr. Mikhail Chester, for Stephane Frijia on February 26, 2011.

Table 11

Roadway Infrastructure Layer Geometry Per Lane (Both Directions)

Layer	Width [ft]	Length [miles]	Depth [inches]	Volume [yd^3]
Major Arterial Urban				
Wearing Course 1	35	1	3	1,711
Wearing Course 2	37	1	3.5	2,110
Sub-base 1	41	1	12	8,018
Total			18.5	11,839
Collector Urban				
Wearing Course 1	32	1	2.5	1,304
Wearing Course 2	34	1	3	1,662
Sub-base 1	38	1	12	7,431
Total			17.5	10,397
Local Urban				
Wearing Course 1	26	1	2.5	1,059
Wearing Course 2	26	1	3	1,271
Sub-base 1	26	1	12	5,084
Total			17.5	7,415

Table 12

Initial Construction Material List and Maintenance Processes

Wearing Course	Sub-base
Materials	
RAP transportation	RAP to recycling plant
RCM transportation	RAP from recycling plant to site
Coal Fly Ash	RCM to recycling plant
Coal Bottom Ash	RCM from recycling plant to site
Blast Furnace Slag	Cement
Foundry Sand	Coal Fly Ash
Recycled Tires/ Crumb Rubber	Coal Bottom Ash
Glass Cullet	Blast Furnace Slag
Virgin Aggregate	Foundry Sand
Bitumen	Recycled Tires/ Crumb Rubber
	Glass Cullet
	Rock
	Gravel
	Sand
	Soil
Maintenance Processes	
Hot in Place Recycling (HIPR)	
Cold in Plane Recycling (CIR	
Patching	
Microsurfacing	
Crack Sealing	
Full-depth Reclamation	

The emissions include the following gasses: Carbon Dioxide (CO_2); Mono-Nitrogen Oxides, and Nitrogen Dioxide (NOx), Carbon Oxide (CO), Particular Matter smaller than 10 nanometer (PM_{10})–, Sulfur Dioxide (SO_2)–;– Volatile Organic Compound (VOC).

Highways and freeway, are not-included in this analysis because their primary function is regional traffic movement across large distances. Since arterial roads do not always fall within the boundaries of a single TAZ, if an arterial road is located on the boundary of two TAZs the total impacts are apportioned equally between the two TAZs.

CHAPTER 6

RESULTS

The LCA analysis described in Chapter 5 provided detailed information about the data and parameters used in assessing the total energy use and GHG emissions for various combinations of materials by unit type and size and for roadway infrastructure.

In this chapter, the individual results per unit type are used to estimate the impacts of material selection, building typology and street layout, for entire residential TAZ groups, or neighborhoods. The purpose of these calculations is to then create a matrix of comparable values for each TAZ group, which would allow us to identify the neighborhood layout and density that is more or less efficient in minimizing life cycle energy use and emissions. This is particularly important because, while two residential neighborhoods may have the same land use and density classification (in term of dwellings per acre) it should not be implied that they are equal in terms of total energy and GHG emission. The differences are highlighted as part of the analysis.

This chapter is organized in four sections. The first section provides an analysis of energy and GHG emission for each residential unit type, previously identified. In the second, similar energy and GHG emission results are provided for each road type. The total energy and

GHG emission by TAZ group is provided in the third section. Finally, in the fourth section the four groups are compared using various suitable measures.

Energy and GHG Emissions Per Residential Unit Type

As previously discussed, each unit is composed of over 60 major material assemblies, which, in turn, are composed of many more sub-components. However, according to the methodology and calculations outlined in Chapter 3 and Chapter 4, there are only five variable attributes: walls, roof composition, number of stories and size. All the other material assemblies can be held constant. Thus, opportunities to reduce unnecessary duplications in the analysis were identified. All the recurrent material assemblies (e.g., foundations, interior framing, doors, cabinets, etc.) are identified and their respective values of energy and GHG emission are calculated separately.

Grouping the recurrent material assemblies resulted in the creation of ten baseline values (or common values), one for each unit size and number of stories. Once the baseline values are established, additional LCA calculations are performed for each wall and roof combination. These results are later added to the baseline values. (See Appendix E for a list of the total baseline energy and for a list of all the material combinations considered, both one-story and two-story. See

Appendix G for detailed energy and emission results for specific roof and wall systems and sub-components).

When comparing directly one-story with two-story units, the one-story units are found to be more energy intensive than two-story units of equal size. A one-story unit with a clay tile roof with wood shingles or brick exterior walls is very energy intensive. The total energy can range from 1,070.4 GJ, for a 1,500 square-foot unit, to 2,122.0 GJ, for a 3,500 square-foot brick and clay tile unit. Table 13 indicates that this is equal to a 713.1 MJ to 606.0 MJ per square foot range, dependent on size. Wood shingles are typically less costly (economical), and less energy intensive material (16.6 MJ/$) than bricks (31.4 MJ/$). However, when all the other sub-components required in the wood shingle "exterior wall system" are added, the total cost and energy aggregate value is higher than the aggregate system value for a brick wall.

Table 13

Energy Intensity Results for One-Story Units (MJ/Sq. Ft) Per Material Combination and Size

Material Type		Unit Size [Sq. Ft.]				
Exterior Wall	Roof	1500	2000	2450	3000	3500
Wood Shingles	Clay Tile	717.1	678.7	634.3	517.8	602.0
Brick	Clay Tile	713.6	678.6	636.1	521.1	606.3
Wood Shingles	Built Up	668.6	630.5	586.2	569.6	553.9
8" Painted Block	Clay Tile	668.4	633.4	591.0	475.9	561.2
Wood Shingles	Wood	666.4	628.3	584.0	567.4	551.7
Stucco	Clay Tile	665.6	620.2	574.0	455.3	548.2
Brick	Built Up	665.0	630.4	588.0	573.0	558.1
Brick	Wood	662.8	628.2	585.8	570.8	555.9
Wood Shingles	Concrete Tile	659.6	621.1	576.8	517.8	544.5
Brick	Concrete Tile	656.1	621.0	578.6	521.1	548.8
Wood Shingles	Asphalt Shingle	643.0	604.9	560.6	544.1	528.3
Brick	Asphalt Shingle	639.5	604.8	562.4	547.4	532.6
8" Painted Block	Built Up	619.9	585.3	542.8	527.8	513.0
8" Painted Block	Wood	617.7	583.1	540.6	525.6	510.8
Stucco	Built Up	617.1	572.1	525.8	507.2	500.0
Stucco	Wood	614.9	569.9	523.6	505.0	497.8
8" Painted Block	Concrete Tile	610.9	575.9	533.5	475.9	503.7
Stucco	Concrete Tile	608.1	562.7	516.4	455.3	490.6
8" Painted Block	Asphalt Shingle	594.3	559.7	517.3	502.3	487.4
Stucco	Asphalt Shingle	565.2	546.5	500.2	481.7	474.4

A two-story unit with stucco on a wood frame exterior wall with an asphalt shingle roof is found to be the least energy intensive combination. The energy total ranges from 760.47 GJ for a 1,500 square foot unit to 1,416.49 GJ for a 3,500 square foot unit. Table 14 indicates that this is equal to a range of 507.0 MJ to 404.7 MJ per square foot, dependent on size.

For both one-story and two-story units the tables show that the energy intensity values per square foot decreases as the unit increases in size. A closer examination shows that for any of the material combination used, the energy intensity values decreases on average 21 percent. This decrease is due mainly the fact that, as the size of the unit increases, the quantity of the material assemblies used which are less energy intensive (i.e. trusses 13.2 MJ/$) increases at a faster pace than the quantity of the more energy intensive material assemblies (i.e. cement 74.4 MJ/$). This finding highlights the need to properly understand the effect of size and scale when estimating life-cycle energy, or GHG emissions. Using a single, common, intensity value for all types of single -family units is not appropriate, as it would cause to either overestimate or underestimate the total energy or GHG emission for multiple units of various sizes.

Overall, the comparison of these individual results shows that changes in roof and wall material composition and number of stories

can result in significant life cycle energy reduction. For example a two story 3,500 square foot unit with stucco walls and asphalt shingle is 33 percent less energy intensive than a single story unit of same size built with brick walls and clay tiles. Also, even when comparing two units of same size and same material composition, the two story unit is still about 20-24 percent less energy intensive.

Table 14

Energy Intensity Results for Two-Story Units (MJ/Sq. Ft) Per Material Combination and Size

Material Type		Unit Size [Sq. Ft.]				
Exterior Wall	Roof	1500	2000	2450	3000	3500
Brick	Clay Tile	589.9	523.0	506.1	814.3	465.9
Wood Shingles	Clay Tile	587.9	521.3	504.6	812.9	464.7
Brick	Built Up	565.6	498.9	482.1	840.2	441.9
Brick	Wood	564.5	497.8	481.0	839.1	440.8
Wood Shingles	Built Up	563.7	497.2	480.5	838.9	440.6
Wood Shingles	Wood	562.6	496.1	479.4	837.8	439.5
Brick	Concrete Tile	561.1	494.2	477.4	814.3	437.2
Wood Shingles	Concrete Tile	559.2	492.5	475.8	812.9	435.9
8"Paited Block	Clay Tile	557.9	495.3	481.1	792.3	445.1
Brick	Asph. Shingle	552.8	486.1	469.3	827.4	429.1
Wood Shingles	Asph. Shingle	550.9	484.4	467.7	826.1	427.8
Stucco	Clay Tile	544.0	485.5	473.7	787.7	441.6
8"Paited Block	Built Up	533.7	471.3	457.0	818.2	421.0
8"Paited Block	Wood	532.6	470.2	455.9	817.1	419.9
8"Paited Block	Concrete Tile	529.2	466.6	452.3	792.3	416.3
8"Paited Block	Asph. Shingle	520.9	458.5	444.2	805.4	408.2
Stucco	Built Up	519.8	461.4	449.6	813.7	417.5
Stucco	Wood	518.7	460.3	448.5	812.6	416.4
Stucco	Concrete Tile	515.3	456.7	444.9	787.7	412.8
Stucco	Asph. Shingle	507.0	448.6	436.8	800.9	404.7

The one-story unit built with brick exterior walls and a clay tile roof unit has also the highest value of total GHG emission. The total emission ranges from 175.73 to 353.35 metric tons of CO_2 equivalent[6] (CO_2e), for a 1,500, and 3,500 square foot unit respectively.

The two-story units with a stucco exterior wall and an asphalt shingles roof unit is the combination with the lowest total CO_2e emission. Its values range from 116.24 to 214.59 metric tons, for a 1,500, and 3,500 square feet unit respectively.

Similar to the energy results, the intensity of the GHG emission (metric ton x Sq. Ft.) decreases as the size of the unit increases. The maximum average difference in intensity between 1,500 and 3,500 square foot units is 22.5 percent. Table 15 and Table 16 list, from the highest to the lowest listed, the various intensities of CO_2 equivalent GHG emitted, for one-story and two-story building respectively.

As in the case of life cycle energy, there are also potential for reducing GHG emission by changing the unit typology. The potential reduction would be up to 16 percent. (See Appendix F for a complete listing of GHG emission results.)

[6] Carbon dioxide equivalent is defined as "means the amount of carbon dioxide by weight emitted into the atmosphere that would produce the same estimated radiative forcing as a given weight of another radiatively active gas. Carbon dioxide equivalents are computed by multiplying the weight of the gas being measured by its estimated global warming potential" (EIA,2006).

Table 15

GHG Emission Intensity Results for One-Story Units (Metric Ton / Sq. Ft.) Per Size Category

Material Type		Unit Size [Sq. Ft.]				
Exterior Wall	Roof Material	1500	2000	2450	3000	3500
Brick	Clay Tile	0.092	0.084	0.082	0.086	0.078
Wood Shingles	Clay Tile	0.091	0.082	0.081	0.084	0.075
8" Painted Block	Clay Tile	0.088	0.080	0.078	0.082	0.074
Brick	Concrete Tile	0.088	0.079	0.078	0.081	0.073
Stucco	Clay Tile	0.087	0.077	0.075	0.078	0.071
Brick	Built Up	0.087	0.078	0.077	0.081	0.072
Wood Shingles	Concrete Tile	0.087	0.078	0.076	0.079	0.071
Brick	Wood	0.087	0.078	0.077	0.080	0.072
Wood Shingles	Built Up	0.086	0.077	0.075	0.079	0.070
Wood Shingles	Wood	0.086	0.077	0.075	0.078	0.070
Brick	Asph. Shingle	0.085	0.076	0.075	0.078	0.070
Wood Shingles	Asph. Shingle	0.084	0.075	0.073	0.076	0.068
8" Painted Block	Concrete Tile	0.083	0.075	0.074	0.077	0.069
8" Painted Block	Built Up	0.083	0.074	0.073	0.076	0.068
Stucco	Concrete Tile	0.083	0.073	0.071	0.074	0.067
8" Painted Block	Wood	0.083	0.074	0.073	0.076	0.068
Stucco	Built Up	0.082	0.072	0.070	0.073	0.066
Stucco	Wood	0.082	0.072	0.070	0.073	0.066
8" Painted Block	Asph. Shingle	0.081	0.072	0.071	0.074	0.066
Stucco	Asph. Shingle	0.080	0.070	0.068	0.071	0.064

Table 16

GHG Emission Intensity Results for Two-Story Units (Metric Ton / Sq. Ft.) Per Size Category

Material Type		Unit Size [Sq. Ft.]				
Exterior Wall	Roof Material	1500	2000	2450	3000	3500
Brick	Clay Tile	0.085	0.081	0.083	0.089	0.085
Wood Shingles	Clay Tile	0.084	0.079	0.08	0.087	0.082
8"Paited Block	Clay Tile	0.083	0.079	0.08	0.086	0.082
Brick	Wood	0.083	0.077	0.078	0.084	0.078
Brick	Built Up	0.083	0.077	0.078	0.084	0.079
Brick	Concrete Tile	0.083	0.078	0.079	0.085	0.08
Brick	Asph. Shingle	0.082	0.076	0.077	0.082	0.076
Stucco	Clay Tile	0.081	0.076	0.078	0.085	0.08
8"Paited Block	Wood	0.081	0.075	0.076	0.081	0.075
8"Paited Block	Built Up	0.081	0.075	0.076	0.081	0.076
8"Paited Block	Concrete Tile	0.081	0.076	0.077	0.082	0.077
Wood Shingles	Wood	0.081	0.075	0.076	0.081	0.076
Wood Shingles	Built Up	0.081	0.075	0.076	0.081	0.076
Wood Shingles	Concrete Tile	0.081	0.076	0.077	0.082	0.077
8"Paited Block	Asph. Shingle	0.080	0.074	0.074	0.079	0.073
Wood Shingles	Asph. Shingle	0.080	0.074	0.074	0.079	0.073
Stucco	Built Up	0.079	0.073	0.074	0.079	0.074
Stucco	Concrete Tile	0.079	0.073	0.074	0.08	0.075
Stucco	Wood	0.078	0.073	0.074	0.079	0.074
Stucco	Asph. Shingle	0.077	0.071	0.072	0.077	0.071

Roadway Energy and GHG Emissions Unit Matrix

The PaLATE tool was used to estimate the energy and environmental impacts of 1 mile lane (both direction) of typical roadways, as defined in chapter 3 and 4. Thus, rather than running the PaLATE tool for each roadway type in the study area, the original output of the PaLATE tool was adjusted to match the roadway geometries of the City of Phoenix and Town of Gilbert as summarized in Table 17.

This table provides total energy (GJ) and total GHG emission associated with construction and maintenance of one mile (units), curb to curb, of arterial, collector and local residential roads under normal use condition (Chester, 2008).

Furthermore, a breakdown of the energy and GHG emission for each component of the LCA is provided in Table 18, for the roads in Phoenix and Table 19 for the roads in the Town of Gilbert. The LCA components included are: material production, transportation, and processes associated with initial construction and maintenance. (See Appendix H for the original complete output used to derive the above reported results).

Table 17

Total Energy and GHG Emission Per Mile

Type	Unit	Arterial	Collector	Local
		Phoenix		
Energy	GJ	26,878.20	20,998.60	13,439.10
CO_2e	ton	6,658.2	4,712.9	3,016.3
CO_2	ton	2486.37	1731.48	1,108.15
NOx	Ton	13.46	9.62	6.16
PM_{10}	Ton	6.62	4.59	2.94
SO_2	Ton	4.91	3.43	2.20
CO	Ton	7.73	5.39	3.45
VOC	Ton	14.22	9.70	6.21
		Gilbert		
Energy	GJ	39,687.34	19,108.72	13,229.11
CO_2e	Ton	10,148.4	4,28837	2969.10
CO_2	Ton	3,769.66	1,575.65	1,090.83
NOx	Ton	20.40	8.75	6.06
PM_{10}	Ton	10.03	4.18	2.89
SO_2	Ton	7.44	3.12	2.16
CO	Ton	11.72	4.90	3.39
VOC	Ton	21.56	8.83	6.11

Table 18

PaLATE Total Energy Results Per Mile: Phoenix Road Typology

Road Type	Phase	Energy [MJ]	CO_2 Equiv. [ton]
Local	C - Material Production	11,167,820.0	1,252.4
	C - Material Transport	1,149,205.6	1,504.8
	C – Process	84,214.6	46.9
	M - Material Production	957,932.4	110.0
	M - Material Transport	76,295.2	99.9
	M- Process	3,633.1	2.2
Collector	C - Material Production	17,449,718.7	1,956.8
	C - Material Transport	1,795,633.7	2,351.3
	C - Process	131,585.4	73.3
	M - Material Production	1,496,769.3	171.8
	M - Material Transport	119,211.3	156.1
	M- Process	5,676.7	3.5
Arterial	C - Material Production	25,012,185.7	2,810.1
	C - Material Transport	2,495,353.1	3,267.6
	C - Process	169,470.5	94.8
	M - Material Production	2,193,447.4	251.8
	M - Material Transport	174,698.7	228.8
	M- Process	8,319.0	5.1

Table 19

PaLATE Total Energy Results Per Mile: Gilbert Road Typology

Road Type	Phase	Energy [MJ]	CO_2 Equiv. [ton]
Local	C - Material Production	10,993,322.8	1,232.8
	C - Material Transport	1,131,249.3	1,481.3
	C - Process (Equipment)	82,898.8	46.2
	M - Material Production	942,964.7	108.2
	M - Material Transport	75,103.1	98.3
	M- Process (Equipment)	3,576.3	2.2
Collector	C - Material Production	15,879,244.0	1,780.7
	C - Material Transport	1,634,026.7	2,139.7
	C - Process (Equipment)	119,742.7	66.7
	M - Material Production	1,362,060.1	156.3
	M - Material Transport	108,482.3	142.1
	M- Process (Equipment)	5,165.8	3.2
Arterial	C - Material Production	38,123,412.0	4,283.1
	C - Material Transport	3,803,401.1	4,980.4
	C - Process (Equipment)	258,305.9	144.6
	M - Material Production	3,343,238.4	383.8
	M - Material Transport	266,274.7	348.7
	M- Process (Equipment)	12,679.8	7.8

Total Energy and GHG Emission per TAZ Group

In Chapter 3 it was discussed that the four Groups represent specific density (du/acre), median construction year, and over all layout typically found in the Phoenix MSA.

Study area Group One (in Phoenix) and Group Three (in Gilbert) are high density neighborhoods. Study area Group Two (in Phoenix) and Group Four (in Gilbert) are low density. For the purpose of the discussion throughout the remaining of the document, Group One and Group Two will be referred as PHX-High and PHX-Low. Group Three and Four will be referred as GLB-High and GLB-Low respectively.

In the City of Phoenix, the residential land use density similar to the one represented in PHX-High is common. In fact in the entire City of Phoenix over 69 thousand acres of land that are classified as Small Lot Residential (4-6 du per acre), representing about 65 percent of the total residential land use by density. The remaining 35 percent include other single-family residential densities, multifamily, apartments, and mobile units. PHX-Low represents s about 13 percent of the total residential land use; this includes Large Lot Residential and Estate Residential land use. In the town of Gilbert, GLB-High and GLB-Low represent about 33 and 50 percent, respectively, of the total residential land use by density. However, while the blocks and roads layout patterns for study area PHX-Low and GLB-Low are very

similar to one another, as shown in Chapter 3, PHX-High and GLB-High differ significantly both in unit size, type, materials, block size, and roads layout.

Table 20 provides a summary of the main attributes of each of the four study areas. It shows that the TAZs in the Town on Gilbert, GLB-High and GLB-Low, are both the most and least dense both in number of buildings and population (7.44 du/acre and 0.75 du/acre; 17,451 and 1004 residents). While PHX-High is 60 percent smaller than GLB-High, their densities are comparable (6.04 du/acre).

Table 20

Built Environment Attributes: Comparative Summary

Type	Unit	PHX-High	PHX-Low	GLB-High	GLB-Low
Pop.	Ppl	5647	1550	17451	1004
H.hold Size	Ppl/Unit	2.97	2.64	4.82	3.24
Pop. Density	Ppl/Acre	17.93	5.02	38.86	2.44
Med. Cstr.	year	1940	1962	2004	1976
Liv. Area	Sq. Ft	2,240,826	1,681,217	11,515,093	726,957
N. Unit		1,886	587	5,768	302
Res. Area	acres	312.29	303.01	774.87	403.49
Density	du/acre	6.04	1.94	7.44	0.75
Arterial	miles	4.00	5.00	10.50	4.00
Collector	miles	2	1	1.5	0
Local	miles	18	9.4	66.1	8.9

It is because of these differences that the analysis was carried out at the individual parcel level. As part of the analysis residential assessor parcel data (2011) within each of the TAZ Groups was selected and collected according to their property use code (Property Use Codes: 131-134; 141-144; 181-184; 730; 735). Each parcel was then linked with the LCA intensity values previously presented. Using an Excel based model specifically developed for this task, the size, number of stores, wall and roof composition of each parcel was used to identify and match each parcel with one of the 200 energy parameters and with one of the GHG emission parameter (there are 1,000 GHG emission parameters, 200 for each one of the five greenhouse gas type estimated). The livable size (Sq. Ft.) of each unit is then multiplied by the appropriate energy and GHG intensity. The individual parcel results are then aggregated for each TAZ Group.

Table 21 summarizes the aggregated energy (gigajoule) GHG emission (CO_2e) results for both single-family units and roadway infrastructure.

These aggregated results indicate that GLB-High is the most densely developed, and the most energy and GHG emissions intensive. It is estimated that the life cycle energy is equal to at least 7.46 petajoules (7.46 E^6 MJ) and that in the process more than 1,198,074 metric tons of CO_2e were emitted. Yet, about 71 percent of all the units

in this area are two-story and it is almost entirely composed of stucco on a wood-frame and cement tile roof units, which is the one of the least energy intensive material combination for both one and two-story units.

Table 21

Total Single-Family Residential LCA Results

Type	Unit	PHX-High	PHX-Low	GLB-High	GLB-Low
			Single Family Units		
Energy	GJ	1,370,313	900,204	6,080,741	415,530
CO_2e	Ton	184,423	122,775	889,388	55,234
			Roadway Infrastructure		
Energy	GJ	404,786	297,925	1,381,539	299,998
CO_2e	Ton	90,502	66,430	308,686	66,804
			Combined Totals		
Energy	GJ	1,775,099	1,198,129	7,462,280	715,528
CO_2e	Ton	274,925	189,205	1,198,074	122,039

GLB-Low is both the least dense and least intensive. Here the total life cycle embedded energy is 0.71 petajoules (0.71 E^6 MJ) with more estimated 122,039 metric tons of CO_2e emitted. About 95 percent of the units in GLB-Low are single story and half of them are made of cement blocks and asphalt shingle roofs. However, to understand better the differences, and meaning, of these various LCA results it is

necessary to look closer at the aggregated LCA results, and compare them in light of actual differences in the built environment previously listed in Table 20.

The comparative measures chosen for this analysis are: net residential density (acre), livable space (Sq. Ft), population, and number of units built. The first to be considered are the energy – Figure 9 – and GHG emissions – Figure 10 – per acre of net developed residential land use. The net residential land use is calculated here as the sum of the area of all the developed residential parcels (vacant parcels, common areas, green belts are excluded).

Figure 9

Total Life Cycle Energy Per Acre of Developed Residential Land Use

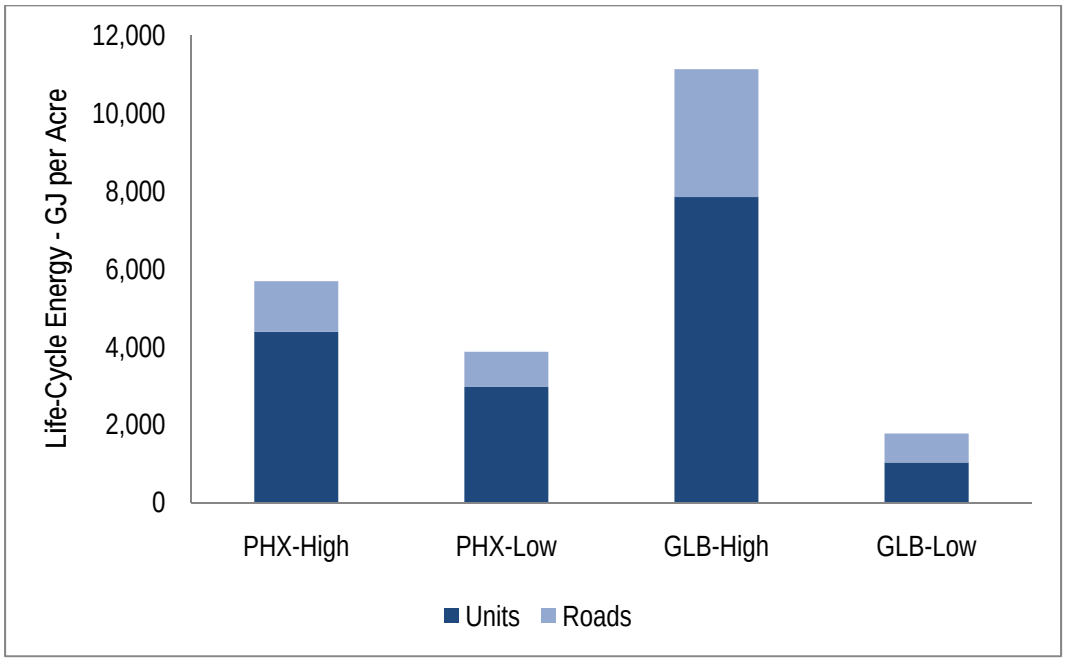
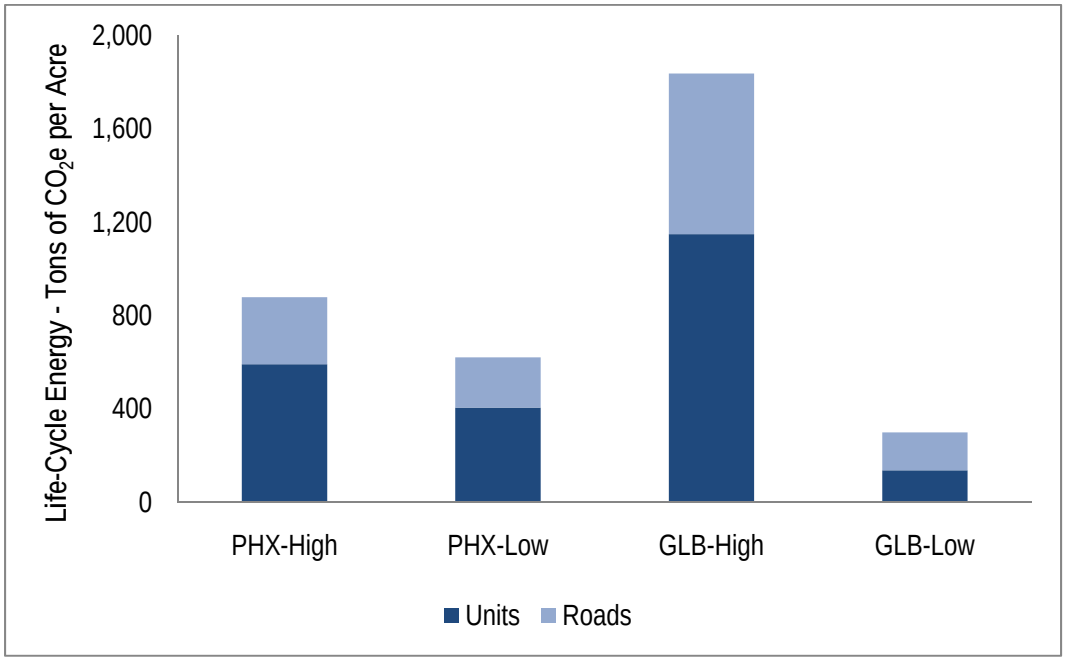


Figure 10

Total Life Cycle GHG Emissions Per Acre of Developed Residential Land Use



Both Figure 9 and Figure 10 show that study area GLB-High is the most energy and CO_2e intensive group (11,129 GJ and 1,835.30 tons of CO_2e per acre). While the difference in dwelling density between PHX-High and GLB-High is only 14 percent, the total life cycle energy for units and roads in LBG-High is 44 and 60 percent, respectively, higher than in PHX-High. A contributing factor to the difference in life cycle unit energy is that the newer units in GLB-High are on average 36 percent larger than in PHX-High (1,871 and 1,198 square feet, respectively). Also, In PHX-High only 6 percent of units are larger than 2450 square feet, while in GLB-High those units

represent about 20 percent of the total units. With regards to the difference in total life-cycle energy in the roadway infrastructure must be noted that, in PHX-High, there are several miles of roads that have been built in areas which don't have any homes yet (vacant parcels).

Study area GLB-Low is estimated to be the least energy and CO_2e intensive group (1,773 GJ and 299.19 tons of CO_2e per acre). Compared to PHX-Low the difference in total energy can be linked to the actual difference in density. In fact a 61 percent difference in density results in a 54 percent difference in total life cycle energy. Figure 11 and Figure 12 show the share in total life cycle energy and GHG emission results per unit built.

Figure 11

Total Life Cycle Energy Per Unit

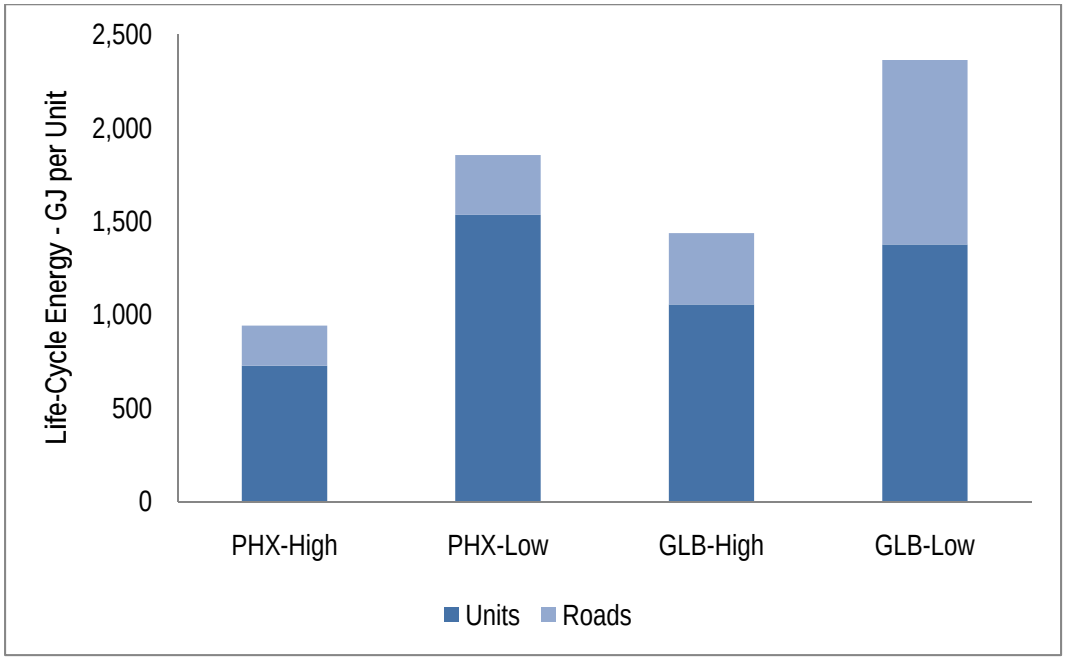
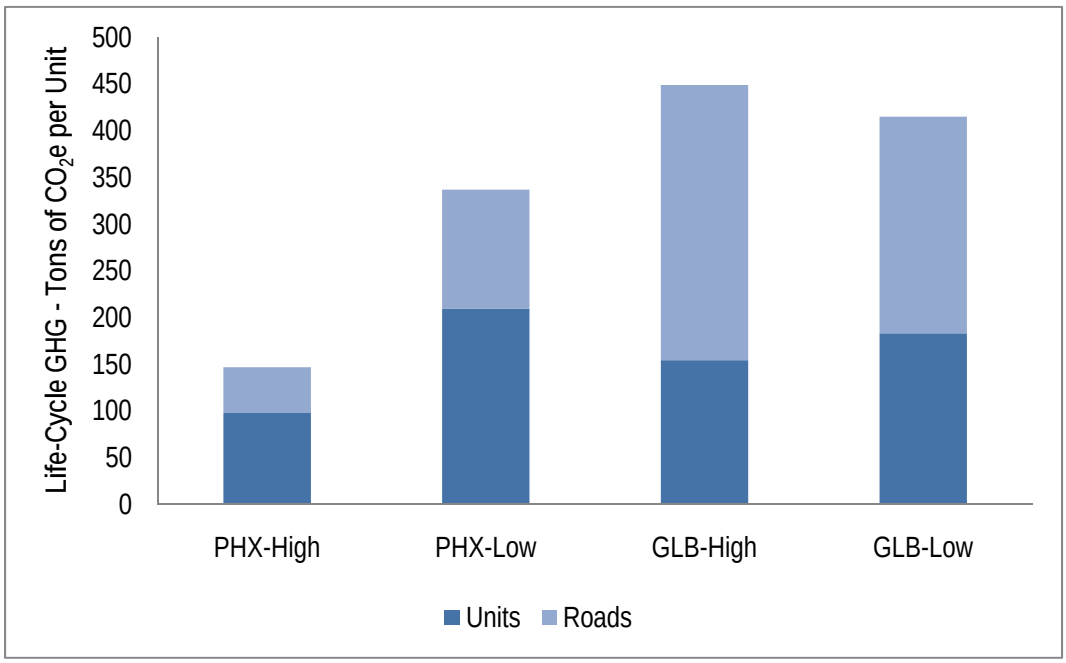


Figure 12

Total Life Cycle GHG Emissions Per Unit



Based on the direct impacts of the material used and quantity of roads (miles) built GLB-Low is 60 percent more energy intensive per unit built (GJ/Unit) than PHX-High, and about 21 and 39 percent more energy intensive than PHX-Low and GLB-High respectively. Also, if the roads to vacant (undeveloped) neighborhoods were to be discounted from GLB-High, then GLB-Low would have the highest GHG emission value per unit, being 64 and 18 percent higher than PHX-High and PHX-Low, respectively.

From per dwelling unit base, PHX-High is the least intensive, despite the fact that 54 percent of the units were built with high

energy material assemblies (bricks exterior walls). Using this measure PHX-High on average requires only 941.17 GJ per unit, 726.57 GJ from the buildings and 214.6 from the roadway infrastructure. This result is particularly important because it shows that the older, dense neighborhood, built in a regular tight grid layout, like the one in PHX-High, are less energy intensive on a per unit base than PHX-Low, GLB-High and GLB-Low by 33, 44 and 78 percent, respectively.

Figure 13 and Figure 14 show the share in total life cycle and GHG emission results per capita using the latest estimates form the U.S Census.

Figure 13

Total Life Cycle Energy Per Capita

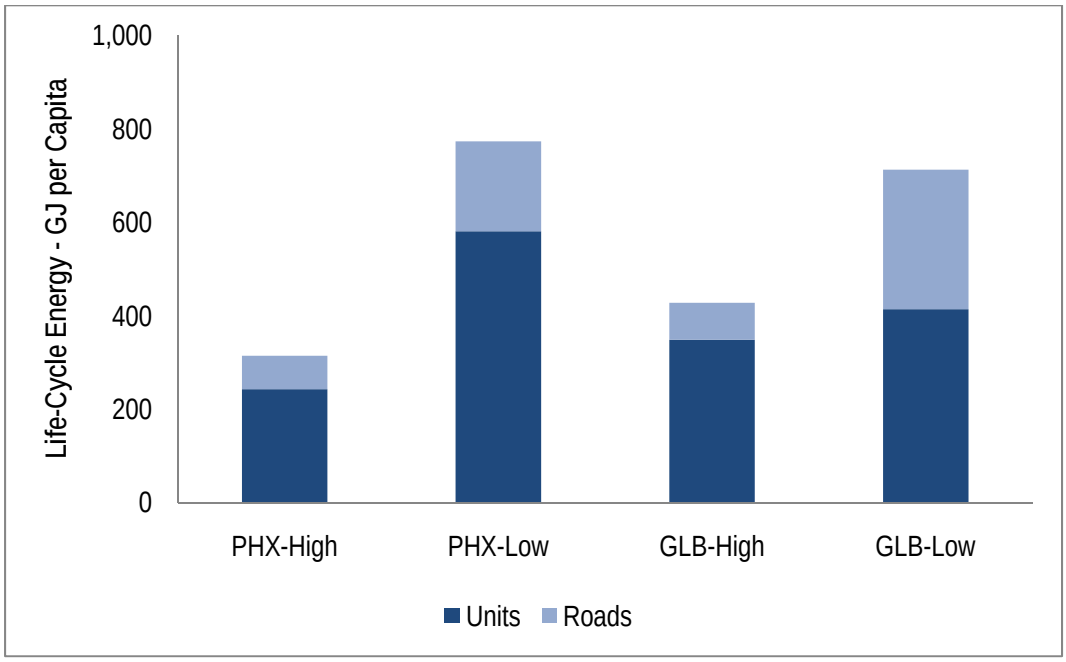
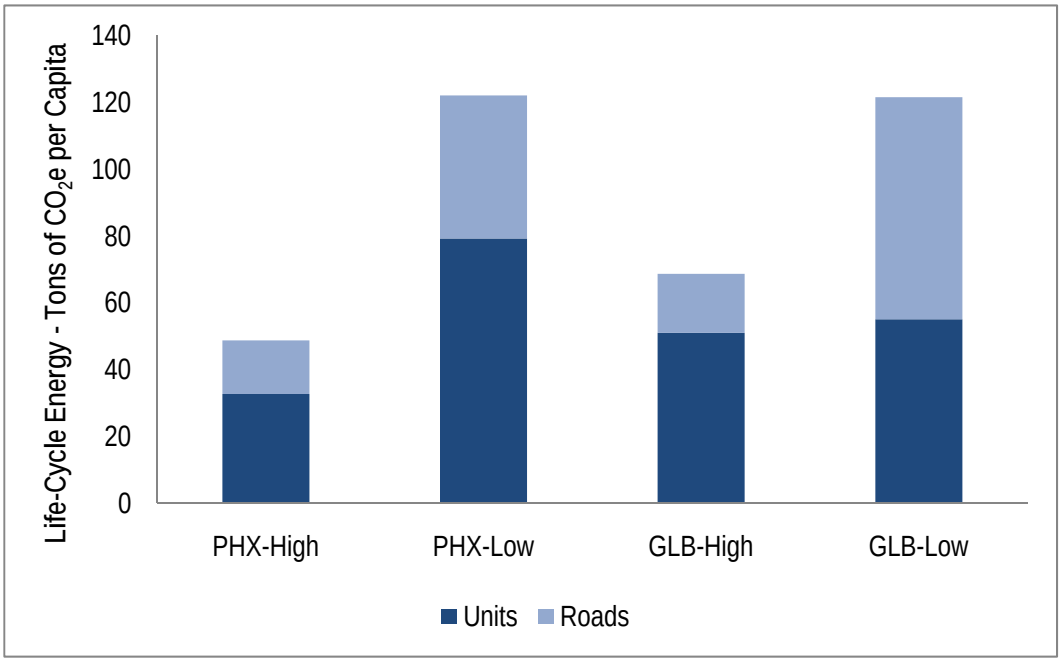


Figure 14

Total Life Cycle GHG Emissions Per Capita



When using a per capita functional unit, PHX-High is again the least energy intensive requiring 314.36 GJ per capita. However, while all the previous functional units are somewhat fixed, household size and thus the population of an area changes due to factors beyond the built environment. A per capita functional unit does not take into account the household size in GLB-High which is almost double that of PHX-High. Nor does it consider other factors that influence the size of family and household and thus the total population in any given area. For example it does not consider which neighborhoods are more attractive to large families, to owners or renters and what neighborhoods are desirable. Therefore, to get a better picture, the

total energy per capita is recalculated after holding the household size constant in all the groups and assuming one household per residential unit. For this scenario the 2011 Arizona average household of 2.68 is used (Census, 2010). The total population per group is computed by multiplying the number of residential units in each group by the average household size. In this scenario, as shown in Figure 15, PHX-High is again the least energy intensive group with 351.19 GJ per capita, while GLB-High and GBL-Low are 54.3 and 60 percent more energy intensive. Also, according to this scenario – Figure 16 – the infrastructure layout of PHX-High is again the least CO_2e Intensive with only 54.39 tons of CO_2e per capita.

Figure 15

Life Cycle Energy Per Capita – Population Simulated

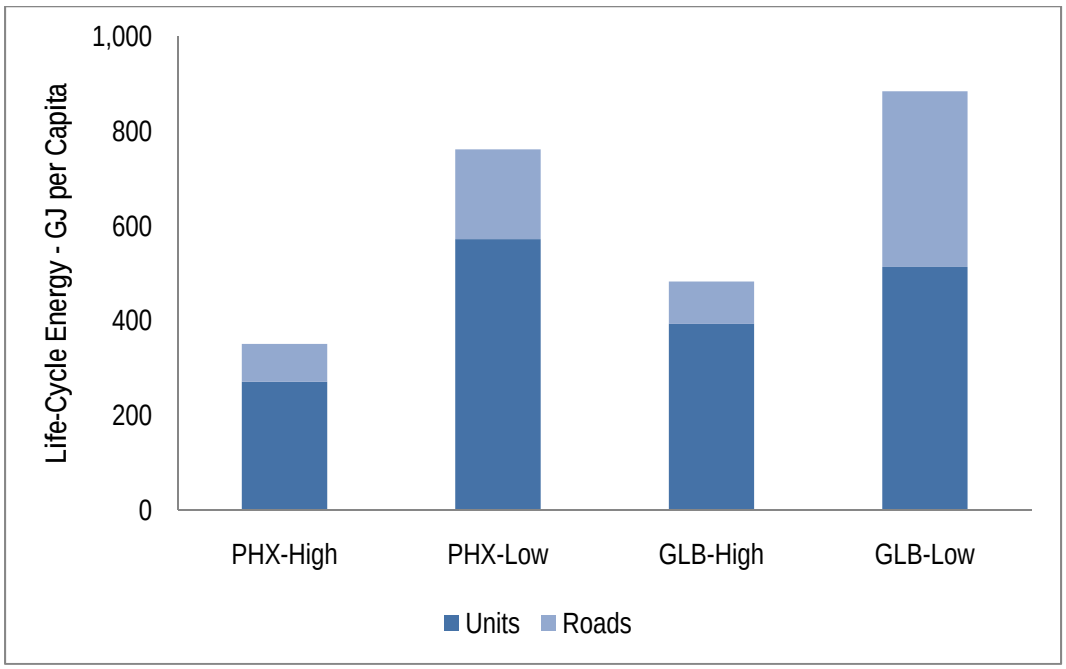
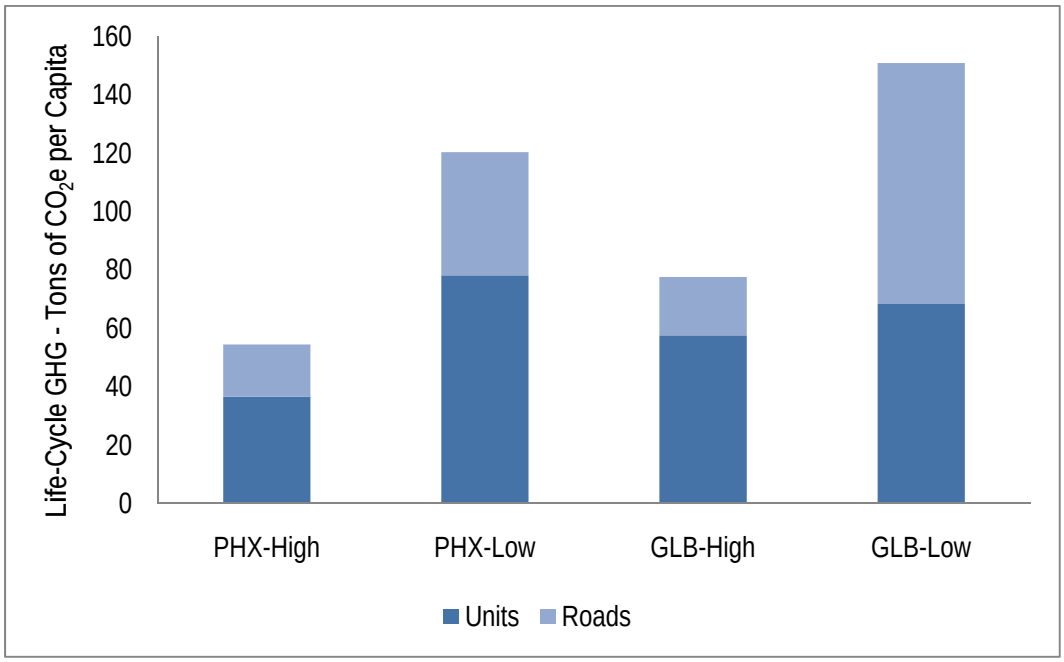


Figure 16

Life Cycle GHG Per Capita – Population Simulated



Summary

Through the comparison of the four TAZ groups it was demonstrated that changes in neighborhood development affects embedded energy and GHG emissions. The results and relative analysis presented in this chapter clearly indicate that unit typology, density and layout do play an important role in the total life cycle energy and GHG emission profile of a neighborhood. It is also clear that older urban development, similar to Group One, despite having a high percentage of units built with higher energy and GHG intensive material are more sustainable, in terms of energy and GHG emissions

than newer ones. Newer master planned communities, while the use low energy intensive materials, they tend to be over built, both in terms of unit's size and miles of road pavement.

Table 22 provides a detail summary of each of functional units comparison previously reviewed.

Table 22

Neighborhoods Comparative Analysis -Energy

Type	Unit	PHX-High	PHX-Low	GLB-High	GLB-Low
		Energy			
Units	GJ/Acre	4,387.9	2,970.8	7,847.4	1,029.8
Road	GJ/Acre	1,297.4	902.0	3,281.6	743.5
Neighborhood	GJ/Acre	5,685.3	3,873.6	11,129.0	1,773.3
Units	GJ/Capita	242.6	580.7	348.4	413.8
Road	GJ/Capita	71.7	192.2	79.2	298.8
Neighborhood	GJ/Capita	314.3	772.9	427.6	712.6
Units	GJ/Unit	726.5	1,533.5	1,054.2	1,375.9
Road	GJ/Unit	214.6	320.7	382.00	986.8
Neighborhood	GJ/Unit	941.1	1,854.2	1,436.2	2,362.7
Units	GJ/Sq. Ft	0.61	0.54	0.53	0.57
Road	GJ/Sq. Ft	0.18	0.14	0.20	0.41
Neighborhood	GJ/Sq. Ft	0.79	0.67	0.73	0.98
		GHG Emissions			
Units	CO_2e/Acre	590.5	405.1	1,147.8	136.8
Roads	CO_2e/Acre	287.4	215.4	687.5	162.3
Neighborhood	CO_2e/Acre	877.9	620.5	1,835.3	299.1
Units	CO_2e/Capita	32.6	79.2	50.9	55.0
Roads	CO_2e/Capita	16.0	42.8	17.6	66.5
Neighborhood	CO_2e/Capita	48.6	122.0	68.6	121.5
Units	CO_2e/Unit	97.7	209.1	154.1	182.9
Roads	CO_2e/Unit	48.8	127.5	294.5	231.9
Neighborhood	CO_2e/Unit	146.6	336.6	448.7	414.8
Units	CO_2e/sq.ft	0.08	0.07	0.08	0.08
Roads	CO_2e/sq.ft	0.04	0.05	0.04	0.09
Neighborhood	CO_2e/sq.ft	0.12	0.12	0.12	0.17

CHAPTER 7

DISCUSSION

This study has provided a detailed reference map of the life-cycle embedded energy and GHG emissions of a variety of single-family detached building, together with the transportation infrastructure (local residential, collector, and arterial roadways). Also, this analysis has provided quantifiable and comparable energy and GHG emissions of single-family detached units and their supporting roadway infrastructure for neighborhoods at the urban core, built before 1965, and in the suburban periphery, built from 1999 until 2010.

These results represent portion of the contributing factors to energy and GHG emissions in single family residential developments; the energy use and GHG emission associated with earthwork, site preparation, utilizes, sidewalks, street lights, landscaping, drainage, and any other structures and infrastructures that may be found in a residential neighborhood were not included in this study. Nonetheless, this extensive LCA analysis shows that significant energy and GHG emissions saving can be achieved by selecting low energy intensive material combinations, by building smaller residential units, and by developing more compact residential neighborhoods.

Based on the data, methodology and assumption used, the results are expected to be reliable and a valid estimate for both

residential units and roadway infrastructure. The results are in line with results obtained by Ochoa (2002), Keoleian (2001), Norman (2006) and Chester (2008) for the roadway infrastructure. Nevertheless, the models used carries the same uncertainties associated with the EIO matrix developed by the Green Design Institute (GDI 2008) and associated with the PaLATE model.

The findings of this study have obvious implications for urban planning and policy dealing with air quality, climate change and energy. Currently, single-family residential urban developments occur in privately owned land and consideration for social, economic development and financial factors have larger bearing, at local level of government, than consideration from energy and GHG emissions. However, this study highlights that policies aimed at increasing residential density, and at regulating the building typology should be part of broader energy conservation and GHG emission reduction policies, at the state and federal level.

This study contributes to the body of knowledge linking variation in residential density, roadway layouts and energy use and GHG emissions. Therefore, if energy use and GHG emission reduction policies are adopted at various local, state and federal levels of government, this study reaffirms highlights the statement made by Norman that "policy makers and urban planners should base their

decisions about urban form on a greater quantitative understanding of the empirical effects of urban development policies" (Norman et al, 2006 p.19).

The finding that energy use and GHG emission can be reduced by controlling for density and roadway design is particularly significant in light of the recent legislative efforts in California and the recently Cap and Trade announcement made by the California Air Resource Board (ARB). In California the ARB has called for a cumulative reduction target of 273 million metric tons of CO_2 by 2020. While the initial focus is on energy producing industries, transportation and other industries, so far little consideration has been given to use planning, zoning and building codes as a way to find energy and GHG emission reductions. Given that energy embedded in construction materials is shown to play greater role in the life cycle energy use, the case for incorporating building codes that encourage better selection of building materials, and high densities is stronger (Frijia, et al 2011).

In fact this study demonstrates that low density single family neighborhood are 2 – 2.5 times as energy and GHG intensive, per unit built, than high density residential neighborhoods. This relationship is true both from area and per capita functional unit. It demonstrates that low density neighborhood require to spend 78 percent more energy

and resource in roadway infrastructure per residential unit. This may no longer be an issue in a highly urbanized area like Phoenix; however, there is still much development in the fringes of the MSA and in more rural area where low density communities are more predominant, thus these impacts should receive more consideration.

Most of the new residential developments in urban areas of the Phoenix MSA are dense and have characteristics similar to the one found in study area GLB-High, both in term of material assemblies used and overall layout. The material assembly combination used in study area GLB-High (stucco and cement tile) is one of the least energy and GHG emission intensive – Stucco with asphalt shingle is the least energy and GHG emission intensive.

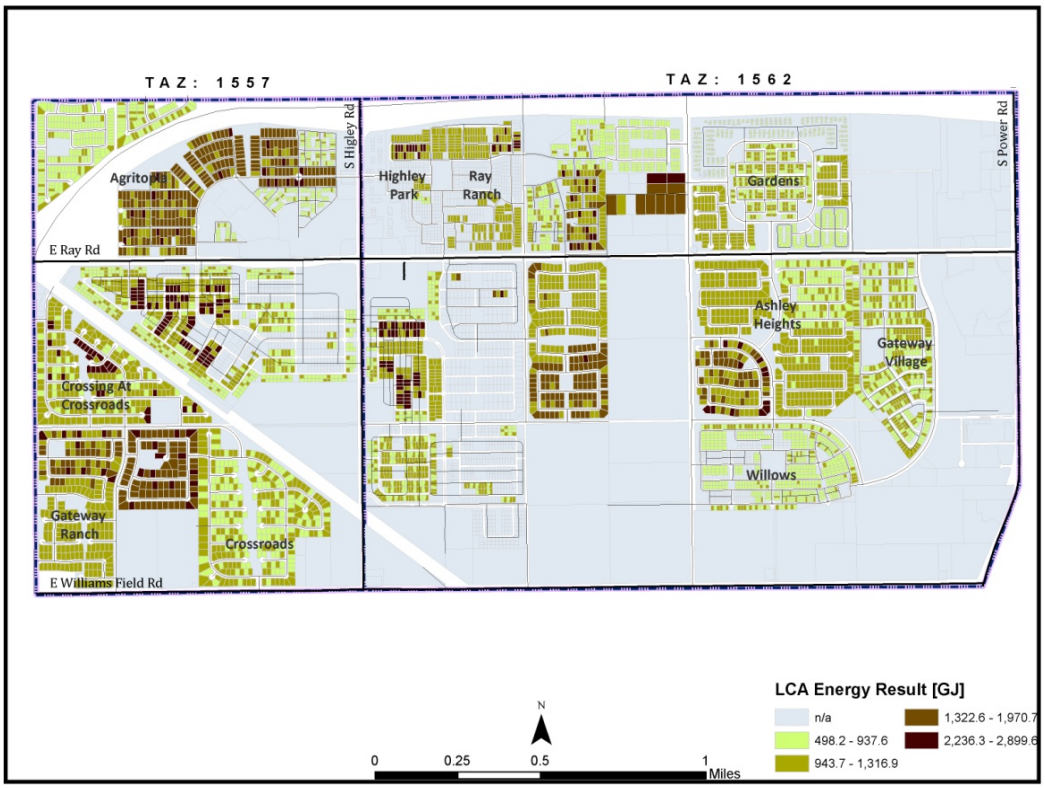
However, the current trend of building ever larger homes has overshadowed the savings found in the material assemblies. This problem is compounded by the fact that these larger homes are more costly to maintain, to cool and to heat. Figure 17 illustrates the effects of this trend along with other obvious planning issues.

The neighborhoods shown above are part of study area GLB-High (the embedded energy in the roads in not included in this graphic). Here, it is evident that certain neighborhoods are more energy intensive than others. Most notable is the Agritopia community in the Town of Gilbert. This community was built according to the

Gilbert Gateway Area Traditional Neighborhood Design guidelines which promotes pedestrian/ bicycle/ transit-oriented design, new urbanism, agriculture, and other planning goals. However, the average size of these units is over 2,650 square feet, much larger than other nearby communities (1,800 square feet).

Figure 17

LCA Energy in Study Area: GLB-High



Another planning issue found in study area GLB-High relates to the large number of incomplete communities, and the large tracts there are still vacant, but with much of the infrastructure already in place. Current regulations require that all grading, utilities, and infrastructure, are in place before the builder is allowed to build any

actual unit. Due to the current economic downturn it is difficult to foresee when the remaining units will be built. This leaves a large financial burden on the builders and potential liabilities for the cities when the builders become unable either to complete their development projects or to maintain the infrastructure built.

Additionally, if a city, a county, or a state enacts policies aimed at reducing energy use and GHG emissions, such policies much be reconciled with existing policies regulating residential development, subdivision zoning, building permits and impact fees. Cities and towns should be discouraged the indiscriminate use of building permits fees and development impact fees as a mean to increase revenue..

In conclusion, while it is generally understood that the construction of units and roads requires a lot of energy, the empirical approach in this study further advances understanding of the relationship and trade off not only between density and energy and density and GHG emission, but also between the personal choices individuals make when they decide to buy or build a home for their family.

As part of future research the data created for this study will be joined with energy use and GHG emission data related to other types of residential developments (multifamily, apartments, condominiums, etc.), retail, commercial and other development types, and

transportation energy use data that will then allow assessment of a more complete profile of these urban environments.

REFERENCES

Adalberth, K., (1997) Energy use during the life cycle of single-unit dwellings: examples. *Building and Environment* 32(4), 321-329.

Anderson, W., Kanaroglou, P., and Miller, E. (1996) Urban Form, Energy and the Environment: A Review of Issues, Evidence and Policy. *Journal of Urban Studies,* 33(1), 7-35.

Bartholomew, K., Ewing, R., (2007). Land Use-transportation Scenario Planning in an Era of Global Climate Change. Transportation Research Board Annual Meeting 2008 Paper #08-2741.

Baumann, H; Tillman A.-M. (2004). *The Hitch Hikers Guide to LCA*. Studentlitteratur AB: Lund, Sweden.

Brownstone, D. and Glob, T., (2009). The Impact of Residential Density on Vehicle Usage and Energy Consumption. *Journal of Urban Economics.* 65, 91-98.

Bullard, C., Herendeen R. (1975) The Energy Cost Of Goods and Services. *Energy Policy*. 268.

Bullard, C., Pennter, P., and Pilati, D. (1978). Net Energy Analysis: Handbook for Combining Process and Input-Output Analysis. *Resources and Energy* 1, 267-313.

California Air Resource Board (2011). *California's Climate Plan.* http://www.arb.ca.gov/cc/cleanenergy/clean_fs2.htm. Retrieved June 1, 2011.

Carnegie Mellon University Green Design Institute (GDI). (2008) Economic Input-Output Life Cycle Assessment (EIO-LCA), US 2002 Industry Benchmark model, Retrieved June 1 2010, http://www.eiolca.net/

Chester, M., and Horvath A.,(2009) Environmental Assessment of Passenger Transportation Should Include Infrastructure and Supply Chains Environmental. *Research Letters* 4, 1-4.

City of Gilbert (2009). *Public Works and Engineering Standards and Details.* Retrieved February 23, 2011, http://www.gilbertaz.gov/eservices/engineering/standards.cfm/

City of Phoenix (2009). *Phoenix Street Planning and Design Guidelines Street Transportation*. Retrieved February 23, 2011, http://phoenix.gov/streets/designman.pdf/

Cole, R. and Kernan, P. (1996). Life-Cycle Energy Use in Office Buildings. Journal of *Building & Environment*. 31(4), 307-317.

Cole, J., (1998). Energy and Greenhouse Gas Emissions Associated with the Construction of Alternative Structural Systems. *Journal of Building & Environment* 34(4), 335-348.

Cooper, J., Ryley, t. and Smyth, A., (2001). Energy Trade-offs and Market Responses in Transport and Residential Land-use Patterns: Promoting Sustainable Development Policy. *Journal of Urban Studies*, 38(9), 1573-1588.

Coronado Neighborhood Association (2011). *Historic Coronado Neighborhood*. Retrieved May 12, 2011, http://www.gcna.info/

Curran, M.A. (1996). *Environmental Life Cycle Assessment*. McGraw-Hill, New York.

Williams, E., C. Weber and T. Hawkins, (2009) Hybrid Approach to Managing Uncertainty in Life Cycle Inventories, *Journal of Industrial Ecology* 15(6), 928-944.

Debnath, A., S. V. Singh, and Y. P. Singh. (1995). Comparative assessment of energy requirements for different types of residential buildings in India. *Journal of Energy & Buildings* 23 141–146.

Energy Information Administration (2002). *Table A6: Approximate Heat Rates For Electricity*. Monthly energy review, DOE/EIA-0035(2002/09), Office of Energy Markets and End Use: Washington, D.C.

Energy Information Administration (2005). *Annual Energy Review 2004*. DOE/EIA-0384(2004), Office of Energy Markets and End Use, Washington, D.C.

Energy Information Administration (2008). *Emissions of Greenhouse Gases in the United States 2007*. DOE/EIA-0573(2008), Office of Energy Markets and End Use, Washington, D.C.

Energy Information Administration (2011). *Annual Energy Review 2011*. DOE/EIA-0383(2011), Office of Energy Markets and End Use, Washington, D.C.

Engelenburg, W., Van Rossum, M., Blok, K., Vringer, K., (1994) Calculating the energy requirements of household purchases: a practical step by step method. *Journal of Energy Policy* 21(8), 648–656.

Environmental Protection Agency (2006). *Life-Cycle Assessment: Principles and Practice* (EPA/600/R-06/060), prepared by Mary Ann Curran, Systems Analysis Branch National Risk Management Research Laboratory Cincinnati, Ohio 45268, May 2006.

Ewing, R., & Rong, F. (2008). The Impact of Urban Form on U.S. Residential Energy Use. *Journal of Housing Policy Debate* , 19 (1), 1-30.

Fay,. R., Treolar, G., and Iyer-Raniga, u. (2000). Life-Cycle Energy Analysis of Buildings: A Case Study. *Journal of Building Research and Information,* 25(1),31-41.

Frijia S., Guhathakurta S., and Williams (2011) E. Re-examining the life cycle energy of residences; functional unit, technological dynamics and scaling. *Journal of Environmental Science and Technology* (in progress for submission)

Gurin, D. (2003). *Understanding Sprawl*: A Citizen's Guide, David Suzuzi Foundation, Vancouver Canada.

Guggemos A., Horvath A. (2005). Comparison of environmental effects of steel- and concrete-framed buildings. *Journal of Infrastructure Systems,* 11(2), 93-101.

Hankey, S., Marshall, D., (2009). Impacts of Urban Form on Future U.S. Passenger-Vehicle Greenhouse Gas Emissions. *Journal of Energy Policy*, doi: 10.1016/j.enpol.2009.07.005.

Hendrickson, C, Lave, L, and Matthews, HS. (2006). *Environmental Life Cycle Assessment of Goods and Services: An Input-Output Approach. Resources for the Future.* Washington DC.

Horvath, A. (2004). *A life-cycle analysis model and decision-support tool for selecting recycled versus virgin materials for highway*

applications. University of California at Berkeley: Final Report for RMRC Research Project No. 23.

Kahhat R., Crittenden J., Sharif F., Fonseca, E., li, K., Sawhney, A. and Zhang P.,(2009). Environmental Impacts over the Life-cycle of Residential Buildings Using Different Exterior Wall Systems. *Journal of Infrastructure Systems* 15(3), 212-221.

Keolian, G., Blanchard, P. Reppe,(2001) Life cycle energy, costs and strategies for improving a single family house. *Journal of Industrial Ecology* 4 (2) 135–157.

Kitou, E. and Horvath, A. (2003). Energy-related Emissions from Telework, *Journal of Environmental Science & Technology* 37(16), 3467-3475.

Konig, M., (1982). *Phoenix in the 1950s, Urban Growth in the "Sunbelt."* Arizona and the West, 19-38.

Matthews S., and Williams, E.,(2005).Telework adoption and energy use in building and transport sectors in the US and Japan. *Journal of Infrastructure Systems*, 11(1), 21-30.

Nathman, R., (2008). Palate User Guide, Example Exercise, And Contextual Discussion. Master Thesis University of Delaware.

National Research Council (2009). *Driving and the Built Environment: The Effects of Compact Development on Motorized Travel, Energy Use, and CO2 Emissions,* Special Report 298. Committee for the Study on the Relationships among Development Patterns, Vehicle Miles Traveled, and Energy Consumption.

Newman, P. and Kenworthy, J. (1989). Gasoline Consumption and Cities: A Comparison of U.S. Cities with a Global Survey. *Journal of American Planning Association*, 55(1), 24-37

Norman, J., MacLean L., and Kennedy, C., (2006) Comparing High and Low Residential Density: Life-Cycle Analysis of Energy Use and Greenhouse Gas Emissions. *Journal of Urban Planning and Development,* 132(1), 10-21

Ochoa, R. Ries, H.S. Matthews, C. Hendrickson, (2002). Economic Input-output Life-Cycle Assessment of U.S. Residential Buildings. *Journal of Infrastructure Systems* 8(4) 132-138

RSMeans Company, Inc.,(2010) *RSMeans Building Construction Cost Data 2010*. Kingston, MA.,

Suh, S., Lenzen, M., Treloar, G., Hondo, H., Arpad Horvath, et al.,(2004). System Boundary Selection in Life-Cycle Inventories Using Hybrid Approaches. *Journal of Environmental Science Technology*, 38 (3), pp 657–664.

Thormark, C. (2002).A Low energy Building in a Life-Cycle – Its Embodied Energy Need for Operation and Recycling Potential. *Journal of Building & Environment*, 37, 429-435

U.S. Bureau of Economic Analysis (2011). *Gross Domestic Product by Industry Data*. Retrieved June 18, 2011, http://www.bea.gov/industry/gdpbyind_data.htm/

U.S. Census Bureau. (2010a). *2010 Population Census. U.S.* Department of Commerce, Washington D.C.

U.S. Census Bureau. (2010b). *Housing Units Authorized By Building Permits*, U.S. Department of Commerce, Washington D.C. Retrieved June 2, 2011, http://www.census.gov/const/www/C40/table3.html#annual,

U.S. Department of Commerce (2005). *2002 Economic Census, Industry Summary: Construction.* Subject Series ECO02-23SG-1. Economics and Statistics Administration: Washington, DC.

U.S. Department of Energy (2006). *Guidelines for Voluntary Greenhouse Gas Reporting* (10 CFR Part 300 -RIN 1901-AB11) Retrieved March 4, 2011, http://www.eia.gov/oiaf/1605/FinalGenGuidelines041306.pdf/

U.S. Department of Energy (2009) *Buildings Energy Data Book*, Residential Sector Energy Consumption Table 2.1.5., Washington D.C. Retrieved January 16, 2011 http://buildingsdatabook.eren.doe.gov/ChapterView.aspx?chap=2

U.S. Department of Housing and Urban Development. (2011). *SOCDS Building Permits Database.* Retrieved June 18, 2011, http://socds.huduser.org/permits/output_annual.odb/

Williams, E. (2004). Energy Intensity of Computer Manufacturing: Hybrid Assessment Combining Process and Economic Input-

Output Methods. *Journal of Environmental Science & Technology* 38(22): 6166-6174.

Zhai, P. and Williams, E., (2010). Dynamic hybrid life cycle assessment of energy and carbon of multi-crystalline silicon photovoltaic (PV) systems. *Journal of Environmental Science & Technology* 44 (20): 7950-7955.

APPENDIX A

MARICOPA COUNTY PROPERETY USE CODE

Property Use Code	Description
01	SINGLE FAMILY RESIDENTIAL
0131	SFR GRADE 010-3 URBAN SUBDIVIDED
0132	SFR GRADE 010-3 URBAN NON-SUBDIVIDED
0133	SFR GRADE 010-3 RURAL SUBDIVIDED
0134	SFR GRADE 010-3 RURAL NON-SUBDIVIDED
0141	SFR GRADE 010-4 URBAN SUBDIVIDED
0142	SFR GRADE 010-4 URBAN NON-SUBDIVIDED
0143	SFR GRADE 010-4 RURAL SUBDIVIDED
0144	SFR GRADE 010-4 RURAL NON-SUBDIVIDED
0181	SFR DOMINANT + ADDITIONAL URBAN SUBDI
0182	SFR DOMINANT + ADDITIONAL URBAN NON-S
0183	SFR DOMINANT + ADDITIONAL RURAL SUBDI
0184	SFR DOMINANT + ADDITIONAL RURAL NON-S

Source: Maricopa County Assessor.

APPENDIX B

RSMEANS MATERIAL AND UNIT COST LIST SAMPLE OUTPUT

Description	Q.ty	Unit	Unit Mat.	Unit Labor	Unit Equip
One-Story – 1500 Sq.Ft Unit					
Footing excavation, building, 26' x 46', 4' deep	1.00	Ea.		211.09	616.42
Footing systems, 8" thick by 18" wide footing	161.29	L.F.	5.36	2.90	0.02
Block wall systems, 8" wall, grouted, full height	645.16	S.F.	5.19	3.77	0.27
Floor slab systems, 4" thick slab	1,500.00	S.F.	1.73	0.61	0.07
Floor Framing Systems, 2" X 10", 16" OC	1,500.00	S.F.	3.45	1.72	0.17
Exterior wall framing systems, 2" x 4", 16" OC	1,135.48	S.F.	0.79	0.75	
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	1,500.00	S.F.	2.01	1.79	
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	1,500.00	L.F.	0.55	0.31	
Furring, 1" x 3", 16" OC	1,500.00	L.F.	0.35	0.49	
Partition framing systems, 2" x 4", 16" OC	1,500.00	S.F.	0.39	0.52	
Furring, wood, on walls, on masonry, 1" x 3"	1,135.48	L.F.	0.44	0.43	
Stucco, 3 coats, on masonry construction, incl. lath	965.16	S.F.	0.19	1.18	0.26
Paints & Coatings, exterior, brick or concrete, primer + 2 coats, brushwork	1,135.48	S.F.	0.19	0.24	
Perlite insulation, R2.7 per inch, poured in	499.61	S.F.	0.45	0.19	
Masonry reinforcing bars, truss type steel joint reinforcing, mill standard galvanized, 8" wide, 9 ga. sides, 9 ga. ties	709.37	S.F.	0.15	0.06	
Concrete block partitions, normal weight blocks, 2000 psi, 8" x 8" x 16", tooled joints both sides, includes mortar, excludes scaffolding, horizontal reinforcing, vertical reinforcing and grout	1,135.48	S.F.	2.22	1.91	
Non-rigid insul, batts, fbgls, kraft faced, 6" thick, R19, 15" wide	1,500.00	S.F.	0.43	0.13	
Non-rigid insulation batts, mineral fiber batts, 3-1/2" thick, R13	1,135.48	S.F.	0.38	0.11	

Description	Q.ty	Unit	Unit Mat.	Unit Labor	Unit Equip
Double hung window systems, builder's quality wood window 2' x 3'	12.90	Ea.	274.94	71.79	
Door systems, solid core birch, flush, 3' x 6'-8"	3.00	Ea.	477.10	129.42	
Storm door, al, combination, storm & screen, anodized, 2'-8" x 6'-8"	3.00	Ea.	155.30	24.57	
Moldings, exterior, verge board, sterling pine, 1" x 6"	60.00	L.F.	1.02	0.87	52.00
Asphalt Shingles, standard strip shingles, inorganic, class A, 210-235 lb/sq	18.00	Sq.	73.04	24.78	446.00
Asphalt Shingles, ridge shingles	63.00	L.F.	1.88	0.41	26.00
Aluminum siding, soffit & fascia, vented, 1' overhang	124.50	L.F.	3.99	3.42	426.00
Felt, asphalt, #15, 4 square per roll, no mopping	19.50	Sq.	5.49	2.71	53.00
Aluminum downspouts, enameled, 2" x 3", .024" thick	52.50	L.F.	1.87	1.03	54.00
Aluminum gutters, stock units, enameled, 5" box, .027" thick	124.50	L.F.	2.48	1.54	192.00
Drip edge, galvanized, 5" wide	225.00	L.F.	0.36	0.41	92.00
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	120.00	S.F.	0.11	0.35	42.00
Windows, aluminum, double hung, anodized, basement, 2'-0" x 3'-5"	12.90	Ea.	89.91	11.41	
Wall system, 1/2" sheetrock, taped & finished	3,000.00	S.F.	0.76	0.70	
Wall system, 1/2" sheetrock, taped & finished	1,135.48	S.F.	0.76	0.70	
Water-resistant sheetrock, 1/2" thick, taped & finished ceilings	1,500.00	S.F.	0.58	0.65	
Birch, flush door, hollow core, interior	6.92	Ea.	281.65	148.30	
Closet door, bi-fold, pine, louvered, 6'-0" x 6'-8"	4.62	Ea.	470.84	177.24	
Carpet, Olefin, 15 oz	600.00	S.F.	1.00	0.35	
Padding, sponge rubber cushion, minimum	600.00	S.F.	0.45	0.11	
Resilient flooring, vinyl comp tile, 12" x 12", 1/16" thk, plain	225.00	S.F.	2.79	0.31	
Resilient flooring, prefinished, oak, 2-1/2" wide	600.00	S.F.	4.77	1.01	

Description	Q.ty	Unit	Unit Mat.	Unit Labor	Unit Equip
Resilient flooring, sleepers, treated, 16" OC, 1" x 3"	1,500.00	S.F.	0.53	0.17	
Resilient flooring, subfloor, plywood, 1/2" thick	1,275.00	S.F.	0.42	0.23	
Resilient flooring, subfloor, plywood, 1/2" thick	1,500.00	S.F.	0.42	0.23	
Resilient flooring, ceramic tile, color group 2, 1" x 1"	75.00	S.F.	4.72	1.52	
A/C and Heating systems, heat pump	1,500.00	S.F.	3.65	2.43	
Kitchen, average grade	12.00	L.F.	208.11	32.05	
Sinks, stainless steel, single bowl 22" x 25"	1.00	Ea.	890.02	230.38	
Water heater, electric, 40 gallon	1.00	Ea.	613.02	98.74	
Three fixture bathroom installed with vanity	2.00	Ea.	3,990.00	1,710.00	
Furnace, gas heating only, 100 MBH, area to 1200 SF	1.00	Ea.	694.76	105.76	
Intermittent pilot, 100 MBH furnace	1.00	Ea.	149.85		
Supply duct, rectangular, area to 1200 SF, rigid fiberglass	1.25	S.F.	136.23	265.49	
Return duct, sheet metal galvanized, to 1500 SF	1.25	Lb.	74.47	353.25	
Lateral ducts, flexible round 6" insulated, to 1200 SF	1.25	L.F.	340.57	188.69	
Register elbows, to 1500 SF	1.25	Ea.	322.40	67.58	
Floor registers, enameled steel w/damper, to 1500 SF	1.25	Ea.	308.78	70.65	
Return air grille, area to 1500 SF 12" x 12"	1.25	Ea.	47.23	17.11	
Thermostat, manual, 1 set back	1.00	Ea.	43.59	23.48	
Plenum, heating only, 100 MBH	1.00	Ea.	79.92	21.06	21.00
200 amp electric service	1.00	Ea.	799.29	454.03	454.00
Duplex receptacles using non-metallic sheathed cable	45.00	Ea.	19.98	14.48	652.00

Source: RSMeans Inc. CostWorks 2011

Description	Q.ty	Unit	Unit Mat.	Unit Labor	Unit Equip
Two-Stories – 1500 Sq.Ft Unit					
Footing excavation, building, 26' x 46', 4' deep	1.00	Ea.		211.09	616.42
Footing systems, 8" thick by 18" wide footing	161.29	L.F.	5.36	2.90	0.02
Block wall systems, 8" wall, grouted, full height	645.16	S.F.	5.19	3.77	0.27
Floor slab systems, 4" thick slab	1,500.00	S.F.	1.73	0.61	0.07
Floor Framing Systems, 2" X 10", 16" OC	1,500.00	S.F.	3.45	1.72	0.17
Exterior wall framing systems, 2" x 4", 16" OC	1,135.48	S.F.	0.79	0.75	
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	1,500.00	S.F.	2.01	1.79	
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	1,500.00	L.F.	0.55	0.31	
Furring, 1" x 3", 16" OC	1,500.00	L.F.	0.35	0.49	
Partition framing systems, 2" x 4", 16" OC	1,500.00	S.F.	0.39	0.52	

Description	Q.ty	Unit	Unit Mat.	Unit Labor	Unit Equip
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	1,249.00	S.F.	0.15	0.11	
1" x 4" pine, exterior trim, cornice board	141.93	S.F.	0.07	0.20	
Masonry anchors, veneer wall ties, corrugated, galvanized, 22 ga., 7/8" x 7"	11.35	S.F.	0.10	0.38	
Brink veener masonry, red brick	1,135.48	S.F.	4.60	8.30	
Non-rigid insul, batts, fbgls, kraft faced, 6" thick, R19, 15" wide	1,500.00	S.F.	0.43	0.13	
Non-rigid insulation batts, mineral fiber batts, 3-1/2" thick, R13	1,135.48	S.F.	0.38	0.11	
Double hung window systems, builder's quality wood window 2' x 3'	12.90	Ea.	274.94	71.79	
Door systems, solid core birch, flush, 3' x 6'-8"	3.00	Ea.	477.10	129.42	
Storm door, al, combination, storm & screen, anodized, 2'-8" x 6'-8"	3.00	Ea.	155.30	24.57	
Windows, aluminum, double hung, anodized, basement, 2'-0" x 3'-5"	12.90	Ea.	89.91	11.41	
Moldings, exterior, verge board, sterling pine, 1" x 6"	60.00	L.F.	1.02	0.87	
Asphalt Shingles, standard strip shingles, inorganic, class A, 210-235 lb/sq	18.00	Sq.	73.04	24.78	
Asphalt Shingles, ridge shingles	63.00	L.F.	1.88	0.41	
Aluminum siding, soffit & fascia, vented, 1' overhang	124.50	L.F.	3.99	3.42	
Felt, asphalt, #15, 4 square per roll, no mopping	19.50	Sq.	5.49	2.71	
Aluminum downspouts, enameled, 2" x 3", .024" thick	52.50	L.F.	1.87	1.03	
Aluminum gutters, stock units, enameled, 5" box, .027" thick	124.50	L.F.	2.48	1.54	
Drip edge, galvanized, 5" wide	225.00	L.F.	0.36	0.41	
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	120.00	S.F.	0.11	0.35	
Wall system, 1/2" sheetrock, taped & finished	3,000.00	S.F.	0.76	0.70	
Wall system, 1/2" sheetrock, taped & finished	1,135.48	S.F.	0.76	0.70	

Description	Q.ty	Unit	Unit Mat.	Unit Labor	Unit Equip
Water-resistant sheetrock, 1/2" thick, taped & finished ceilings	1,500.00	S.F.	0.58	0.65	
Birch, flush door, hollow core, interior	6.92	Ea.	281.65	148.30	
Closet door, bi-fold, pine, louvered, 6'-0" x 6'-8"	4.62	Ea.	470.84	177.24	
Carpet, Olefin, 15 oz	600.00	S.F.	1.00	0.35	
Padding, sponge rubber cushion, minimum	600.00	S.F.	0.45	0.11	
Resilient flooring, vinyl comp tile, 12" x 12", 1/16" thk, plain	225.00	S.F.	2.79	0.31	
Resilient flooring, prefinished, oak, 2-1/2" wide	600.00	S.F.	4.77	1.01	
Resilient flooring, sleepers, treated, 16" OC, 1" x 3"	1,500.00	S.F.	0.53	0.17	
Resilient flooring, subfloor, plywood, 1/2" thick	1,275.00	S.F.	0.42	0.23	
Resilient flooring, subfloor, plywood, 1/2" thick	1,500.00	S.F.	0.42	0.23	
Resilient flooring, ceramic tile, color group 2, 1" x 1"	75.00	S.F.	4.72	1.52	
A/C and Heating systems, heat pump	1,500.00	S.F.	3.65	2.43	
Kitchen, average grade	12.00	L.F.	208.11	32.05	
Sinks, stainless steel, single bowl 22" x 25"	1.00	Ea.	890.02	230.38	
Water heater, electric, 40 gallon	1.00	Ea.	613.02	98.74	
Three fixture bathroom installed with vanity	2.00	Ea.	3990.00	1710.00	
Furnace, gas heating only, 100 MBH, area to 1200 SF	1.00	Ea.	694.76	105.76	
Intermittent pilot, 100 MBH furnace	1.00	Ea.	149.85		
Supply duct, rectangular, area to 1200 SF, rigid fiberglass	1.25	S.F.	136.23	265.49	
Return duct, sheet metal galvanized, to 1500 SF	1.25	Lb.	74.47	353.25	
Lateral ducts, flexible round 6" insulated, to 1200 SF	1.25	L.F.	340.57	188.69	
Register elbows, to 1500 SF	1.25	Ea.	322.40	67.58	
Floor registers, enameled steel w/damper, to 1500 SF	1.25	Ea.	308.78	70.65	

Description	Q.ty	Unit	Unit Mat.	Unit Labor	Unit Equip
Return air grille, area to 1500 SF 12" x 12"	1.25	Ea.	47.23	17.11	
Thermostat, manual, 1 set back	1.00	Ea.	43.59	23.48	
Plenum, heating only, 100 MBH	1.00	Ea.	79.92	21.06	
200 amp electric service	1.00	Ea.	799.29	454.03	
Duplex receptacles using non-metallic sheathed cable	45.00	Ea.	19.98	14.48	

Source: RSMeans Inc. CostWorks 2011

APPENDIX C

PRODUCER PURCHASER INDEX RATIO

Producer NAICS Code	Purchaser NAICS Code	Producer	Rail	Truck	Water	Air	Wholesale	Retail	Purchaser	Ratio
333415	230201	2502.7	1	50.7	0	5	559.9	1338.7	4458	0.561395245
32712A	230201	1032.9	12.2	69.5	0.7	1.6	351.9	817.5	2286.3	0.451777982
327310	230201	702.6	26.8	59.6	0.5	1.1	106.1	0	896.7	0.783539645
327330	230201	1464.9	3.3	112.6	1.1	2.5	152.6	841.5	2578.5	0.568121001
32121B	230201	2283.3	15.9	85.4	0.4	1.4	23.9	1111.6	3521.9	0.64831483
313100	314110	2242.7	0.3	186	0	4.6	284.6	0	2718.2	0.82506806
3274A0	230201	970.2	29.7	72.9	1.5	0	166.7	42.4	1283.4	0.755960729
333920	230201	86.7	0	2.2	0	0.2	3.3	0	92.4	0.938311688
327993	230201	1836.4	1.1	16.6	0	3.5	65.8	0	1923.4	0.954767599
313230	230201	56	0	2.3	0	0.1	5.4	5.6	69.4	0.806916427
332320	230201	5321.7	4.1	38.4	0.3	7.7	468.9	2756.6	8597.7	0.618967863
33299C	230201	493.8	0.4	13.4	0	0.7	167.4	137.8	813.5	0.607006761
335228	230201	600	2.4	86.8	0	1.3	154.3	0	844.8	0.710227273
32619A	230201	5717	4.6	101.9	0	6.7	1026.3	3006.9	9863.4	0.579617576
325510	230201	2178.9	16	41.6	0.4	32.3	242	344.7	2855.9	0.762946882
321100	230201	4643.1	117.2	268.9	1.2	3	711.3	596	6340.7	0.732269308
32121A	230201	1854.3	36.3	70.6	0.6	1.7	273.5	0	2237	0.828922664
335930	230201	1819.5	1.8	20.3	0	5.8	506.2	1332.4	3686	0.493624525
337110	230201	4157.3	4.9	417.9	0	2.4	212	2510	7304.5	0.56914231
321910	230201	4511.1	10.8	206	0.9	2.8	400.4	2062.2	7194.2	0.627046788
33221B	230201	530.7	0.6	13	0	0.9	133.3	184.5	863	0.614947856
331110	230201	382	8.2	14.7	1.5	1.3	62.2	0	469.9	0.812938923
33131B	230201	16.4	0	0.5	0	0	1.6	0	18.5	0.886486486
324122	230201	406.6	2.3	44.6	2.9	0	50.8	0	507.2	0.801656151

APPENDIX D

GHG EMISSIONS PER MILLION DOLLAR OF ECONOMIC ACTIVITY

Producer	Total CO_2 [ton]	CO_2 [ton]	CO_2 pr.ss [ton]	CH_4 [ton]	N_2O [ton]	HFC/PFC [ton]
Air conditioning, refrigeration, and warm air heating equip. mfg.	581.00	413.00	114.00	34.00	5.01	14.10
Cement mfg.	11,600.00	5,340.00	6,060.00	131.00	8.47	12.60
Concrete pipe, brick, and block mfg.	1,920.00	1,090.00	767.00	50.10	5.20	741.00
Engineered wood member and truss mfg.	522.00	413.00	25.90	38.70	40.40	4.31
Lime and gypsum product mfg.	5,320.00	2,510.00	2,630.00	144.00	24.20	11.40
Material handling equip. mfg.	747.00	496.00	185.00	42.70	5.16	18.00
Mineral wool mfg.	1,380.00	1,200.00	65.90	90.10	12.10	15.10
Nonwoven fabric mills	1,210.00	981.00	39.70	102.00	73.10	15.90
Ornamental and architectural metal products mfg.	873.00	565.00	227.00	48.80	6.02	27.10
Other fabricated metal mfg.	839.00	601.00	155.00	49.20	6.28	27.30
Other major household appliance mfg.	655.00	480.00	113.00	41.10	7.61	14.00
Other plastics product mfg.	904.00	749.00	50.30	68.60	20.50	15.20
Paint and coating mfg.	1,070.00	831.00	79.20	99.50	38.00	26.00
Sawmills and wood preservation	735.00	532.00	29.10	58.50	111.00	3.99
Veneer and plywood mfg.	777.00	592.00	40.90	56.00	84.80	4.03
Wiring device mfg.	683.00	498.00	113.00	40.20	7.48	23.90
Wood kitchen cabinet and countertop mfg.	520.00	414.00	25.60	53.80	20.70	5.81
Wood windows and doors and millwork	595.00	478.00	27.60	43.80	40.30	5.56
Fiber, yarn, and thread mills	1,670.00	1,200.00	45.10	108.00	306.00	14.50
Handtool mfg.	782.00	526.00	189.00	43.80	5.52	18.30

On-Site Energy Use (Residential permanent site single- and multi-family structures)	659.00	510.00	90.20	37.90	16.20	4.54
Concrete Block and Brick Mfg.	3,660.00	1,800.00	1,630.00	175.00	7.04	39.20
Other Structural Clay Product Mfg.	2,010.00	1,860.00	30.20	108.00	9.89	8.74
Asphalt shingle and coating materials mfg.	1,160.00	862.00	111.00	170.00	5.92	8.60
Aluminum product mfg. from purchased aluminum	1,560.00	1,080.00	195.00	69.70	7.04	206.00
Iron and Steel Mill	3,660.00	1,800.00	1,630.00	175.00	7.04	39.20
Other Concrete mfg.	1,250.00	756.00	434.00	43.80	5.33	7.57

Source: Green Development Initiative EIO-LCA

APPENDIX E

TOTAL ENERGY AND GHG EMISSIONS

Size - 1 Story		1500	2000	2450	3000	3500
Baseline (only) [MJ]		763,483.59	948,708.24	1,058,192.26	1,250,741.52	1,407,345.73
Material Combinations			Energy Results (baseline values included) [MJ]			
Stucco	Asphalt Shingle	847,799.59	1,093,011.28	1,225,595.29	1,444,970.95	1,660,518.20
Stucco	Wood	922,322.37	1,139,737.24	1,282,834.59	1,515,059.89	1,742,288.64
Stucco	Build Up	925,622.54	1,144,137.46	1,288,224.86	1,521,660.22	1,749,989.02
Stucco	Concrete Tile	912,160.63	1,125,421.35	1,265,297.62	1,366,014.32	1,717,235.83
Stucco	Clay Tile	998,432.53	1,240,450.56	1,406,208.40	1,366,014.32	1,918,536.94
8" Painted Block	Asphalt Shingle	891,505.85	1,119,404.59	1,267,295.29	1,506,786.04	1,706,084.35
8" Painted Block	Wood	926,550.33	1,166,190.55	1,324,534.60	1,576,874.99	1,787,834.78
8" Painted Block	Build Up	929,850.49	1,170,590.77	1,329,924.86	1,583,475.31	1,795,535.16
8" Painted Block	Concrete Tile	916,388.58	1,151,814.66	1,306,997.63	1,427,829.41	1,762,781.97
8" Painted Block	Clay Tile	1,002,660.49	1,266,843.87	1,447,908.41	1,427,829.41	1,964,083.09
Brick	Asphalt Shingle	959,203.08	1,209,667.56	1,377,867.43	1,642,180.49	1,884,024.54
Brick	Wood	994,247.55	1,256,393.52	1,435,106.73	1,712,269.44	1,945,794.97
Brick	Build Up	997,547.71	1,260,793.74	1,440,497.00	1,718,869.76	1,953,495.36
Brick	Concrete Tile	984,085.81	1,242,077.63	1,417,569.77	1,583,223.86	1,920,742.17
Brick	Clay Tile	1,070,357.71	1,357,106.84	1,558,480.54	1,583,223.86	2,122,043.23
Wood Shingles	Asphalt Shingle	964,480.83	1,209,874.48	1,373,510.61	1,652,245.77	1,849,018.99
Wood Shingles	Wood	999,525.30	1,256,600.44	1,430,749.91	1,702,334.71	1,930,789.42
Wood Shingles	Build Up	1,002,825.46	1,261,000.66	1,436,140.18	1,708,935.04	1,938,489.80
Wood Shingles	Concrete Tile	989,363.55	1,242,284.55	1,413,212.95	1,553,289.13	1,905,736.61
Wood Shingles	Clay Tile	1,075,635.46	1,357,313.76	1,554,123.72	1,553,289.13	2,107,037.72

Size - 2 Story [Sq.Ft]		1500	2000	2450	3000	3500
Baseline (only) [MJ]		664169.97	778331.16	931436.20	2242775.37	1234250.00
Material Combinations			**Energy Results (baseline values included) [MJ]**			
Stucco	Asphalt Shingle	760472.51	897283.26	1070196.56	2402667.20	1416493.21
Stucco	Wood	777994.74	920646.25	1098816.21	2437711.68	1457378.42
Stucco	Build Up	779644.82	922846.35	1101511.35	2441011.84	1461228.62
Stucco	Concrete Tile	772913.87	913488.30	1090047.73	2363188.89	1444852.02
Stucco	Clay Tile	816049.82	971002.90	1160503.12	2363188.89	1545502.58
8" Painted Block	Asphalt Shingle	781307.47	916965.08	1088346.70	2416307.45	1428724.81
8" Painted Block	Wood	798829.70	940328.06	1116966.36	2451351.92	1469610.02
8" Painted Block	Build Up	800479.79	942528.17	1119661.49	2454652.09	1473460.22
8" Painted Block	Concrete Tile	793748.83	933170.12	1108197.87	2376829.14	1457083.62
8" Painted Block	Clay Tile	836884.78	990684.72	1178653.26	2376829.14	1557734.18
Brick	Asphalt Shingle	829254.22	972254.95	1149718.54	2482298.74	1501786.64
Brick	Wood	846776.45	995617.93	1178338.19	2517343.21	1542671.86
Brick	Build Up	848426.53	997818.04	1181033.33	2520643.38	1546522.05
Brick	Concrete Tile	841695.58	988459.98	1169569.71	2442820.43	1530145.46
Brick	Clay Tile	884831.53	1045974.59	1240025.10	2442820.43	1630796.01
Wood Shigles	Asphalt Shingle	826320.03	968871.39	1145962.79	2478260.29	1497315.50
Wood Shigles	Wood	843842.27	992234.37	1174582.44	2513304.76	1538200.71
Wood Shigles	Build Up	845492.35	994434.48	1177277.57	2516604.92	1542050.91
Wood Shigles	Concrete Tile	838761.40	985076.42	1165813.95	2438781.97	1525674.31
Wood Shigles	Clay Tile	881897.35	1042591.03	1236269.34	2438781.97	1626324.87

APPENDIX F

ENERGY RESULTS FOR WALL AND ROOF SUB-SYSTEMS

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
One-Story Unit				
Wall Structure				
Stucco on Framewood [1500]				56,914.59
Exterior wall framing systems, 2" x 4", 16" OC	934.31	605.73	13.60	8,237.88
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	2,959.90	1,918.95	13.60	26,097.68
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	834.26	540.86	13.60	7,355.72
Furring, wood, 1" x 3", 12" OC	380.64	278.73	13.20	3,679.29
Stucco, 2 coats	164.37	124.26	44.70	5,554.27
Painting, primer & 1 coat	164.37	125.41	16.50	2,069.18
Painting, lath, metal lath expanded 2.5 lb/SY, painted	311.44	237.61	16.50	3,920.56
Stucco on Framewood [2000]				61,881.59
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	2,240.61	1,452.62	13.60	19,755.66
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	1,112.34	721.15	13.60	9,807.62
Exterior wall framing systems, 2" x 4", 16" OC	1,645.66	1,066.90	13.60	14,509.91
Furring, wood, 1" x 3", 12" OC	445.28	326.07	13.20	4,304.08
Stucco, 2 coats	192.28	145.36	44.70	6,497.45
Painting, primer & 1 coat	192.28	146.70	16.50	2,420.55
Painting, lath, metal lath expanded 2.5 lb/SY, painted	364.32	277.96	16.50	4,586.31
Stucco on Framewood [2450]				69,541.36
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	2,240.61	1,452.62	13.60	19,755.66
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	1,362.62	883.41	13.60	12,014.34

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Exterior wall framing systems, 2" x 4", 16" OC	2,015.93	1,306.96	13.60	17,774.64
Furring, wood, 1" x 3", 12" OC	500.00	366.13	13.20	4,832.97
Stucco, 2 coats	215.91	163.22	44.70	7,295.87
Painting, primer & 1 coat	215.91	164.73	16.50	2,717.99
Painting, lath, metal lath expanded 2.5 lb/SY, painted	409.09	312.11	16.50	5,149.88
Stucco on Framewood [3000]				78,013.00
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	2,240.61	1,452.62	13.60	19,755.66
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	1,668.52	1,081.72	13.60	14,711.43
Exterior wall framing systems, 2" x 4", 16" OC	2,468.49	1,600.36	13.60	21,764.86
Furring, wood, 1" x 3", 12" OC	544.61	398.80	13.20	5,264.22
Stucco, 2 coats	235.17	177.78	44.70	7,946.89
Painting, primer & 1 coat	235.17	179.43	16.50	2,960.52
Painting, lath, metal lath expanded 2.5 lb/SY, painted	445.59	339.96	16.50	5,609.41
Stucco on Framewood [3500]				109,396.92
Exterior wall framing systems, 2" x 4", 16" OC	934.31	605.73	13.60	8,237.88
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	6,906.43	4,477.54	13.60	60,894.59
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	1,946.60	1,262.01	13.60	17,163.34
Furring, wood, 1" x 3", 12" OC	577.62	422.97	13.20	5,583.26
Stucco, 2 coats	249.43	188.56	44.70	8,428.51
Painting, primer & 1 coat	249.43	190.30	16.50	3,139.95
Painting, lath, metal lath expanded 2.5 lb/SY, painted	472.60	360.57	16.50	5,949.38
Block masonry systems, 8" thick concrete block wall [1500]				63,463.79

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Masonry reinforcing bars, truss type steel joint reinforcing, mill standard galvanized, 8" wide, 9 ga. sides, 9 ga. ties	107.14	87.10	43.30	3,771.33
Concrete block partitions, normal weight blocks, 2000 psi, 8" x 8" x 16", tooled joints both sides, includes mortar, excludes scaffolding, horizontal reinforcing, vertical reinforcing and grout	2,537.06	1,441.36	17.10	24,647.18
Furring, wood, on walls, on masonry, 1" x 3"	365.70	267.79	13.20	3,534.86
Perlite insulation, R2.7 per inch, poured in	975.51	931.39	23.10	21,515.00
Stucco, 3 coats, on masonry construction, incl. lath	223.42	168.90	44.70	7,549.72
Paints & Coatings, exterior, brick or concrete, primer + 2 coats, brushwork	194.28	148.22	16.50	2,445.71
Block masonry systems, 8" thick concrete block wall [2000]				84,618.39
Masonry reinforcing bars, truss type steel joint reinforcing, mill standard galvanized, 8" wide, 9 ga. sides, 9 ga. ties	142.85	116.13	43.30	5,028.44
Concrete block partitions, normal weight blocks, 2000 psi, 8" x 8" x 16", tooled joints both sides, includes mortar, excludes scaffolding, horizontal reinforcing, vertical reinforcing and grout	3,382.74	1,921.81	17.10	32,862.91
Furring, wood, on walls, on masonry, 1" x 3"	487.60	357.06	13.20	4,713.14
Perlite insulation, R2.7 per inch, poured in	1,300.68	1,241.85	23.10	28,686.67
Stucco, 3 coats, on masonry construction, incl. lath	297.89	225.20	44.70	10,066.29
Paints & Coatings, exterior, brick or concrete, primer + 2 coats, brushwork	259.04	197.63	16.50	3,260.94
Block masonry systems, 8" thick concrete block wall [2450]				103,657.53
Masonry reinforcing bars, truss type steel joint reinforcing, mill standard galvanized, 8" wide, 9 ga. sides, 9 ga. ties	174.99	142.26	43.30	6,159.84

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Concrete block partitions, normal weight blocks, 2000 psi, 8" x 8" x 16", tooled joints both sides, includes mortar, excludes scaffolding, horizontal reinforcing, vertical reinforcing and grout	4,143.86	2,354.21	17.10	40,257.06
Furring, wood, on walls, on masonry, 1" x 3"	597.31	437.39	13.20	5,773.60
Perlite insulation, R2.7 per inch, poured in	1,593.33	1,521.26	23.10	35,141.17
Stucco, 3 coats, on masonry construction, incl. lath	364.92	275.87	44.70	12,331.21
Paints & Coatings, exterior, brick or concrete, primer + 2 coats, brushwork	317.32	242.10	16.50	3,994.66
Block masonry systems, 8" thick concrete block wall [3000]				126,927.59
Masonry reinforcing bars, truss type steel joint reinforcing, mill standard galvanized, 8" wide, 9 ga. sides, 9 ga. ties	214.28	174.20	43.30	7,542.66
Concrete block partitions, normal weight blocks, 2000 psi, 8" x 8" x 16", tooled joints both sides, includes mortar, excludes scaffolding, horizontal reinforcing, vertical reinforcing and grout	5,074.11	2,882.71	17.10	49,294.36
Furring, wood, on walls, on masonry, 1" x 3"	731.40	535.58	13.20	7,069.72
Perlite insulation, R2.7 per inch, poured in	1,951.02	1,862.77	23.10	43,030.00
Stucco, 3 coats, on masonry construction, incl. lath	446.84	337.80	44.70	15,099.44
Paints & Coatings, exterior, brick or concrete, primer + 2 coats, brushwork	388.56	296.45	16.50	4,891.41
Block masonry systems, 8" thick concrete block wall [3500]				148,082.18
Masonry reinforcing bars, truss type steel joint reinforcing, mill standard galvanized, 8" wide, 9 ga. sides, 9 ga. ties	249.99	203.23	43.30	8,799.77
Concrete block partitions, normal weight blocks, 2000 psi, 8" x 8" x 16", tooled joints both sides, includes mortar, excludes scaffolding, horizontal reinforcing, vertical reinforcing and grout	5,919.80	3,363.16	17.10	57,510.08
Furring, wood, on walls, on masonry, 1" x 3"	853.30	624.85	13.20	8,248.00

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Perlite insulation, R2.7 per inch, poured in	2,276.19	2,173.23	23.10	50,201.67
Stucco, 3 coats, on masonry construction, incl. lath	521.32	394.09	44.70	17,616.01
Paints & Coatings, exterior, brick or concrete, primer + 2 coats, brushwork	453.32	345.86	16.50	5,706.65
Brick/stone veneer systems, red faced common brick [1500]				120,478.93
Masonry anchors, veneer wall ties, corrugated, galvanized, 22 ga., 7/8" x 7"	102.74	83.52	43.30	3,616.45
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	2,959.90	1,918.95	13.60	26,097.68
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	834.26	540.86	13.60	7,355.72
Brick veneer masonry, red brick, running bond, T.L. lots, 6.75/S.F., 4" x 2-2/3" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	4,434.14	2,519.13	31.40	79,100.55
1" x 4" pine, exterior trim, cornice board	72.85	53.35	13.20	704.21
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	163.42	156.03	23.10	3,604.32
Brick/stone veneer systems, red faced common brick [2000]				160,638.57
Masonry anchors, veneer wall ties, corrugated, galvanized, 22 ga., 7/8" x 7"	136.99	111.36	43.30	4,821.94
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	3,946.53	2,558.60	13.60	34,796.91
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	1,112.34	721.15	13.60	9,807.62
Brick veneer masonry, red brick, running bond, T.L. lots, 6.75/S.F., 4" x 2-2/3" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	5,912.18	3,358.83	31.40	105,467.40
1" x 4" pine, exterior trim, cornice board	97.14	71.13	13.20	938.95
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	217.90	208.04	23.10	4,805.76
Brick/stone veneer systems, red faced common brick [2450]				196,782.25

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Masonry anchors, veneer wall ties, corrugated, galvanized, 22 ga., 7/8" x 7"	167.81	136.42	43.30	5,906.87
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	4,834.50	3,134.28	13.60	42,626.21
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	1,362.62	883.41	13.60	12,014.34
Brick veneer masonry, red brick, running bond, T.L. lots, 6.75/S.F., 4" x 2-2/3" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	7,242.42	4,114.57	31.40	129,197.57
1" x 4" pine, exterior trim, cornice board	119.00	87.14	13.20	1,150.21
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	266.92	254.85	23.10	5,887.05
Brick/stone veneer systems, red faced common brick [3000]				240,957.86
Masonry anchors, veneer wall ties, corrugated, galvanized, 22 ga., 7/8" x 7"	205.48	167.04	43.30	7,232.91
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	5,919.80	3,837.89	13.60	52,195.36
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	1,668.52	1,081.72	13.60	14,711.43
Brick veneer masonry, red brick, running bond, T.L. lots, 6.75/S.F., 4" x 2-2/3" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	8,868.27	5,038.25	31.40	158,201.10
1" x 4" pine, exterior trim, cornice board	145.71	106.70	13.20	1,408.42
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	326.85	312.06	23.10	7,208.63
Brick/stone veneer systems, red faced common brick [3500]				281,117.50
Masonry anchors, veneer wall ties, corrugated, galvanized, 22 ga., 7/8" x 7"	239.73	194.88	43.30	8,438.39
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	6,906.43	4,477.54	13.60	60,894.59
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	1,946.60	1,262.01	13.60	17,163.34

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Brick veneer masonry, red brick, running bond, T.L. lots, 6.75/S.F., 4" x 2-2/3" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	10,346.32	5,877.96	31.40	184,567.95
1" x 4" pine, exterior trim, cornice board	169.99	124.48	13.20	1,643.16
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	381.32	364.07	23.10	8,410.07
Wood siding systems, 1" x 4" tongue & groove, redwood, vertical grain [1500]				126,206.35
Moldings, exterior, verge board, redwood, 1" x 4"	161.42	133.81	16.60	2,221.20
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	2,959.90	1,918.95	13.60	26,097.68
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	834.26	540.86	13.60	7,355.72
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	163.42	156.03	23.10	3,604.32
Wood Siding, Boards, board & batten, redwood, clear, vertical grain, 1" x 10"	5,197.90	4,308.66	16.60	71,523.77
Exterior wall framing systems, 2" x 4", 16" OC	934.31	605.73	13.60	8,237.88
Furring, wood, 1" x 3", 12" OC	577.62	422.97	13.20	5,583.26
Paints & Coatings, wood siding, primer + 1 coat, incl. puttying	125.71	95.91	16.50	1,582.52
Wood siding systems, 1" x 4" tongue & groove, redwood, vertical grain [2000]				163,668.08
Moldings, exterior, verge board, redwood, 1" x 4"	215.23	178.41	16.60	2,961.60
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	3,946.53	2,558.60	13.60	34,796.91
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	1,112.34	721.15	13.60	9,807.62
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	217.90	208.04	23.10	4,805.76
Wood Siding, Boards, board & batten, redwood, clear, vertical grain, 1" x 10"	6,930.54	5,744.88	16.60	95,365.03
Exterior wall framing systems, 2" x 4", 16" OC	934.31	605.73	13.60	8,237.88

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Furring, wood, 1" x 3", 12" OC	577.62	422.97	13.20	5,583.26
Paints & Coatings, wood siding, primer + 1 coat, incl. puttying	167.61	127.88	16.50	2,110.02
Wood siding systems, 1" x 4" tongue & groove, redwood, vertical grain [2450]				197,383.65
Moldings, exterior, verge board, redwood, 1" x 4"	263.66	218.55	16.60	3,627.96
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	4,834.50	3,134.28	13.60	42,626.21
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	1,362.62	883.41	13.60	12,014.34
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	266.92	254.85	23.10	5,887.05
Wood Siding, Boards, board & batten, redwood, clear, vertical grain, 1" x 10"	8,489.91	7,037.48	16.60	116,822.16
Exterior wall framing systems, 2" x 4", 16" OC	934.31	605.73	13.60	8,237.88
Furring, wood, 1" x 3", 12" OC	577.62	422.97	13.20	5,583.26
Paints & Coatings, wood siding, primer + 1 coat, incl. puttying	205.33	156.65	16.50	2,584.78
Wood siding systems, 1" x 4" tongue & groove, redwood, vertical grain [3000]				238,591.55
Moldings, exterior, verge board, redwood, 1" x 4"	322.85	267.61	16.60	4,442.40
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	5,919.80	3,837.89	13.60	52,195.36
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	1,668.52	1,081.72	13.60	14,711.43
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	326.85	312.06	23.10	7,208.63
Wood Siding, Boards, board & batten, redwood, clear, vertical grain, 1" x 10"	10,395.81	8,617.32	16.60	143,047.54
Exterior wall framing systems, 2" x 4", 16" OC	934.31	605.73	13.60	8,237.88
Furring, wood, 1" x 3", 12" OC	577.62	422.97	13.20	5,583.26
Paints & Coatings, wood siding, primer + 1 coat, incl. puttying	251.42	191.82	16.50	3,165.03

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Wood siding systems, 1" x 4" tongue & groove, redwood, vertical grain [3500]				276,053.29
Moldings, exterior, verge board, redwood, 1" x 4"	376.65	312.22	16.60	5,182.80
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	6,906.43	4,477.54	13.60	60,894.59
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	1,946.60	1,262.01	13.60	17,163.34
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	381.32	364.07	23.10	8,410.07
Wood Siding, Boards, board & batten, redwood, clear, vertical grain, 1" x 10"	12,128.44	10,053.54	16.60	166,888.80
Exterior wall framing systems, 2" x 4", 16" OC	934.31	605.73	13.60	8,237.88
Furring, wood, 1" x 3", 12" OC	577.62	422.97	13.20	5,583.26
Paints & Coatings, wood siding, primer + 1 coat, incl. puttying	293.32	223.79	16.50	3,692.54
Roof Structure				
Gable end roofing, asphalt, roof shingles, class A [1500]				32,541.08
Moldings, exterior, verge board, sterling pine, 1" x 6"	46.63	38.65	16.60	641.59
Asphalt Shingles, standard strip shingles, inorganic, class A, 210-235 lb/sq	1,001.66	802.98	15.70	12,606.86
Asphalt Shingles, ridge shingles	90.24	72.34	15.70	1,135.72
Aluminum siding, soffit & fascia, vented, 1' overhang	378.47	335.51	24.30	8,152.80
Felt, asphalt, #15, 4 square per roll, no mopping	81.56	65.39	15.70	1,026.55
Aluminum downspouts, enameled, 2" x 3", .024" thick	74.80	66.31	24.30	1,611.26
Drip edge, galvanized, 5" wide	61.71	50.17	43.30	2,172.29
Aluminum gutters, stock units, enameled, 5" box, .027" thick	235.24	208.54	24.30	5,067.40
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	10.06	7.67	16.50	126.60

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Gable end roofing, asphalt, roof shingles, class A [2000]				43,388.10
Moldings, exterior, verge board, sterling pine, 1" x 6"	62.17	51.53	16.60	855.46
Asphalt Shingles, standard strip shingles, inorganic, class A, 210-235 lb/sq	1,335.54	1,070.65	15.70	16,809.15
Asphalt Shingles, ridge shingles	120.32	96.45	15.70	1,514.30
Aluminum siding, soffit & fascia, vented, 1' overhang	504.62	447.34	24.30	10,870.40
Felt, asphalt, #15, 4 square per roll, no mopping	108.75	87.18	15.70	1,368.74
Aluminum downspouts, enameled, 2" x 3", .024" thick	99.73	88.41	24.30	2,148.35
Drip edge, galvanized, 5" wide	82.28	66.89	43.30	2,896.38
Aluminum gutters, stock units, enameled, 5" box, .027" thick	313.65	278.05	24.30	6,756.54
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	13.41	10.23	16.50	168.80
Gable end roofing, asphalt, roof shingles, class A [2450]				53,150.43
Moldings, exterior, verge board, sterling pine, 1" x 6"	76.16	63.13	16.60	1,047.94
Asphalt Shingles, standard strip shingles, inorganic, class A, 210-235 lb/sq	1,636.04	1,311.54	15.70	20,591.21
Asphalt Shingles, ridge shingles	147.39	118.15	15.70	1,855.01
Aluminum siding, soffit & fascia, vented, 1' overhang	618.16	547.99	24.30	13,316.24
Felt, asphalt, #15, 4 square per roll, no mopping	133.22	106.80	15.70	1,676.70
Aluminum downspouts, enameled, 2" x 3", .024" thick	122.17	108.30	24.30	2,631.72
Drip edge, galvanized, 5" wide	100.80	81.94	43.30	3,548.07
Aluminum gutters, stock units, enameled, 5" box, .027" thick	384.22	340.61	24.30	8,276.76
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	16.43	12.53	16.50	206.78
Gable end roofing, asphalt, roof shingles, class A [3000]				65,082.16

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Moldings, exterior, verge board, sterling pine, 1" x 6"	93.25	77.30	16.60	1,283.19
Asphalt Shingles, standard strip shingles, inorganic, class A, 210-235 lb/sq	2,003.32	1,605.97	15.70	25,213.73
Asphalt Shingles, ridge shingles	180.47	144.68	15.70	2,271.44
Aluminum siding, soffit & fascia, vented, 1' overhang	756.93	671.01	24.30	16,305.60
Felt, asphalt, #15, 4 square per roll, no mopping	163.13	130.77	15.70	2,053.10
Aluminum downspouts, enameled, 2" x 3", .024" thick	149.59	132.61	24.30	3,222.52
Drip edge, galvanized, 5" wide	123.42	100.34	43.30	4,344.57
Aluminum gutters, stock units, enameled, 5" box, .027" thick	470.48	417.07	24.30	10,134.81
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	20.11	15.35	16.50	253.20
Gable end roofing, asphalt, roof shingles, class A [3500]				75,929.18
Moldings, exterior, verge board, sterling pine, 1" x 6"	108.80	90.18	16.60	1,497.05
Asphalt Shingles, standard strip shingles, inorganic, class A, 210-235 lb/sq	2,337.20	1,873.63	15.70	29,416.02
Asphalt Shingles, ridge shingles	210.55	168.79	15.70	2,650.02
Aluminum siding, soffit & fascia, vented, 1' overhang	883.09	782.85	24.30	19,023.19
Felt, asphalt, #15, 4 square per roll, no mopping	190.31	152.57	15.70	2,395.29
Aluminum downspouts, enameled, 2" x 3", .024" thick	174.53	154.72	24.30	3,759.60
Drip edge, galvanized, 5" wide	144.00	117.06	43.30	5,068.67
Aluminum gutters, stock units, enameled, 5" box, .027" thick	548.89	486.58	24.30	11,823.94
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	23.47	17.90	16.50	295.40
Gable end roofing, wood, cedar shingles no. 1 perfections, 18" long [1500]				62,118.28
Moldings, exterior, verge board, sterling pine, 1" x 6"	46.63	38.65	16.60	641.59

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Wood shingles, no. 1 red cedar perfections, 18" long, 5-1/2" exposure on roof	2,977.82	2,468.38	16.60	40,975.14
Wood shingles, ridge shakes or shingle wood	170.39	141.24	16.60	2,344.64
Aluminum siding, soffit & fascia, vented, 1' overhang	378.47	335.51	24.30	8,152.80
Felt, asphalt, #15, 4 square per roll, no mopping	81.56	65.39	15.70	1,026.55
Aluminum downspouts, enameled, 2" x 3", .024" thick	74.80	66.31	24.30	1,611.26
Drip edge, galvanized, 5" wide	61.71	50.17	43.30	2,172.29
Aluminum gutters, stock units, enameled, 5" box, .027" thick	235.24	208.54	24.30	5,067.40
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	10.06	7.67	16.50	126.60
Gable end roofing, wood, cedar shingles no. 1 perfections, 18" long [2000]				82,824.37
Moldings, exterior, verge board, sterling pine, 1" x 6"	62.17	51.53	16.60	855.46
Wood shingles, no. 1 red cedar perfections, 18" long, 5-1/2" exposure on roof	3,970.43	3,291.18	16.60	54,633.52
Wood shingles, ridge shakes or shingle wood	227.19	188.32	16.60	3,126.19
Aluminum siding, soffit & fascia, vented, 1' overhang	504.62	447.34	24.30	10,870.40
Felt, asphalt, #15, 4 square per roll, no mopping	108.75	87.18	15.70	1,368.74
Aluminum downspouts, enameled, 2" x 3", .024" thick	99.73	88.41	24.30	2,148.35
Drip edge, galvanized, 5" wide	82.28	66.89	43.30	2,896.38
Aluminum gutters, stock units, enameled, 5" box, .027" thick	313.65	278.05	24.30	6,756.54
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	13.41	10.23	16.50	168.80
Gable end roofing, wood, cedar shingles no. 1 perfections, 18" long [2450]				101,459.85
Moldings, exterior, verge board, sterling pine, 1" x 6"	76.16	63.13	16.60	1,047.94
Wood shingles, no. 1 red cedar perfections, 18" long, 5-1/2" exposure on roof	4,863.77	4,031.69	16.60	66,926.07

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Wood shingles, ridge shakes or shingle wood	278.31	230.70	16.60	3,829.59
Aluminum siding, soffit & fascia, vented, 1' overhang	618.16	547.99	24.30	13,316.24
Felt, asphalt, #15, 4 square per roll, no mopping	133.22	106.80	15.70	1,676.70
Aluminum downspouts, enameled, 2" x 3", .024" thick	122.17	108.30	24.30	2,631.72
Drip edge, galvanized, 5" wide	100.80	81.94	43.30	3,548.07
Aluminum gutters, stock units, enameled, 5" box, .027" thick	384.22	340.61	24.30	8,276.76
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	16.43	12.53	16.50	206.78
Gable end roofing, wood, cedar shingles no. 1 perfections, 18" long [3000]				124,236.56
Moldings, exterior, verge board, sterling pine, 1" x 6"	93.25	77.30	16.60	1,283.19
Wood shingles, no. 1 red cedar perfections, 18" long, 5-1/2" exposure on roof	5,955.64	4,936.76	16.60	81,950.28
Wood shingles, ridge shakes or shingle wood	340.79	282.49	16.60	4,689.29
Aluminum siding, soffit & fascia, vented, 1' overhang	756.93	671.01	24.30	16,305.60
Felt, asphalt, #15, 4 square per roll, no mopping	163.13	130.77	15.70	2,053.10
Aluminum downspouts, enameled, 2" x 3", .024" thick	149.59	132.61	24.30	3,222.52
Drip edge, galvanized, 5" wide	123.42	100.34	43.30	4,344.57
Aluminum gutters, stock units, enameled, 5" box, .027" thick	470.48	417.07	24.30	10,134.81
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	20.11	15.35	16.50	253.20
Gable end roofing, wood, cedar shingles no. 1 perfections, 18" long [3500]				144,942.65
Moldings, exterior, verge board, sterling pine, 1" x 6"	108.80	90.18	16.60	1,497.05
Wood shingles, no. 1 red cedar perfections, 18" long, 5-1/2" exposure on roof	6,948.25	5,759.56	16.60	95,608.67
Wood shingles, ridge shakes or shingle wood	397.59	329.57	16.60	5,470.84

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Aluminum siding, soffit & fascia, vented, 1' overhang	883.09	782.85	24.30	19,023.19
Felt, asphalt, #15, 4 square per roll, no mopping	190.31	152.57	15.70	2,395.29
Aluminum downspouts, enameled, 2" x 3", .024" thick	174.53	154.72	24.30	3,759.60
Drip edge, galvanized, 5" wide	144.00	117.06	43.30	5,068.67
Aluminum gutters, stock units, enameled, 5" box, .027" thick	548.89	486.58	24.30	11,823.94
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	23.47	17.90	16.50	295.40
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [1500]				50,108.11
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	2,937.04	1,668.60	12.70	21,191.17
Aluminum siding, soffit & fascia, vented, 1' overhang	1,003.17	889.29	24.30	21,609.83
Felt, asphalt, #15, 4 square per roll, no mopping	94.11	75.44	15.70	1,184.48
Sheet metal flashing, stainless steel, flexible sheets, .018" thick, 26 gauge, including up to 4 bends	83.43	67.82	43.30	2,936.61
Drip edge, galvanized, 5" wide	90.51	73.58	43.30	3,186.02
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [2000]				66,070.62
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	3,916.06	2,224.79	12.70	28,254.90
Aluminum siding, soffit & fascia, vented, 1' overhang	1,337.55	1,185.72	24.30	28,813.10
Felt, asphalt, #15, 4 square per roll, no mopping	125.48	100.59	15.70	1,579.31
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	90.21	73.33	43.30	3,175.29
Drip edge, galvanized, 5" wide	120.68	98.11	43.30	4,248.02

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [2450]				80,936.51
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	4,797.17	2,725.37	12.70	34,612.25
Aluminum siding, soffit & fascia, vented, 1' overhang	1,638.50	1,452.51	24.30	35,296.05
Felt, asphalt, #15, 4 square per roll, no mopping	153.71	123.23	15.70	1,934.65
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	110.50	89.83	43.30	3,889.73
Drip edge, galvanized, 5" wide	147.84	120.18	43.30	5,203.83
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [3000]				99,105.93
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	5,874.09	3,337.19	12.70	42,382.34
Aluminum siding, soffit & fascia, vented, 1' overhang	2,006.33	1,778.59	24.30	43,219.65
Felt, asphalt, #15, 4 square per roll, no mopping	188.22	150.89	15.70	2,368.97
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	135.31	110.00	43.30	4,762.94
Drip edge, galvanized, 5" wide	181.02	147.16	43.30	6,372.04
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [3500]				115,623.59
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	6,853.10	3,893.39	12.70	49,446.07
Aluminum siding, soffit & fascia, vented, 1' overhang	2,340.72	2,075.02	24.30	50,422.93
Felt, asphalt, #15, 4 square per roll, no mopping	219.59	176.04	15.70	2,763.79
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	157.86	128.33	43.30	5,556.76

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Drip edge, galvanized, 5" wide	211.19	171.69	43.30	7,434.04
Built-up roof, asphalt, organic, 4-ply, insulated deck [1500]				65,583.84
2" x 6" miscellaneous wood blocking, to wood construction	69.94	51.22	13.20	676.04
Wood framing, roof cants, split, 4" x 4"	64.00	46.86	13.20	618.60
Roof Deck Insulation, fiberglass, 1-1/16" thick, R4.17	2,034.22	1,942.20	23.10	44,864.92
Built-up roofing systems, asphalt flood coat with gravel/slag surfacing, coated & saturated base sheet, 4-plies #15 asphalt felt, mopped, excl. insulation, flashing or wood nailers	1,199.73	961.77	15.70	15,099.82
Sheet metal flashing, aluminum, flexible, mill finish, .040" thick, including up to 4 bends	122.85	99.87	43.30	4,324.46
Built-up roof, asphalt, organic, 4-ply, insulated deck [2000]				87,445.12
2" x 6" miscellaneous wood blocking, to wood construction	93.25	68.29	13.20	901.39
Wood framing, roof cants, split, 4" x 4"	85.33	62.48	13.20	824.80
Roof Deck Insulation, fiberglass, 1-1/16" thick, R4.17	2,712.29	2,589.61	23.10	59,819.90
Built-up roofing systems, asphalt flood coat with gravel/slag surfacing, coated & saturated base sheet, 4-plies #15 asphalt felt, mopped, excl. insulation, flashing or wood nailers	1,599.64	1,282.36	15.70	20,133.09
Sheet metal flashing, aluminum, flexible, mill finish, .040" thick, including up to 4 bends	163.80	133.16	43.30	5,765.94
Built-up roof, asphalt, organic, 4-ply, insulated deck [2450]				107,120.27
2" x 6" miscellaneous wood blocking, to wood construction	114.24	83.65	13.20	1,104.20
Wood framing, roof cants, split, 4" x 4"	104.53	76.54	13.20	1,010.38
Roof Deck Insulation, fiberglass, 1-1/16" thick, R4.17	3,322.55	3,172.27	23.10	73,279.38

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Built-up roofing systems, asphalt flood coat with gravel/slag surfacing, coated & saturated base sheet, 4-plies #15 asphalt felt, mopped, excl. insulation, flashing or wood nailers	1,959.56	1,570.89	15.70	24,663.03
Sheet metal flashing, aluminum, flexible, mill finish, .040" thick, including up to 4 bends	200.66	163.12	43.30	7,063.28
Built-up roof, asphalt, organic, 4-ply, insulated deck [3000]				131,167.68
2" x 6" miscellaneous wood blocking, to wood construction	139.88	102.43	13.20	1,352.08
Wood framing, roof cants, split, 4" x 4"	128.00	93.73	13.20	1,237.20
Roof Deck Insulation, fiberglass, 1-1/16" thick, R4.17	4,068.43	3,884.41	23.10	89,729.85
Built-up roofing systems, asphalt flood coat with gravel/slag surfacing, coated & saturated base sheet, 4-plies #15 asphalt felt, mopped, excl. insulation, flashing or wood nailers	2,399.46	1,923.54	15.70	30,199.63
Sheet metal flashing, aluminum, flexible, mill finish, .040" thick, including up to 4 bends	245.71	199.74	43.30	8,648.91
Built-up roof, asphalt, organic, 4-ply, insulated deck [3500]				153,028.96
2" x 6" miscellaneous wood blocking, to wood construction	163.19	119.50	13.20	1,577.43
Wood framing, roof cants, split, 4" x 4"	149.33	109.35	13.20	1,443.40
Roof Deck Insulation, fiberglass, 1-1/16" thick, R4.17	4,746.51	4,531.81	23.10	104,684.82
Built-up roofing systems, asphalt flood coat with gravel/slag surfacing, coated & saturated base sheet, 4-plies #15 asphalt felt, mopped, excl. insulation, flashing or wood nailers	2,799.37	2,244.13	15.70	35,232.90
Sheet metal flashing, aluminum, flexible, mill finish, .040" thick, including up to 4 bends	286.66	233.03	43.30	10,090.40
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [1500]				65,425.32

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	2,857.05	1,623.15	31.40	50,966.85
Aluminum siding, soffit & fascia, vented, 1' overhang	501.58	444.65	24.30	10,804.91
Felt, asphalt, #15, 4 square per roll, no mopping	47.06	37.72	15.70	592.24
Sheet metal flashing, stainless steel, flexible sheets, .018" thick, 26 gauge, including up to 4 bends	41.71	33.91	43.30	1,468.30
Drip edge, galvanized, 5" wide	45.26	36.79	43.30	1,593.01
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [2000]				86,863.66
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	3,809.40	2,164.20	31.40	67,955.80
Aluminum siding, soffit & fascia, vented, 1' overhang	668.78	592.86	24.30	14,406.55
Felt, asphalt, #15, 4 square per roll, no mopping	62.74	50.30	15.70	789.66
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	45.10	36.67	43.30	1,587.65
Drip edge, galvanized, 5" wide	60.34	49.05	43.30	2,124.01
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [2450]				106,407.99
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	4,666.51	2,651.14	31.40	83,245.85
Aluminum siding, soffit & fascia, vented, 1' overhang	819.25	726.26	24.30	17,648.02
Felt, asphalt, #15, 4 square per roll, no mopping	76.86	61.61	15.70	967.33
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	55.25	44.92	43.30	1,944.87
Drip edge, galvanized, 5" wide	73.92	60.09	43.30	2,601.92
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [3000]				130,295.49

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	5,714.09	3,246.30	31.40	101,933.70
Aluminum siding, soffit & fascia, vented, 1' overhang	1,003.17	889.29	24.30	21,609.83
Felt, asphalt, #15, 4 square per roll, no mopping	94.11	75.44	15.70	1,184.48
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	67.65	55.00	43.30	2,381.47
Drip edge, galvanized, 5" wide	90.51	73.58	43.30	3,186.02
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [3500]				152,011.41
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	6,666.44	3,787.35	31.40	118,922.65
Aluminum siding, soffit & fascia, vented, 1' overhang	1,170.36	1,037.51	24.30	25,211.46
Felt, asphalt, #15, 4 square per roll, no mopping	109.80	88.02	15.70	1,381.90
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	78.93	64.17	43.30	2,778.38
Drip edge, galvanized, 5" wide	105.60	85.84	43.30	3,717.02

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Two Stories Units				
Wall Structures				
Stucco on Framewood [1500]				50818.74
Exterior wall framing systems, 2" x 4", 16" OC	1357.67	880.20	13.60	11970.67
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	1479.95	959.47	13.60	13048.84
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	417.13	270.43	13.60	3677.86
Furring, wood, 1" x 3", 12" OC	553.12	405.04	13.20	5346.47
Stucco, 2 coats	238.85	180.56	44.70	8071.06
Painting, primer & 1 coat	238.85	182.23	16.50	3006.78
Painting, lath, metal lath expanded 2.5 lb/SY, painted	452.56	345.28	16.50	5697.06
Stucco on Framewood [2000]				61615.56
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	1973.27	1279.30	13.60	17398.45
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	556.17	360.57	13.60	4903.81
Exterior wall framing systems, 2" x 4", 16" OC	1565.60	1015.00	13.60	13804.00
Furring, wood, 1" x 3", 12" OC	637.84	467.07	13.20	6165.29
Stucco, 2 coats	275.43	208.21	44.70	9307.15
Painting, primer & 1 coat	275.43	210.14	16.50	3467.27
Painting, lath, metal lath expanded 2.5 lb/SY, painted	521.87	398.16	16.50	6569.57
Stucco on Framewood [2450]				70958.09
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	2417.25	1567.14	13.60	21313.11
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	681.31	441.70	13.60	6007.17
Exterior wall framing systems, 2" x 4", 16" OC	1737.82	1126.65	13.60	15322.46
Furring, wood, 1" x 3", 12" OC	708.00	518.45	13.20	6843.49
Stucco, 2 coats	305.73	231.12	44.70	10330.95
Painting, primer & 1 coat	305.73	233.25	16.50	3848.68

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Painting, lath, metal lath expanded 2.5 lb/SY, painted	579.27	441.95	16.50	7292.24
Stucco on Framewood [3000]				80375.83
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	2959.90	1918.95	13.60	26097.68
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	834.26	540.86	13.60	7355.72
Exterior wall framing systems, 2" x 4", 16" OC	1868.62	1211.45	13.60	16475.78
Furring, wood, 1" x 3", 12" OC	761.29	557.47	13.20	7358.59
Stucco, 2 coats	328.74	248.51	44.70	11108.56
Painting, primer & 1 coat	328.74	250.81	16.50	4138.37
Painting, lath, metal lath expanded 2.5 lb/SY, painted	622.87	475.22	16.50	7841.12
Stucco on Framewood [3500]				90978.83
Exterior wall framing systems, 2" x 4", 16" OC	2068.83	1341.25	13.60	18241.06
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	3453.22	2238.77	13.60	30447.29
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	973.30	631.01	13.60	8581.67
Furring, wood, 1" x 3", 12" OC	842.86	617.20	13.20	8147.02
Stucco, 2 coats	363.96	275.14	44.70	12298.77
Painting, primer & 1 coat	363.96	277.68	16.50	4581.77
Painting, lath, metal lath expanded 2.5 lb/SY, painted	689.61	526.14	16.50	8681.25
Block masonry systems, 8" thick concrete block wall [1500]				69810.17
Masonry reinforcing bars, truss type steel joint reinforcing, mill standard galvanized, 8" wide, 9 ga. sides, 9 ga. ties	117.85	95.81	43.30	4148.46
Concrete block partitions, normal weight blocks, 2000 psi, 8" x 8" x 16", tooled joints both sides, includes mortar, excludes scaffolding, horizontal reinforcing, vertical reinforcing and grout	2790.76	1585.49	17.10	27111.90
Furring, wood, on walls, on masonry, 1" x 3"	402.27	294.57	13.20	3888.34

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Perlite insulation, R2.7 per inch, poured in	1073.06	1024.52	23.10	23666.50
Stucco, 3 coats, on masonry construction, incl. lath	245.76	185.79	44.70	8304.69
Paints & Coatings, exterior, brick or concrete, primer + 2 coats, brushwork	213.71	163.05	16.50	2690.28
Block masonry systems, 8" thick concrete block wall [2000]				80501.71
Masonry reinforcing bars, truss type steel joint reinforcing, mill standard galvanized, 8" wide, 9 ga. sides, 9 ga. ties	135.90	110.48	43.30	4783.80
Concrete block partitions, normal weight blocks, 2000 psi, 8" x 8" x 16", tooled joints both sides, includes mortar, excludes scaffolding, horizontal reinforcing, vertical reinforcing and grout	3218.17	1828.31	17.10	31264.12
Furring, wood, on walls, on masonry, 1" x 3"	463.88	339.69	13.20	4483.85
Perlite insulation, R2.7 per inch, poured in	1237.40	1181.43	23.10	27291.06
Stucco, 3 coats, on masonry construction, incl. lath	283.40	214.24	44.70	9576.57
Paints & Coatings, exterior, brick or concrete, primer + 2 coats, brushwork	246.44	188.02	16.50	3102.30
Block masonry systems, 8" thick concrete block wall [2450]				89357.02
Masonry reinforcing bars, truss type steel joint reinforcing, mill standard galvanized, 8" wide, 9 ga. sides, 9 ga. ties	150.85	122.63	43.30	5310.03
Concrete block partitions, normal weight blocks, 2000 psi, 8" x 8" x 16", tooled joints both sides, includes mortar, excludes scaffolding, horizontal reinforcing, vertical reinforcing and grout	3572.18	2029.43	17.10	34703.23
Furring, wood, on walls, on masonry, 1" x 3"	514.91	377.05	13.20	4977.08

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Perlite insulation, R2.7 per inch, poured in	1373.52	1311.39	23.10	30293.12
Stucco, 3 coats, on masonry construction, incl. lath	314.58	237.81	44.70	10630.00
Paints & Coatings, exterior, brick or concrete, primer + 2 coats, brushwork	273.55	208.70	16.50	3443.56
Block masonry systems, 8" thick concrete block wall [3000]				96082.91
Masonry reinforcing bars, truss type steel joint reinforcing, mill standard galvanized, 8" wide, 9 ga. sides, 9 ga. ties	162.21	131.86	43.30	5709.72
Concrete block partitions, normal weight blocks, 2000 psi, 8" x 8" x 16", tooled joints both sides, includes mortar, excludes scaffolding, horizontal reinforcing, vertical reinforcing and grout	3841.05	2182.18	17.10	37315.34
Furring, wood, on walls, on masonry, 1" x 3"	553.67	405.43	13.20	5351.71
Perlite insulation, R2.7 per inch, poured in	1476.90	1410.10	23.10	32573.28
Stucco, 3 coats, on masonry construction, incl. lath	338.25	255.71	44.70	11430.12
Paints & Coatings, exterior, brick or concrete, primer + 2 coats, brushwork	294.13	224.41	16.50	3702.75
Block masonry systems, 8" thick concrete block wall [3500]				106377.59
Masonry reinforcing bars, truss type steel joint reinforcing, mill standard galvanized, 8" wide, 9 ga. sides, 9 ga. ties	179.59	145.99	43.30	6321.48
Concrete block partitions, normal weight blocks, 2000 psi, 8" x 8" x 16", tooled joints both sides, includes mortar, excludes scaffolding, horizontal reinforcing, vertical reinforcing and grout	4252.60	2415.99	17.10	41313.44
Furring, wood, on walls, on masonry, 1" x 3"	612.99	448.87	13.20	5925.11

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Perlite insulation, R2.7 per inch, poured in	1635.14	1561.18	23.10	36063.30
Stucco, 3 coats, on masonry construction, incl. lath	374.50	283.10	44.70	12654.79
Paints & Coatings, exterior, brick or concrete, primer + 2 coats, brushwork	325.65	248.45	16.50	4099.48
Brick/stone veneer systems, red faced common brick [1500]				114127.45
Masonry anchors, veneer wall ties, corrugated, galvanized, 22 ga., 7/8" x 7"	113.01	91.87	43.30	3978.10
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	1627.95	1055.42	13.60	14353.72
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	458.84	297.47	13.60	4045.64
Brick veneer masonry, red brick, running bond, T.L. lots, 6.75/S.F., 4" x 2-2/3" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	4877.55	2771.04	31.40	87010.61
1" x 4" pine, exterior trim, cornice board	80.14	58.68	13.20	774.63
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	179.77	171.63	23.10	3964.75
Brick/stone veneer systems, red faced common brick [2000]				131606.24
Masonry anchors, veneer wall ties, corrugated, galvanized, 22 ga., 7/8" x 7"	130.32	105.94	43.30	4587.35
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	1877.27	1217.06	13.60	16552.02
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	529.11	343.03	13.60	4665.24
Brick veneer masonry, red brick, running bond, T.L. lots, 6.75/S.F., 4" x 2-2/3" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	5624.55	3195.43	31.40	100336.41
1" x 4" pine, exterior trim, cornice board	92.41	67.67	13.20	893.27

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	207.30	197.92	23.10	4571.96
Brick/stone veneer systems, red faced common brick [2450]				146083.14
Masonry anchors, veneer wall ties, corrugated, galvanized, 22 ga., 7/8" x 7"	144.66	117.60	43.30	5091.97
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	2083.77	1350.94	13.60	18372.77
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	587.32	380.77	13.60	5178.42
Brick veneer masonry, red brick, running bond, T.L. lots, 6.75/S.F., 4" x 2-2/3" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	6243.26	3546.93	31.40	111373.58
1" x 4" pine, exterior trim, cornice board	102.58	75.12	13.20	991.53
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	230.10	219.69	23.10	5074.88
Brick/stone veneer systems, red faced common brick [3000]				157078.80
Masonry anchors, veneer wall ties, corrugated, galvanized, 22 ga., 7/8" x 7"	155.55	126.45	43.30	5475.24
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	2240.61	1452.62	13.60	19755.68
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	631.52	409.43	13.60	5568.20
Brick veneer masonry, red brick, running bond, T.L. lots, 6.75/S.F., 4" x 2-2/3" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	6713.19	3813.91	31.40	119756.65
1" x 4" pine, exterior trim, cornice board	110.30	80.77	13.20	1066.16
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	247.42	236.23	23.10	5456.86
Brick/stone veneer systems, red faced common brick [3500]				173908.80

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Masonry anchors, veneer wall ties, corrugated, galvanized, 22 ga., 7/8" x 7"	172.21	140.00	43.30	6061.87
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	2480.68	1608.26	13.60	21872.38
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	699.19	453.29	13.60	6164.80
Brick veneer masonry, red brick, running bond, T.L. lots, 6.75/S.F., 4" x 2-2/3" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	7432.47	4222.54	31.40	132587.82
1" x 4" pine, exterior trim, cornice board	122.12	89.42	13.20	1180.39
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	273.93	261.54	23.10	6041.53
Wood siding systems, 1" x 4" tongue & groove, redwood, vertical grain [1500]				114532.47
Moldings, exterior, verge board, redwood, 1" x 4"	177.57	147.19	16.60	2443.32
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	1627.95	1055.42	13.60	14353.72
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	458.84	297.47	13.60	4045.64
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	179.77	171.63	23.10	3964.75
Wood Siding, Boards, board & batten, redwood, clear, vertical grain, 1" x 10"	5717.70	4739.53	16.60	78676.15
Exterior wall framing systems, 2" x 4", 16" OC	629.23	407.94	13.60	5547.96
Furring, wood, 1" x 3", 12" OC	389.01	284.86	13.20	3760.16
Paints & Coatings, wood siding, primer + 1 coat, incl. puttying	138.28	105.50	16.50	1740.77
Wood siding systems, 1" x 4" tongue & groove, redwood, vertical grain [2000]				132073.30
Moldings, exterior, verge board, redwood, 1" x 4"	204.76	169.73	16.60	2817.52
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	1877.27	1217.06	13.60	16552.02

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	529.11	343.03	13.60	4665.24
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	207.30	197.92	23.10	4571.96
Wood Siding, Boards, board & batten, redwood, clear, vertical grain, 1" x 10"	6593.37	5465.39	16.60	90725.52
Exterior wall framing systems, 2" x 4", 16" OC	725.60	470.41	13.60	6397.64
Furring, wood, 1" x 3", 12" OC	448.59	328.49	13.20	4336.03
Paints & Coatings, wood siding, primer + 1 coat, incl. puttying	159.46	121.66	16.50	2007.37
Wood siding systems, 1" x 4" tongue & groove, redwood, vertical grain [2450]				146601.57
Moldings, exterior, verge board, redwood, 1" x 4"	227.28	188.40	16.60	3127.45
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	2083.77	1350.94	13.60	18372.77
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	587.32	380.77	13.60	5178.42
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	230.10	219.69	23.10	5074.88
Wood Siding, Boards, board & batten, redwood, clear, vertical grain, 1" x 10"	7318.65	6066.59	16.60	100705.47
Exterior wall framing systems, 2" x 4", 16" OC	805.41	522.16	13.60	7101.39
Furring, wood, 1" x 3", 12" OC	497.93	364.62	13.20	4813.00
Paints & Coatings, wood siding, primer + 1 coat, incl. puttying	177.00	135.04	16.50	2228.18
Wood siding systems, 1" x 4" tongue & groove, redwood, vertical grain [3000]				157636.25
Moldings, exterior, verge board, redwood, 1" x 4"	244.39	202.58	16.60	3362.85
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	2240.61	1452.62	13.60	19755.68
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	631.52	409.43	13.60	5568.20
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	247.42	236.23	23.10	5456.86

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Wood Siding, Boards, board & batten, redwood, clear, vertical grain, 1" x 10"	7869.52	6523.23	16.60	108285.56
Exterior wall framing systems, 2" x 4", 16" OC	866.04	561.46	13.60	7635.91
Furring, wood, 1" x 3", 12" OC	535.41	392.07	13.20	5175.28
Paints & Coatings, wood siding, primer + 1 coat, incl. puttying	190.32	145.21	16.50	2395.90
Wood siding systems, 1" x 4" tongue & groove, redwood, vertical grain [3500]				174525.97
Moldings, exterior, verge board, redwood, 1" x 4"	270.58	224.29	16.60	3723.16
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	2480.68	1608.26	13.60	21872.38
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	699.19	453.29	13.60	6164.80
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	273.93	261.54	23.10	6041.53
Wood Siding, Boards, board & batten, redwood, clear, vertical grain, 1" x 10"	8712.69	7222.15	16.60	119887.67
Exterior wall framing systems, 2" x 4", 16" OC	958.83	621.62	13.60	8454.05
Furring, wood, 1" x 3", 12" OC	592.78	434.07	13.20	5729.77
Paints & Coatings, wood siding, primer + 1 coat, incl. puttying	210.71	160.76	16.50	2652.60
Roof Structure				
Gable end roofing, asphalt, roof shingles, class A [1500]				16270.54
Moldings, exterior, verge board, sterling pine, 1" x 6"	23.31	19.33	16.60	320.80
Asphalt Shingles, standard strip shingles, inorganic, class A, 210-235 lb/sq	500.83	401.49	15.70	6303.43
Asphalt Shingles, ridge shingles	45.12	36.17	15.70	567.86
Aluminum siding, soffit & fascia, vented, 1' overhang	189.23	167.75	24.30	4076.40
Felt, asphalt, #15, 4 square per roll, no mopping	40.78	32.69	15.70	513.28

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Aluminum downspouts, enameled, 2" x 3", .024" thick	37.40	33.15	24.30	805.63
Drip edge, galvanized, 5" wide	30.86	25.08	43.30	1086.14
Aluminum gutters, stock units, enameled, 5" box, .027" thick	117.62	104.27	24.30	2533.70
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	5.03	3.84	16.50	63.30
Gable end roofing, asphalt, roof shingles, class A [2000]				21694.05
Moldings, exterior, verge board, sterling pine, 1" x 6"	31.08	25.77	16.60	427.73
Asphalt Shingles, standard strip shingles, inorganic, class A, 210-235 lb/sq	667.77	535.32	15.70	8404.58
Asphalt Shingles, ridge shingles	60.16	48.23	15.70	757.15
Aluminum siding, soffit & fascia, vented, 1' overhang	252.31	223.67	24.30	5435.20
Felt, asphalt, #15, 4 square per roll, no mopping	54.38	43.59	15.70	684.37
Aluminum downspouts, enameled, 2" x 3", .024" thick	49.86	44.20	24.30	1074.17
Drip edge, galvanized, 5" wide	41.14	33.45	43.30	1448.19
Aluminum gutters, stock units, enameled, 5" box, .027" thick	156.83	139.02	24.30	3378.27
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	6.70	5.12	16.50	84.40
Gable end roofing, asphalt, roof shingles, class A [2450]				26575.21
Moldings, exterior, verge board, sterling pine, 1" x 6"	38.08	31.56	16.60	523.97
Asphalt Shingles, standard strip shingles, inorganic, class A, 210-235 lb/sq	818.02	655.77	15.70	10295.61
Asphalt Shingles, ridge shingles	73.69	59.08	15.70	927.51
Aluminum siding, soffit & fascia, vented, 1' overhang	309.08	274.00	24.30	6658.12
Felt, asphalt, #15, 4 square per roll, no mopping	66.61	53.40	15.70	838.35
Aluminum downspouts, enameled, 2" x 3", .024" thick	61.08	54.15	24.30	1315.86
Drip edge, galvanized, 5" wide	50.40	40.97	43.30	1774.03

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Aluminum gutters, stock units, enameled, 5" box, .027" thick	192.11	170.30	24.30	4138.38
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	8.21	6.27	16.50	103.39
Gable end roofing, asphalt, roof shingles, class A [3000]				32541.08
Moldings, exterior, verge board, sterling pine, 1" x 6"	46.63	38.65	16.60	641.59
Asphalt Shingles, standard strip shingles, inorganic, class A, 210-235 lb/sq	1001.66	802.98	15.70	12606.86
Asphalt Shingles, ridge shingles	90.24	72.34	15.70	1135.72
Aluminum siding, soffit & fascia, vented, 1' overhang	378.47	335.51	24.30	8152.80
Felt, asphalt, #15, 4 square per roll, no mopping	81.56	65.39	15.70	1026.55
Aluminum downspouts, enameled, 2" x 3", .024" thick	74.80	66.31	24.30	1611.26
Drip edge, galvanized, 5" wide	61.71	50.17	43.30	2172.29
Aluminum gutters, stock units, enameled, 5" box, .027" thick	235.24	208.54	24.30	5067.40
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	10.06	7.67	16.50	126.60
Gable end roofing, asphalt, roof shingles, class A [3500]				37964.59
Moldings, exterior, verge board, sterling pine, 1" x 6"	54.40	45.09	16.60	748.53
Asphalt Shingles, standard strip shingles, inorganic, class A, 210-235 lb/sq	1168.60	936.82	15.70	14708.01
Asphalt Shingles, ridge shingles	105.28	84.40	15.70	1325.01
Aluminum siding, soffit & fascia, vented, 1' overhang	441.55	391.42	24.30	9511.60
Felt, asphalt, #15, 4 square per roll, no mopping	95.16	76.28	15.70	1197.64
Aluminum downspouts, enameled, 2" x 3", .024" thick	87.26	77.36	24.30	1879.80
Drip edge, galvanized, 5" wide	72.00	58.53	43.30	2534.33
Aluminum gutters, stock units, enameled, 5" box, .027" thick	274.44	243.29	24.30	5911.97

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	11.73	8.95	16.50	147.70
Gable end roofing, wood, cedar shingles no. 1 perfections, 18" long [1500]				31059.14
Moldings, exterior, verge board, sterling pine, 1" x 6"	23.31	19.33	16.60	320.80
Wood shingles, no. 1 red cedar perfections, 18" long, 5-1/2" exposure on roof	1488.91	1234.19	16.60	20487.57
Wood shingles, ridge shakes or shingle wood	85.20	70.62	16.60	1172.32
Aluminum siding, soffit & fascia, vented, 1' overhang	189.23	167.75	24.30	4076.40
Felt, asphalt, #15, 4 square per roll, no mopping	40.78	32.69	15.70	513.28
Aluminum downspouts, enameled, 2" x 3", .024" thick	37.40	33.15	24.30	805.63
Drip edge, galvanized, 5" wide	30.86	25.08	43.30	1086.14
Aluminum gutters, stock units, enameled, 5" box, .027" thick	117.62	104.27	24.30	2533.70
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	5.03	3.84	16.50	63.30
Gable end roofing, wood, cedar shingles no. 1 perfections, 18" long [2000]				41412.19
Moldings, exterior, verge board, sterling pine, 1" x 6"	31.08	25.77	16.60	427.73
Wood shingles, no. 1 red cedar perfections, 18" long, 5-1/2" exposure on roof	1985.21	1645.59	16.60	27316.76
Wood shingles, ridge shakes or shingle wood	113.60	94.16	16.60	1563.10
Aluminum siding, soffit & fascia, vented, 1' overhang	252.31	223.67	24.30	5435.20
Felt, asphalt, #15, 4 square per roll, no mopping	54.38	43.59	15.70	684.37
Aluminum downspouts, enameled, 2" x 3", .024" thick	49.86	44.20	24.30	1074.17
Drip edge, galvanized, 5" wide	41.14	33.45	43.30	1448.19
Aluminum gutters, stock units, enameled, 5" box, .027" thick	156.83	139.02	24.30	3378.27

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	6.70	5.12	16.50	84.40
Gable end roofing, wood, cedar shingles no. 1 perfections, 18" long [2450]				50729.93
Moldings, exterior, verge board, sterling pine, 1" x 6"	38.08	31.56	16.60	523.97
Wood shingles, no. 1 red cedar perfections, 18" long, 5-1/2" exposure on roof	2431.89	2015.85	16.60	33463.03
Wood shingles, ridge shakes or shingle wood	139.16	115.35	16.60	1914.79
Aluminum siding, soffit & fascia, vented, 1' overhang	309.08	274.00	24.30	6658.12
Felt, asphalt, #15, 4 square per roll, no mopping	66.61	53.40	15.70	838.35
Aluminum downspouts, enameled, 2" x 3", .024" thick	61.08	54.15	24.30	1315.86
Drip edge, galvanized, 5" wide	50.40	40.97	43.30	1774.03
Aluminum gutters, stock units, enameled, 5" box, .027" thick	192.11	170.30	24.30	4138.38
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	8.21	6.27	16.50	103.39
Gable end roofing, wood, cedar shingles no. 1 perfections, 18" long [3000]				62118.28
Moldings, exterior, verge board, sterling pine, 1" x 6"	46.63	38.65	16.60	641.59
Wood shingles, no. 1 red cedar perfections, 18" long, 5-1/2" exposure on roof	2977.82	2468.38	16.60	40975.14
Wood shingles, ridge shakes or shingle wood	170.39	141.24	16.60	2344.64
Aluminum siding, soffit & fascia, vented, 1' overhang	378.47	335.51	24.30	8152.80
Felt, asphalt, #15, 4 square per roll, no mopping	81.56	65.39	15.70	1026.55
Aluminum downspouts, enameled, 2" x 3", .024" thick	74.80	66.31	24.30	1611.26
Drip edge, galvanized, 5" wide	61.71	50.17	43.30	2172.29
Aluminum gutters, stock units, enameled, 5" box, .027" thick	235.24	208.54	24.30	5067.40

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	10.06	7.67	16.50	126.60
Gable end roofing, wood, cedar shingles no. 1 perfections, 18" long [3500]				72471.32
Moldings, exterior, verge board, sterling pine, 1" x 6"	54.40	45.09	16.60	748.53
Wood shingles, no. 1 red cedar perfections, 18" long, 5-1/2" exposure on roof	3474.12	2879.78	16.60	47804.33
Wood shingles, ridge shakes or shingle wood	198.79	164.78	16.60	2735.42
Aluminum siding, soffit & fascia, vented, 1' overhang	441.55	391.42	24.30	9511.60
Felt, asphalt, #15, 4 square per roll, no mopping	95.16	76.28	15.70	1197.64
Aluminum downspouts, enameled, 2" x 3", .024" thick	87.26	77.36	24.30	1879.80
Drip edge, galvanized, 5" wide	72.00	58.53	43.30	2534.33
Aluminum gutters, stock units, enameled, 5" box, .027" thick	274.44	243.29	24.30	5911.97
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	11.73	8.95	16.50	147.70
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [1500]				25054.05
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	1468.52	834.30	12.70	10595.59
Aluminum siding, soffit & fascia, vented, 1' overhang	501.58	444.65	24.30	10804.91
Felt, asphalt, #15, 4 square per roll, no mopping	47.06	37.72	15.70	592.24
Sheet metal flashing, stainless steel, flexible sheets, .018" thick, 26 gauge, including up to 4 bends	41.71	33.91	43.30	1468.30
Drip edge, galvanized, 5" wide	45.26	36.79	43.30	1593.01
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [2000]				33035.31

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	1958.03	1112.40	12.70	14127.45
Aluminum siding, soffit & fascia, vented, 1' overhang	668.78	592.86	24.30	14406.55
Felt, asphalt, #15, 4 square per roll, no mopping	62.74	50.30	15.70	789.66
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	45.10	36.67	43.30	1587.65
Drip edge, galvanized, 5" wide	60.34	49.05	43.30	2124.01
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [2450]				40468.26
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	2398.59	1362.69	12.70	17306.12
Aluminum siding, soffit & fascia, vented, 1' overhang	819.25	726.26	24.30	17648.02
Felt, asphalt, #15, 4 square per roll, no mopping	76.86	61.61	15.70	967.33
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	55.25	44.92	43.30	1944.87
Drip edge, galvanized, 5" wide	73.92	60.09	43.30	2601.92
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [3000]				49552.97
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	2937.04	1668.60	12.70	21191.17
Aluminum siding, soffit & fascia, vented, 1' overhang	1003.17	889.29	24.30	21609.83
Felt, asphalt, #15, 4 square per roll, no mopping	94.11	75.44	15.70	1184.48
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	67.65	55.00	43.30	2381.47
Drip edge, galvanized, 5" wide	90.51	73.58	43.30	3186.02

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [3500]				57811.79
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	3426.55	1946.70	12.70	24723.03
Aluminum siding, soffit & fascia, vented, 1' overhang	1170.36	1037.51	24.30	25211.46
Felt, asphalt, #15, 4 square per roll, no mopping	109.80	88.02	15.70	1381.90
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	78.93	64.17	43.30	2778.38
Drip edge, galvanized, 5" wide	105.60	85.84	43.30	3717.02
Built-up roof, asphalt, organic, 4-ply, insulated deck [1500]				32791.92
2" x 6" miscellaneous wood blocking, to wood construction	34.97	25.61	13.20	338.02
Wood framing, roof cants, split, 4" x 4"	32.00	23.43	13.20	309.30
Roof Deck Insulation, fiberglass, 1-1/16" thick, R4.17	1017.11	971.10	23.10	22432.46
Built-up roofing systems, asphalt flood coat with gravel/slag surfacing, coated & saturated base sheet, 4-plies #15 asphalt felt, mopped, excl. insulation, flashing or wood nailers	599.87	480.89	15.70	7549.91
Sheet metal flashing, aluminum, flexible, mill finish, .040" thick, including up to 4 bends	61.43	49.94	43.30	2162.23
Built-up roof, asphalt, organic, 4-ply, insulated deck [2000]				43722.56
2" x 6" miscellaneous wood blocking, to wood construction	46.63	34.14	13.20	450.69
Wood framing, roof cants, split, 4" x 4"	42.67	31.24	13.20	412.40
Roof Deck Insulation, fiberglass, 1-1/16" thick, R4.17	1356.14	1294.80	23.10	29909.95

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Built-up roofing systems, asphalt flood coat with gravel/slag surfacing, coated & saturated base sheet, 4-plies #15 asphalt felt, mopped, excl. insulation, flashing or wood nailers	799.82	641.18	15.70	10066.54
Sheet metal flashing, aluminum, flexible, mill finish, .040" thick, including up to 4 bends	81.90	66.58	43.30	2882.97
Built-up roof, asphalt, organic, 4-ply, insulated deck [2450]				53560.14
2" x 6" miscellaneous wood blocking, to wood construction	57.12	41.83	13.20	552.10
Wood framing, roof cants, split, 4" x 4"	52.26	38.27	13.20	505.19
Roof Deck Insulation, fiberglass, 1-1/16" thick, R4.17	1661.28	1586.13	23.10	36639.69
Built-up roofing systems, asphalt flood coat with gravel/slag surfacing, coated & saturated base sheet, 4-plies #15 asphalt felt, mopped, excl. insulation, flashing or wood nailers	979.78	785.45	15.70	12331.52
Sheet metal flashing, aluminum, flexible, mill finish, .040" thick, including up to 4 bends	100.33	81.56	43.30	3531.64
Built-up roof, asphalt, organic, 4-ply, insulated deck [3000]				65583.84
2" x 6" miscellaneous wood blocking, to wood construction	69.94	51.22	13.20	676.04
Wood framing, roof cants, split, 4" x 4"	64.00	46.86	13.20	618.60
Roof Deck Insulation, fiberglass, 1-1/16" thick, R4.17	2034.22	1942.20	23.10	44864.92
Built-up roofing systems, asphalt flood coat with gravel/slag surfacing, coated & saturated base sheet, 4-plies #15 asphalt felt, mopped, excl. insulation, flashing or wood nailers	1199.73	961.77	15.70	15099.82
Sheet metal flashing, aluminum, flexible, mill finish, .040" thick, including up to 4 bends	122.85	99.87	43.30	4324.46
Built-up roof, asphalt, organic, 4-ply, insulated deck [3500]				76514.48

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
2" x 6" miscellaneous wood blocking, to wood construction	81.60	59.75	13.20	788.72
Wood framing, roof cants, split, 4" x 4"	74.66	54.67	13.20	721.70
Roof Deck Insulation, fiberglass, 1-1/16" thick, R4.17	2373.25	2265.91	23.10	52342.41
Built-up roofing systems, asphalt flood coat with gravel/slag surfacing, coated & saturated base sheet, 4-plies #15 asphalt felt, mopped, excl. insulation, flashing or wood nailers	1399.69	1122.07	15.70	17616.45
Sheet metal flashing, aluminum, flexible, mill finish, .040" thick, including up to 4 bends	143.33	116.52	43.30	5045.20
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [1500]				65425.32
ClayTiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	2857.05	1623.15	31.40	50966.85
Aluminum siding, soffit & fascia, vented, 1' overhang	501.58	444.65	24.30	10804.91
Felt, asphalt, #15, 4 square per roll, no mopping	47.06	37.72	15.70	592.24
Sheet metal flashing, stainless steel, flexible sheets, .018" thick, 26 gauge, including up to 4 bends	41.71	33.91	43.30	1468.30
Drip edge, galvanized, 5" wide	45.26	36.79	43.30	1593.01
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [2000]				86863.66
ClayTiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	3809.40	2164.20	31.40	67955.80
Aluminum siding, soffit & fascia, vented, 1' overhang	668.78	592.86	24.30	14406.55
Felt, asphalt, #15, 4 square per roll, no mopping	62.74	50.30	15.70	789.66
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	45.10	36.67	43.30	1587.65

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Drip edge, galvanized, 5" wide	60.34	49.05	43.30	2124.01
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [2450]				106407.99
ClayTiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	4666.51	2651.14	31.40	83245.85
Aluminum siding, soffit & fascia, vented, 1' overhang	819.25	726.26	24.30	17648.02
Felt, asphalt, #15, 4 square per roll, no mopping	76.86	61.61	15.70	967.33
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	55.25	44.92	43.30	1944.87
Drip edge, galvanized, 5" wide	73.92	60.09	43.30	2601.92
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [3000]				130295.49
ClayTiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	5714.09	3246.30	31.40	101933.70
Aluminum siding, soffit & fascia, vented, 1' overhang	1003.17	889.29	24.30	21609.83
Felt, asphalt, #15, 4 square per roll, no mopping	94.11	75.44	15.70	1184.48
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	67.65	55.00	43.30	2381.47
Drip edge, galvanized, 5" wide	90.51	73.58	43.30	3186.02
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [3500]				152011.41
ClayTiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	6666.44	3787.35	31.40	118922.65
Aluminum siding, soffit & fascia, vented, 1' overhang	1170.36	1037.51	24.30	25211.46
Felt, asphalt, #15, 4 square per roll, no mopping	109.80	88.02	15.70	1381.90

Description	Adj. Material Price (2002 PPI)	Adj. Producer Cost (2002)	MJ/$	Total MJ
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	78.93	64.17	43.30	2778.38
Drip edge, galvanized, 5" wide	105.60	85.84	43.30	3717.02

Description	Total CO2 (ton)	CO2 (ton)	CH4 (ton)	N2O (ton)	HFC/ PFC (ton)
One-Story Unit					
Wall Systems					
Stucco on Framewood [1500]	11.761	10.61	0.692	0.372	0.087
Exterior wall framing systems, 2" x 4", 16" OC	0.459	0.386	0.034	0.036	0.004
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.501	0.421	0.037	0.039	0.004
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.141	0.119	0.01	0.011	0.001
Furring, wood, 1" x 3", 12" OC	0.298	0.227	0.024	0.045	0.002
Stucco, 2 coats	0.961	0.928	0.026	0.004	0.002
Painting, primer & 1 coat	0.195	0.166	0.018	0.007	0.005
Painting, lath, metal lath expanded 2.5 lb/SY, painted	0.369	0.314	0.034	0.013	0.009
Stucco on Framewood [2000]	14.162	12.773	0.834	0.45	0.105
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.668	0.561	0.05	0.052	0.006
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.188	0.158	0.014	0.015	0.002
Exterior wall framing systems, 2" x 4", 16" OC	0.53	0.445	0.039	0.041	0.004
Furring, wood, 1" x 3", 12" OC	0.343	0.262	0.027	0.052	0.002
Stucco, 2 coats	1.108	1.07	0.03	0.005	0.002
Painting, primer & 1 coat	0.225	0.191	0.021	0.008	0.005
Painting, lath, metal lath expanded 2.5 lb/SY, painted	0.426	0.362	0.04	0.015	0.01
Stucco on Framewood [2450]	16.23	14.636	0.957	0.517	0.12
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.818	0.688	0.061	0.063	0.007
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.231	0.194	0.017	0.018	0.002

Description	Total CO2 (ton)	CO2 (ton)	CH4 (ton)	N2O (ton)	HFC/ PFC (ton)
Exterior wall framing systems, 2" x 4", 16" OC	0.588	0.494	0.044	0.046	0.005
Furring, wood, 1" x 3", 12" OC	0.381	0.291	0.03	0.058	0.002
Stucco, 2 coats	1.23	1.188	0.033	0.006	0.003
Painting, primer & 1 coat	0.25	0.212	0.023	0.009	0.006
Painting, lath, metal lath expanded 2.5 lb/SY, painted	0.473	0.402	0.044	0.017	0.011
Stucco on Framewood [3000]	18.263	16.466	1.079	0.584	0.135
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	1.002	0.842	0.074	0.078	0.008
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.282	0.237	0.021	0.022	0.002
Exterior wall framing systems, 2" x 4", 16" OC	0.632	0.532	0.047	0.049	0.005
Furring, wood, 1" x 3", 12" OC	0.41	0.313	0.033	0.062	0.002
Stucco, 2 coats	1.322	1.277	0.036	0.006	0.003
Painting, primer & 1 coat	0.268	0.228	0.025	0.01	0.007
Painting, lath, metal lath expanded 2.5 lb/SY, painted	0.508	0.433	0.047	0.018	0.012
Stucco on Framewood [3500]	20.616	18.586	1.218	0.66	0.152
Exterior wall framing systems, 2" x 4", 16" OC	0.7	0.589	0.052	0.054	0.006
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	1.169	0.983	0.087	0.09	0.01
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.329	0.277	0.024	0.025	0.003
Furring, wood, 1" x 3", 12" OC	0.454	0.346	0.036	0.069	0.002
Stucco, 2 coats	1.464	1.414	0.04	0.007	0.003
Painting, primer & 1 coat	0.297	0.253	0.028	0.011	0.007
Painting, lath, metal lath expanded 2.5 lb/SY, painted	0.563	0.479	0.052	0.02	0.014

Description	Total CO2 (ton)	CO2 (ton)	CH4 (ton)	N2O (ton)	HFC/ PFC (ton)
Block masonry systems, 8" thick concrete block wall [1500]	15.282	14.121	0.772	0.288	1.264
Masonry reinforcing bars, truss type steel joint reinforcing, mill standard galvanized, 8" wide, 9 ga. sides, 9 ga. ties	0.351	0.329	0.017	0.001	0.004
Concrete block partitions, normal weight blocks, 2000 psi, 8" x 8" x 16", tooled joints both sides, includes mortar, excludes scaffolding, horizontal reinforcing, vertical reinforcing and grout	3.044	2.944	0.079	0.008	1.175
Furring, wood, on walls, on masonry, 1" x 3"	0.217	0.165	0.017	0.033	0.001
Perlite insulation, R2.7 per inch, poured in	1.414	1.297	0.092	0.012	0.015
Stucco, 3 coats, on masonry construction, incl. lath	0.988	0.955	0.027	0.004	0.002
Paints & Coatings, exterior, brick or concrete, primer + 2 coats, brushwork	0.174	0.148	0.016	0.006	0.004
Block masonry systems, 8" thick concrete block wall [2000]	17.623	16.284	0.89	0.332	1.458
Masonry reinforcing bars, truss type steel joint reinforcing, mill standard galvanized, 8" wide, 9 ga. sides, 9 ga. ties	0.404	0.379	0.019	0.001	0.004
Concrete block partitions, normal weight blocks, 2000 psi, 8" x 8" x 16", tooled joints both sides, includes mortar, excludes scaffolding, horizontal reinforcing, vertical reinforcing and grout	3.51	3.395	0.092	0.01	1.355
Furring, wood, on walls, on masonry, 1" x 3"	0.25	0.191	0.02	0.038	0.001
Perlite insulation, R2.7 per inch, poured in	1.63	1.496	0.106	0.014	0.018

Description	Total CO2 (ton)	CO2 (ton)	CH4 (ton)	N2O (ton)	HFC/ PFC (ton)
Stucco, 3 coats, on masonry construction, incl. lath	1.14	1.101	0.031	0.005	0.002
Paints & Coatings, exterior, brick or concrete, primer + 2 coats, brushwork	0.201	0.171	0.019	0.007	0.005
Block masonry systems, 8" thick concrete block wall [2450]	19.562	18.075	0.988	0.369	1.618
Masonry reinforcing bars, truss type steel joint reinforcing, mill standard galvanized, 8" wide, 9 ga. sides, 9 ga. ties	0.449	0.421	0.021	0.001	0.005
Concrete block partitions, normal weight blocks, 2000 psi, 8" x 8" x 16", tooled joints both sides, includes mortar, excludes scaffolding, horizontal reinforcing, vertical reinforcing and grout	3.897	3.769	0.102	0.011	1.504
Furring, wood, on walls, on masonry, 1" x 3"	0.277	0.212	0.022	0.042	0.002
Perlite insulation, R2.7 per inch, poured in	1.81	1.66	0.118	0.016	0.02
Stucco, 3 coats, on masonry construction, incl. lath	1.265	1.222	0.034	0.006	0.003
Paints & Coatings, exterior, brick or concrete, primer + 2 coats, brushwork	0.223	0.19	0.021	0.008	0.005
Block masonry systems, 8" thick concrete block wall [3000]	21.034	19.436	1.062	0.397	1.74
Masonry reinforcing bars, truss type steel joint reinforcing, mill standard galvanized, 8" wide, 9 ga. sides, 9 ga. ties	0.483	0.452	0.023	0.001	0.005

Description	Total CO2 (ton)	CO2 (ton)	CH4 (ton)	N2O (ton)	HFC/ PFC (ton)
Concrete block partitions, normal weight blocks, 2000 psi, 8" x 8" x 16", tooled joints both sides, includes mortar, excludes scaffolding, horizontal reinforcing, vertical reinforcing and grout	4.19	4.052	0.109	0.011	1.617
Furring, wood, on walls, on masonry, 1" x 3"	0.298	0.227	0.024	0.045	0.002
Perlite insulation, R2.7 per inch, poured in	1.946	1.785	0.127	0.017	0.021
Stucco, 3 coats, on masonry construction, incl. lath	1.36	1.314	0.037	0.006	0.003
Paints & Coatings, exterior, brick or concrete, primer + 2 coats, brushwork	0.24	0.204	0.022	0.009	0.006
Block masonry systems, 8" thick concrete block wall [3500]	23.288	21.518	1.176	0.439	1.926
Masonry reinforcing bars, truss type steel joint reinforcing, mill standard galvanized, 8" wide, 9 ga. sides, 9 ga. ties	0.534	0.501	0.026	0.001	0.006
Concrete block partitions, normal weight blocks, 2000 psi, 8" x 8" x 16", tooled joints both sides, includes mortar, excludes scaffolding, horizontal reinforcing, vertical reinforcing and grout	4.639	4.486	0.121	0.013	1.79
Furring, wood, on walls, on masonry, 1" x 3"	0.33	0.252	0.026	0.05	0.002
Perlite insulation, R2.7 per inch, poured in	2.154	1.976	0.141	0.019	0.024
Stucco, 3 coats, on masonry construction, incl. lath	1.506	1.455	0.041	0.007	0.003
Paints & Coatings, exterior, brick or concrete, primer + 2 coats, brushwork	0.266	0.226	0.025	0.009	0.006
Brick/stone veneer systems, red faced common brick [1500]	18.257	16.748	1.04	0.371	0.115

Description	Total CO2 (ton)	CO2 (ton)	CH4 (ton)	N2O (ton)	HFC/ PFC (ton)
Masonry anchors, veneer wall ties, corrugated, galvanized, 22 ga., 7/8" x 7"	0.336	0.315	0.016	0.001	0.004
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.551	0.463	0.041	0.043	0.005
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.155	0.131	0.012	0.012	0.001
Brick veneer masonry, red brick, running bond, T.L. lots, 6.75/S.F., 4" x 2-2/3" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	5.57	5.238	0.299	0.027	0.024
1" x 4" pine, exterior trim, cornice board	0.043	0.033	0.003	0.007	0
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	0.237	0.217	0.015	0.002	0.003
Brick/stone veneer systems, red faced common brick [2000]	21.053	19.313	1.2	0.427	0.132
Masonry anchors, veneer wall ties, corrugated, galvanized, 22 ga., 7/8" x 7"	0.388	0.363	0.019	0.001	0.004
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.635	0.534	0.047	0.049	0.005
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.179	0.151	0.013	0.014	0.001
Brick veneer masonry, red brick, running bond, T.L. lots, 6.75/S.F., 4" x 2-2/3" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	6.423	6.04	0.345	0.032	0.028
1" x 4" pine, exterior trim, cornice board	0.05	0.038	0.004	0.008	0

Description	Total CO2 (ton)	CO2 (ton)	CH4 (ton)	N2O (ton)	HFC/ PFC (ton)
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	0.273	0.251	0.018	0.002	0.003
Brick/stone veneer systems, red faced common brick [2450]	23.369	21.437	1.331	0.474	0.147
Masonry anchors, veneer wall ties, corrugated, galvanized, 22 ga., 7/8" x 7"	0.43	0.403	0.021	0.001	0.005
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.705	0.593	0.052	0.055	0.006
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.199	0.167	0.015	0.015	0.002
Brick veneer masonry, red brick, running bond, T.L. lots, 6.75/S.F., 4" x 2-2/3" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	7.129	6.704	0.383	0.035	0.031
1" x 4" pine, exterior trim, cornice board	0.055	0.042	0.004	0.008	0
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	0.303	0.278	0.02	0.003	0.003
Brick/stone veneer systems, red faced common brick [3000]	25.128	23.051	1.432	0.51	0.158
Masonry anchors, veneer wall ties, corrugated, galvanized, 22 ga., 7/8" x 7"	0.463	0.434	0.022	0.001	0.005
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.758	0.638	0.056	0.059	0.006
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.214	0.18	0.016	0.017	0.002

Description	Total CO2 (ton)	CO2 (ton)	CH4 (ton)	N2O (ton)	HFC/ PFC (ton)
Brick veneer masonry, red brick, running bond, T.L. lots, 6.75/S.F., 4" x 2-2/3" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	7.666	7.209	0.412	0.038	0.033
1" x 4" pine, exterior trim, cornice board	0.059	0.045	0.005	0.009	0
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	0.326	0.299	0.021	0.003	0.004
Brick/stone veneer systems, red faced common brick [3500]	27.82	25.52	1.585	0.565	0.175
Masonry anchors, veneer wall ties, corrugated, galvanized, 22 ga., 7/8" x 7"	0.512	0.48	0.024	0.001	0.005
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.84	0.706	0.062	0.065	0.007
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.237	0.199	0.018	0.018	0.002
Brick veneer masonry, red brick, running bond, T.L. lots, 6.75/S.F., 4" x 2-2/3" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	8.487	7.981	0.456	0.042	0.037
1" x 4" pine, exterior trim, cornice board	0.066	0.05	0.005	0.01	0
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	0.361	0.331	0.024	0.003	0.004
Wood siding systems, 1" x 4" tongue & groove, redwood, vertical grain [1500]	15.425	13.583	0.968	0.773	0.104
Moldings, exterior, verge board, redwood, 1" x 4"	0.114	0.093	0.008	0.012	0.001

Description	Total CO2 (ton)	CO2 (ton)	CH4 (ton)	N2O (ton)	HFC/ PFC (ton)
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.551	0.463	0.041	0.043	0.005
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.155	0.131	0.012	0.012	0.001
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	0.237	0.217	0.015	0.002	0.003
Wood Siding, Boards, board & batten, redwood, clear, vertical grain, 1" x 10"	3.683	3	0.265	0.402	0.019
Exterior wall framing systems, 2" x 4", 16" OC	0.213	0.179	0.016	0.016	0.002
Furring, wood, 1" x 3", 12" OC	0.209	0.16	0.017	0.032	0.001
Paints & Coatings, wood siding, primer + 1 coat, incl. puttying	0.113	0.096	0.01	0.004	0.003
Wood siding systems, 1" x 4" tongue & groove, redwood, vertical grain [2000]	17.787	15.663	1.116	0.891	0.12
Moldings, exterior, verge board, redwood, 1" x 4"	0.132	0.107	0.01	0.014	0.001
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.635	0.534	0.047	0.049	0.005
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.179	0.151	0.013	0.014	0.001
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	0.273	0.251	0.018	0.002	0.003
Wood Siding, Boards, board & batten, redwood, clear, vertical grain, 1" x 10"	4.247	3.459	0.306	0.463	0.022
Exterior wall framing systems, 2" x 4", 16" OC	0.246	0.206	0.018	0.019	0.002
Furring, wood, 1" x 3", 12" OC	0.241	0.184	0.019	0.036	0.001

Description	Total CO2 (ton)	CO2 (ton)	CH4 (ton)	N2O (ton)	HFC/ PFC (ton)
Paints & Coatings, wood siding, primer + 1 coat, incl. puttying	0.13	0.111	0.012	0.005	0.003
Wood siding systems, 1" x 4" tongue & groove, redwood, vertical grain [2450]	19.744	17.386	1.239	0.989	0.133
Moldings, exterior, verge board, redwood, 1" x 4"	0.146	0.119	0.011	0.016	0.001
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.705	0.593	0.052	0.055	0.006
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.199	0.167	0.015	0.015	0.002
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	0.303	0.278	0.02	0.003	0.003
Wood Siding, Boards, board & batten, redwood, clear, vertical grain, 1" x 10"	4.714	3.84	0.34	0.514	0.024
Exterior wall framing systems, 2" x 4", 16" OC	0.273	0.229	0.02	0.021	0.002
Furring, wood, 1" x 3", 12" OC	0.268	0.205	0.021	0.04	0.001
Paints & Coatings, wood siding, primer + 1 coat, incl. puttying	0.144	0.123	0.013	0.005	0.004
Wood siding systems, 1" x 4" tongue & groove, redwood, vertical grain [3000]	21.23	18.694	1.332	1.064	0.143
Moldings, exterior, verge board, redwood, 1" x 4"	0.157	0.128	0.011	0.017	0.001
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.758	0.638	0.056	0.059	0.006
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.214	0.18	0.016	0.017	0.002

Description	Total CO2 (ton)	CO2 (ton)	CH4 (ton)	N2O (ton)	HFC/ PFC (ton)
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	0.326	0.299	0.021	0.003	0.004
Wood Siding, Boards, board & batten, redwood, clear, vertical grain, 1" x 10"	5.069	4.129	0.365	0.553	0.026
Exterior wall framing systems, 2" x 4", 16" OC	0.293	0.246	0.022	0.023	0.002
Furring, wood, 1" x 3", 12" OC	0.288	0.22	0.023	0.044	0.002
Paints & Coatings, wood siding, primer + 1 coat, incl. puttying	0.155	0.132	0.014	0.006	0.004
Wood siding systems, 1" x 4" tongue & groove, redwood, vertical grain [3500]	23.504	20.697	1.475	1.178	0.158
Moldings, exterior, verge board, redwood, 1" x 4"	0.174	0.142	0.013	0.019	0.001
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.84	0.706	0.062	0.065	0.007
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.237	0.199	0.018	0.018	0.002
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	0.361	0.331	0.024	0.003	0.004
Wood Siding, Boards, board & batten, redwood, clear, vertical grain, 1" x 10"	5.612	4.571	0.404	0.612	0.029
Exterior wall framing systems, 2" x 4", 16" OC	0.324	0.273	0.024	0.025	0.003
Furring, wood, 1" x 3", 12" OC	0.319	0.244	0.025	0.048	0.002
Paints & Coatings, wood siding, primer + 1 coat, incl. puttying	0.172	0.146	0.016	0.006	0.004

Description	Total CO2 (ton)	CO2 (ton)	CH4 (ton)	N2O (ton)	HFC/ PFC (ton)
		Roof Systems			
Gable end roofing, asphalt, roof shingles, class A [1500]	2.395	2.099	0.18	0.038	0.077
Moldings, exterior, verge board, sterling pine, 1" x 6"	0.015	0.012	0.001	0.002	0
Asphalt Shingles, standard strip shingles, inorganic, class A, 210-235 lb/sq	0.466	0.391	0.068	0.002	0.003
Asphalt Shingles, ridge shingles	0.042	0.035	0.006	0	0
Aluminum siding, soffit & fascia, vented, 1' overhang	0.262	0.214	0.012	0.001	0.035
Felt, asphalt, #15, 4 square per roll, no mopping	0.038	0.032	0.006	0	0
Aluminum downspouts, enameled, 2" x 3", .024" thick	0.052	0.042	0.002	0	0.007
Drip edge, galvanized, 5" wide	0.092	0.086	0.004	0	0.001
Aluminum gutters, stock units, enameled, 5" box, .027" thick	0.163	0.133	0.007	0.001	0.021
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	0.004	0.003	0	0	0
Gable end roofing, asphalt, roof shingles, class A [2000]	3.194	2.798	0.24	0.051	0.102
Moldings, exterior, verge board, sterling pine, 1" x 6"	0.02	0.016	0.001	0.002	0
Asphalt Shingles, standard strip shingles, inorganic, class A, 210-235 lb/sq	0.621	0.521	0.091	0.003	0.005
Asphalt Shingles, ridge shingles	0.056	0.047	0.008	0	0
Aluminum siding, soffit & fascia, vented, 1' overhang	0.349	0.285	0.016	0.002	0.046
Felt, asphalt, #15, 4 square per roll, no mopping	0.051	0.042	0.007	0	0
Aluminum downspouts, enameled, 2" x 3", .024" thick	0.069	0.056	0.003	0	0.009
Drip edge, galvanized, 5" wide	0.122	0.115	0.006	0	0.001

Description	Total CO2 (ton)	CO2 (ton)	CH4 (ton)	N2O (ton)	HFC/ PFC (ton)
Aluminum gutters, stock units, enameled, 5" box, .027" thick	0.217	0.177	0.01	0.001	0.029
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	0.005	0.005	0.001	0	0
Gable end roofing, asphalt, roof shingles, class A [2450]	3.912	3.428	0.294	0.062	0.125
Moldings, exterior, verge board, sterling pine, 1" x 6"	0.025	0.02	0.002	0.003	0
Asphalt Shingles, standard strip shingles, inorganic, class A, 210-235 lb/sq	0.761	0.638	0.111	0.004	0.006
Asphalt Shingles, ridge shingles	0.069	0.057	0.01	0	0.001
Aluminum siding, soffit & fascia, vented, 1' overhang	0.427	0.349	0.019	0.002	0.056
Felt, asphalt, #15, 4 square per roll, no mopping	0.062	0.052	0.009	0	0
Aluminum downspouts, enameled, 2" x 3", .024" thick	0.084	0.069	0.004	0	0.011
Drip edge, galvanized, 5" wide	0.15	0.141	0.007	0	0.002
Aluminum gutters, stock units, enameled, 5" box, .027" thick	0.266	0.217	0.012	0.001	0.035
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	0.007	0.006	0.001	0	0
Gable end roofing, asphalt, roof shingles, class A [3000]	4.791	4.197	0.359	0.076	0.154
Moldings, exterior, verge board, sterling pine, 1" x 6"	0.03	0.024	0.002	0.003	0
Asphalt Shingles, standard strip shingles, inorganic, class A, 210-235 lb/sq	0.931	0.781	0.137	0.005	0.007
Asphalt Shingles, ridge shingles	0.084	0.07	0.012	0	0.001
Aluminum siding, soffit & fascia, vented, 1' overhang	0.523	0.428	0.023	0.002	0.069
Felt, asphalt, #15, 4 square per roll, no mopping	0.076	0.064	0.011	0	0.001

Description	Total CO2 (ton)	CO2 (ton)	CH4 (ton)	N2O (ton)	HFC/ PFC (ton)
Aluminum downspouts, enameled, 2" x 3", .024" thick	0.103	0.085	0.005	0	0.014
Drip edge, galvanized, 5" wide	0.184	0.172	0.009	0	0.002
Aluminum gutters, stock units, enameled, 5" box, .027" thick	0.325	0.266	0.015	0.001	0.043
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	0.008	0.007	0.001	0	0
Gable end roofing, asphalt, roof shingles, class A [3500]	5.589	4.897	0.419	0.089	0.179
Moldings, exterior, verge board, sterling pine, 1" x 6"	0.035	0.029	0.003	0.004	0
Asphalt Shingles, standard strip shingles, inorganic, class A, 210-235 lb/sq	1.087	0.912	0.159	0.006	0.008
Asphalt Shingles, ridge shingles	0.098	0.082	0.014	0	0.001
Aluminum siding, soffit & fascia, vented, 1' overhang	0.611	0.499	0.027	0.003	0.081
Felt, asphalt, #15, 4 square per roll, no mopping	0.088	0.074	0.013	0	0.001
Aluminum downspouts, enameled, 2" x 3", .024" thick	0.121	0.099	0.005	0.001	0.016
Drip edge, galvanized, 5" wide	0.214	0.201	0.01	0	0.002
Aluminum gutters, stock units, enameled, 5" box, .027" thick	0.38	0.31	0.017	0.002	0.05
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	0.01	0.008	0.001	0	0
Gable end roofing, wood, cedar shingles no. 1 perfections, 18" long [1500]	3.897	3.405	0.236	0.17	0.085
Moldings, exterior, verge board, sterling pine, 1" x 6"	0.015	0.012	0.001	0.002	0
Wood shingles, no. 1 red cedar perfections, 18" long, 5-1/2" exposure on roof	0.959	0.781	0.069	0.105	0.005
Wood shingles, ridge shakes or shingle wood	0.055	0.045	0.004	0.006	0

Description	Total CO2 (ton)	CO2 (ton)	CH4 (ton)	N2O (ton)	HFC/ PFC (ton)
Aluminum siding, soffit & fascia, vented, 1' overhang	0.262	0.214	0.012	0.001	0.035
Felt, asphalt, #15, 4 square per roll, no mopping	0.038	0.032	0.006	0	0
Aluminum downspouts, enameled, 2" x 3", .024" thick	0.052	0.042	0.002	0	0.007
Drip edge, galvanized, 5" wide	0.092	0.086	0.004	0	0.001
Aluminum gutters, stock units, enameled, 5" box, .027" thick	0.163	0.133	0.007	0.001	0.021
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	0.004	0.003	0	0	0
Gable end roofing, wood, cedar shingles no. 1 perfections, 18" long [2000]	5.196	4.54	0.314	0.227	0.113
Moldings, exterior, verge board, sterling pine, 1" x 6"	0.02	0.016	0.001	0.002	0
Wood shingles, no. 1 red cedar perfections, 18" long, 5-1/2" exposure on roof	1.279	1.041	0.092	0.14	0.007
Wood shingles, ridge shakes or shingle wood	0.073	0.06	0.005	0.008	0
Aluminum siding, soffit & fascia, vented, 1' overhang	0.349	0.285	0.016	0.002	0.046
Felt, asphalt, #15, 4 square per roll, no mopping	0.051	0.042	0.007	0	0
Aluminum downspouts, enameled, 2" x 3", .024" thick	0.069	0.056	0.003	0	0.009
Drip edge, galvanized, 5" wide	0.122	0.115	0.006	0	0.001
Aluminum gutters, stock units, enameled, 5" box, .027" thick	0.217	0.177	0.01	0.001	0.029
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	0.005	0.005	0.001	0	0
Gable end roofing, wood, cedar shingles no. 1 perfections, 18" long [2450]	6.365	5.561	0.385	0.278	0.139
Moldings, exterior, verge board, sterling pine, 1" x 6"	0.025	0.02	0.002	0.003	0

Description	Total CO2 (ton)	CO2 (ton)	CH4 (ton)	N2O (ton)	HFC/ PFC (ton)
Wood shingles, no. 1 red cedar perfections, 18" long, 5-1/2" exposure on roof	1.566	1.276	0.113	0.171	0.008
Wood shingles, ridge shakes or shingle wood	0.09	0.073	0.006	0.01	0
Aluminum siding, soffit & fascia, vented, 1' overhang	0.427	0.349	0.019	0.002	0.056
Felt, asphalt, #15, 4 square per roll, no mopping	0.062	0.052	0.009	0	0
Aluminum downspouts, enameled, 2" x 3", .024" thick	0.084	0.069	0.004	0	0.011
Drip edge, galvanized, 5" wide	0.15	0.141	0.007	0	0.002
Aluminum gutters, stock units, enameled, 5" box, .027" thick	0.266	0.217	0.012	0.001	0.035
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	0.007	0.006	0.001	0	0
Gable end roofing, wood, cedar shingles no. 1 perfections, 18" long [3000]	7.793	6.81	0.471	0.341	0.17
Moldings, exterior, verge board, sterling pine, 1" x 6"	0.03	0.024	0.002	0.003	0
Wood shingles, no. 1 red cedar perfections, 18" long, 5-1/2" exposure on roof	1.918	1.562	0.138	0.209	0.01
Wood shingles, ridge shakes or shingle wood	0.11	0.089	0.008	0.012	0.001
Aluminum siding, soffit & fascia, vented, 1' overhang	0.523	0.428	0.023	0.002	0.069
Felt, asphalt, #15, 4 square per roll, no mopping	0.076	0.064	0.011	0	0.001
Aluminum downspouts, enameled, 2" x 3", .024" thick	0.103	0.085	0.005	0	0.014
Drip edge, galvanized, 5" wide	0.184	0.172	0.009	0	0.002
Aluminum gutters, stock units, enameled, 5" box, .027" thick	0.325	0.266	0.015	0.001	0.043
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	0.008	0.007	0.001	0	0

Description	Total CO2 (ton)	CO2 (ton)	CH4 (ton)	N2O (ton)	HFC/ PFC (ton)
Gable end roofing, wood, cedar shingles no. 1 perfections, 18" long [3500]	9.092	7.945	0.55	0.398	0.199
Moldings, exterior, verge board, sterling pine, 1" x 6"	0.035	0.029	0.003	0.004	0
Wood shingles, no. 1 red cedar perfections, 18" long, 5-1/2" exposure on roof	2.238	1.823	0.161	0.244	0.012
Wood shingles, ridge shakes or shingle wood	0.128	0.104	0.009	0.014	0.001
Aluminum siding, soffit & fascia, vented, 1' overhang	0.611	0.499	0.027	0.003	0.081
Felt, asphalt, #15, 4 square per roll, no mopping	0.088	0.074	0.013	0	0.001
Aluminum downspouts, enameled, 2" x 3", .024" thick	0.121	0.099	0.005	0.001	0.016
Drip edge, galvanized, 5" wide	0.214	0.201	0.01	0	0.002
Aluminum gutters, stock units, enameled, 5" box, .027" thick	0.38	0.31	0.017	0.002	0.05
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	0.01	0.008	0.001	0	0
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [1500]	4.633	4.202	0.236	0.072	0.119
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	1.043	0.993	0.037	0.004	0.006
Aluminum siding, soffit & fascia, vented, 1' overhang	0.694	0.567	0.031	0.003	0.092
Felt, asphalt, #15, 4 square per roll, no mopping	0.044	0.037	0.006	0	0
Sheet metal flashing, stainless steel, flexible sheets, .018" thick, 26 gauge, including up to 4 bends	0.124	0.116	0.006	0	0.001
Drip edge, galvanized, 5" wide	0.135	0.126	0.006	0	0.001

Description	Total CO2 (ton)	CO2 (ton)	CH4 (ton)	N2O (ton)	HFC/ PFC (ton)
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [2000]	6.142	5.569	0.312	0.096	0.158
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	1.39	1.324	0.049	0.006	0.008
Aluminum siding, soffit & fascia, vented, 1' overhang	0.925	0.756	0.041	0.004	0.122
Felt, asphalt, #15, 4 square per roll, no mopping	0.058	0.049	0.009	0	0
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	0.134	0.126	0.006	0	0.001
Drip edge, galvanized, 5" wide	0.18	0.168	0.009	0	0.002
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [2450]	7.524	6.822	0.383	0.118	0.194
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	1.703	1.622	0.06	0.007	0.01
Aluminum siding, soffit & fascia, vented, 1' overhang	1.133	0.926	0.051	0.005	0.15
Felt, asphalt, #15, 4 square per roll, no mopping	0.071	0.06	0.01	0	0.001
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	0.164	0.154	0.008	0	0.002
Drip edge, galvanized, 5" wide	0.22	0.206	0.011	0	0.002

Description	Total CO2 (ton)	CO2 (ton)	CH4 (ton)	N2O (ton)	HFC/ PFC (ton)
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [3000]	9.213	8.353	0.468	0.144	0.237
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	2.086	1.986	0.073	0.009	0.013
Aluminum siding, soffit & fascia, vented, 1' overhang	1.387	1.134	0.062	0.006	0.183
Felt, asphalt, #15, 4 square per roll, no mopping	0.088	0.073	0.013	0	0.001
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	0.201	0.189	0.01	0	0.002
Drip edge, galvanized, 5" wide	0.269	0.252	0.013	0.001	0.003
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [3500]	10.748	9.745	0.546	0.168	0.277
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	2.433	2.317	0.085	0.01	0.015
Aluminum siding, soffit & fascia, vented, 1' overhang	1.619	1.323	0.072	0.007	0.214
Felt, asphalt, #15, 4 square per roll, no mopping	0.102	0.086	0.015	0.001	0.001
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	0.235	0.22	0.011	0	0.003
Drip edge, galvanized, 5" wide	0.314	0.294	0.015	0.001	0.003
Built-up roof, asphalt, organic, 4-ply, insulated deck [1500]	3.966	3.58	0.287	0.066	0.034
2" x 6" miscellaneous wood blocking, to wood construction	0.019	0.014	0.001	0.003	0

Description	Total CO2 (ton)	CO2 (ton)	CH4 (ton)	N2O (ton)	HFC/ PFC (ton)
Wood framing, roof cants, split, 4" x 4"	0.017	0.013	0.001	0.003	0
Roof Deck Insulation, fiberglass, 1-1/16" thick, R4.17	1.34	1.229	0.087	0.012	0.015
Built-up roofing systems, asphalt flood coat with gravel/slag surfacing, coated & saturated base sheet, 4-plies #15 asphalt felt, mopped, excl. insulation, flashing or wood nailers	0.558	0.468	0.082	0.003	0.004
Sheet metal flashing, aluminum, flexible, mill finish, .040" thick, including up to 4 bends	0.183	0.171	0.009	0	0.002
Built-up roof, asphalt, organic, 4-ply, insulated deck [2000]	5.288	4.774	0.383	0.088	0.045
2" x 6" miscellaneous wood blocking, to wood construction	0.025	0.019	0.002	0.004	0
Wood framing, roof cants, split, 4" x 4"	0.023	0.018	0.002	0.003	0
Roof Deck Insulation, fiberglass, 1-1/16" thick, R4.17	1.787	1.639	0.117	0.016	0.02
Built-up roofing systems, asphalt flood coat with gravel/slag surfacing, coated & saturated base sheet, 4-plies #15 asphalt felt, mopped, excl. insulation, flashing or wood nailers	0.744	0.624	0.109	0.004	0.006
Sheet metal flashing, aluminum, flexible, mill finish, .040" thick, including up to 4 bends	0.244	0.228	0.012	0	0.003
Built-up roof, asphalt, organic, 4-ply, insulated deck [2450]	6.478	5.848	0.469	0.108	0.055
2" x 6" miscellaneous wood blocking, to wood construction	0.031	0.023	0.002	0.005	0
Wood framing, roof cants, split, 4" x 4"	0.028	0.021	0.002	0.004	0
Roof Deck Insulation, fiberglass, 1-1/16" thick, R4.17	2.189	2.008	0.143	0.019	0.024

Description	Total CO2 (ton)	CO2 (ton)	CH4 (ton)	N2O (ton)	HFC/ PFC (ton)
Built-up roofing systems, asphalt flood coat with gravel/slag surfacing, coated & saturated base sheet, 4-plies #15 asphalt felt, mopped, excl. insulation, flashing or wood nailers	0.911	0.764	0.134	0.005	0.007
Sheet metal flashing, aluminum, flexible, mill finish, .040" thick, including up to 4 bends	0.299	0.28	0.014	0.001	0.003
Built-up roof, asphalt, organic, 4-ply, insulated deck [3000]	7.933	7.161	0.574	0.132	0.067
2" x 6" miscellaneous wood blocking, to wood construction	0.038	0.029	0.003	0.006	0
Wood framing, roof cants, split, 4" x 4"	0.034	0.026	0.003	0.005	0
Roof Deck Insulation, fiberglass, 1-1/16" thick, R4.17	2.68	2.459	0.175	0.024	0.029
Built-up roofing systems, asphalt flood coat with gravel/slag surfacing, coated & saturated base sheet, 4-plies #15 asphalt felt, mopped, excl. insulation, flashing or wood nailers	1.116	0.936	0.164	0.006	0.008
Sheet metal flashing, aluminum, flexible, mill finish, .040" thick, including up to 4 bends	0.366	0.343	0.017	0.001	0.004
Built-up roof, asphalt, organic, 4-ply, insulated deck [3500]	9.255	8.354	0.67	0.154	0.079
2" x 6" miscellaneous wood blocking, to wood construction	0.044	0.034	0.003	0.007	0
Wood framing, roof cants, split, 4" x 4"	0.04	0.031	0.003	0.006	0
Roof Deck Insulation, fiberglass, 1-1/16" thick, R4.17	3.127	2.868	0.204	0.027	0.034

Description	Total CO2 (ton)	CO2 (ton)	CH4 (ton)	N2O (ton)	HFC/ PFC (ton)
Built-up roofing systems, asphalt flood coat with gravel/slag surfacing, coated & saturated base sheet, 4-plies #15 asphalt felt, mopped, excl. insulation, flashing or wood nailers	1.302	1.092	0.191	0.007	0.01
Sheet metal flashing, aluminum, flexible, mill finish, .040" thick, including up to 4 bends	0.426	0.4	0.02	0.001	0.005
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [1500]	7.86	7.194	0.432	0.108	0.134
ClayTiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	3.263	3.068	0.175	0.016	0.014
Aluminum siding, soffit & fascia, vented, 1' overhang	0.694	0.567	0.031	0.003	0.092
Felt, asphalt, #15, 4 square per roll, no mopping	0.044	0.037	0.006	0	0
Sheet metal flashing, stainless steel, flexible sheets, .018" thick, 26 gauge, including up to 4 bends	0.124	0.116	0.006	0	0.001
Drip edge, galvanized, 5" wide	0.135	0.126	0.006	0	0.001
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [2000]	10.443	9.558	0.574	0.144	0.178
ClayTiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	4.35	4.091	0.234	0.021	0.019
Aluminum siding, soffit & fascia, vented, 1' overhang	0.925	0.756	0.041	0.004	0.122

Description	Total CO2 (ton)	CO2 (ton)	CH4 (ton)	N2O (ton)	HFC/ PFC (ton)
Felt, asphalt, #15, 4 square per roll, no mopping	0.058	0.049	0.009	0	0
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	0.134	0.126	0.006	0	0.001
Drip edge, galvanized, 5" wide	0.18	0.168	0.009	0	0.002
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [2450]	12.793	11.709	0.704	0.177	0.218
ClayTiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	5.329	5.011	0.286	0.026	0.023
Aluminum siding, soffit & fascia, vented, 1' overhang	1.133	0.926	0.051	0.005	0.15
Felt, asphalt, #15, 4 square per roll, no mopping	0.071	0.06	0.01	0	0.001
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	0.164	0.154	0.008	0	0.002
Drip edge, galvanized, 5" wide	0.22	0.206	0.011	0	0.002
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [3000]	15.665	14.337	0.862	0.217	0.267
ClayTiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	6.525	6.136	0.351	0.032	0.028
Aluminum siding, soffit & fascia, vented, 1' overhang	1.387	1.134	0.062	0.006	0.183
Felt, asphalt, #15, 4 square per roll, no mopping	0.088	0.073	0.013	0	0.001

Description	Total CO2 (ton)	CO2 (ton)	CH4 (ton)	N2O (ton)	HFC/ PFC (ton)
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	0.201	0.189	0.01	0	0.002
Drip edge, galvanized, 5" wide	0.269	0.252	0.013	0.001	0.003
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [3500]	18.276	16.727	1.005	0.253	0.311
ClayTiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	7.613	7.159	0.409	0.037	0.033
Aluminum siding, soffit & fascia, vented, 1' overhang	1.619	1.323	0.072	0.007	0.214
Felt, asphalt, #15, 4 square per roll, no mopping	0.102	0.086	0.015	0.001	0.001
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	0.235	0.22	0.011	0	0.003
Drip edge, galvanized, 5" wide	0.314	0.294	0.015	0.001	0.003

Description	Total CO2 (tons)	CO2 (tons)	CH4 (tons)	N2O (tons)	HFC/PFC (tons)
Two-Story Units					
Wall Systems					
Stucco on Framewood [1500]	11.761	10.610	0.692	0.372	0.087
Exterior wall framing systems, 2" x 4", 16" OC	0.459	0.386	0.034	0.036	0.004
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.501	0.421	0.037	0.039	0.004
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.141	0.119	0.010	0.011	0.001
Furring, wood, 1" x 3", 12" OC	0.298	0.227	0.024	0.045	0.002
Stucco, 2 coats	0.961	0.928	0.026	0.004	0.002
Painting, primer & 1 coat	0.195	0.166	0.018	0.007	0.005
Painting, lath, metal lath expanded 2.5 lb/SY, painted	0.369	0.314	0.034	0.013	0.009
Stucco on Framewood [2000]	14.162	12.773	0.834	0.450	0.105
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.668	0.561	0.050	0.052	0.006
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.188	0.158	0.014	0.015	0.002
Exterior wall framing systems, 2" x 4", 16" OC	0.530	0.445	0.039	0.041	0.004
Furring, wood, 1" x 3", 12" OC	0.343	0.262	0.027	0.052	0.002
Stucco, 2 coats	1.108	1.070	0.030	0.005	0.002
Painting, primer & 1 coat	0.225	0.191	0.021	0.008	0.005
Painting, lath, metal lath expanded 2.5 lb/SY, painted	0.426	0.362	0.040	0.015	0.010
Stucco on Framewood [2450]	16.230	14.636	0.957	0.517	0.120
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.818	0.688	0.061	0.063	0.007
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.231	0.194	0.017	0.018	0.002
Exterior wall framing systems, 2" x 4", 16" OC	0.588	0.494	0.044	0.046	0.005

Description	Total CO2 (tons)	CO2 (tons)	CH4 (tons)	N2O (tons)	HFC/PFC (tons)
Furring, wood, 1" x 3", 12" OC	0.381	0.291	0.030	0.058	0.002
Stucco, 2 coats	1.230	1.188	0.033	0.006	0.003
Painting, primer & 1 coat	0.250	0.212	0.023	0.009	0.006
Painting, lath, metal lath expanded 2.5 lb/SY, painted	0.473	0.402	0.044	0.017	0.011
Stucco on Framewood [3000]	18.263	16.466	1.079	0.584	0.135
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	1.002	0.842	0.074	0.078	0.008
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.282	0.237	0.021	0.022	0.002
Exterior wall framing systems, 2" x 4", 16" OC	0.632	0.532	0.047	0.049	0.005
Furring, wood, 1" x 3", 12" OC	0.410	0.313	0.033	0.062	0.002
Stucco, 2 coats	1.322	1.277	0.036	0.006	0.003
Painting, primer & 1 coat	0.268	0.228	0.025	0.010	0.007
Painting, lath, metal lath expanded 2.5 lb/SY, painted	0.508	0.433	0.047	0.018	0.012
Stucco on Framewood [3500]	20.616	18.586	1.218	0.660	0.152
Exterior wall framing systems, 2" x 4", 16" OC	0.700	0.589	0.052	0.054	0.006
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	1.169	0.983	0.087	0.090	0.010
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.329	0.277	0.024	0.025	0.003
Furring, wood, 1" x 3", 12" OC	0.454	0.346	0.036	0.069	0.002
Stucco, 2 coats	1.464	1.414	0.040	0.007	0.003
Painting, primer & 1 coat	0.297	0.253	0.028	0.011	0.007
Painting, lath, metal lath expanded 2.5 lb/SY, painted	0.563	0.479	0.052	0.020	0.014
Block masonry systems, 8" thick concrete block wall [1500]	15.282	14.121	0.772	0.288	1.264
Masonry reinforcing bars, truss type steel joint reinforcing, mill standard galvanized, 8" wide, 9 ga. sides, 9 ga. ties	0.351	0.329	0.017	0.001	0.004

Description	Total CO2 (tons)	CO2 (tons)	CH4 (tons)	N2O (tons)	HFC/PFC (tons)
Concrete block partitions, normal weight blocks, 2000 psi, 8" x 8" x 16", tooled joints both sides, includes mortar, excludes scaffolding, horizontal reinforcing, vertical reinforcing and grout	3.044	2.944	0.079	0.008	1.175
Furring, wood, on walls, on masonry, 1" x 3"	0.217	0.165	0.017	0.033	0.001
Perlite insulation, R2.7 per inch, poured in	1.414	1.297	0.092	0.012	0.015
Stucco, 3 coats, on masonry construction, incl. lath	0.988	0.955	0.027	0.004	0.002
Paints & Coatings, exterior, brick or concrete, primer + 2 coats, brushwork	0.174	0.148	0.016	0.006	0.004
Block masonry systems, 8" thick concrete block wall [2000]	17.623	16.284	0.890	0.332	1.458
Masonry reinforcing bars, truss type steel joint reinforcing, mill standard galvanized, 8" wide, 9 ga. sides, 9 ga. ties	0.404	0.379	0.019	0.001	0.004
Concrete block partitions, normal weight blocks, 2000 psi, 8" x 8" x 16", tooled joints both sides, includes mortar, excludes scaffolding, horizontal reinforcing, vertical reinforcing and grout	3.510	3.395	0.092	0.010	1.355
Furring, wood, on walls, on masonry, 1" x 3"	0.250	0.191	0.020	0.038	0.001
Perlite insulation, R2.7 per inch, poured in	1.630	1.496	0.106	0.014	0.018
Stucco, 3 coats, on masonry construction, incl. lath	1.140	1.101	0.031	0.005	0.002
Paints & Coatings, exterior, brick or concrete, primer + 2 coats, brushwork	0.201	0.171	0.019	0.007	0.005
Block masonry systems, 8" thick concrete block wall [2450]	19.562	18.075	0.988	0.369	1.618
Masonry reinforcing bars, truss type steel joint reinforcing, mill standard galvanized, 8" wide, 9 ga. sides, 9 ga. ties	0.449	0.421	0.021	0.001	0.005

Description	Total CO2 (tons)	CO2 (tons)	CH4 (tons)	N2O (tons)	HFC/PFC (tons)
Concrete block partitions, normal weight blocks, 2000 psi, 8" x 8" x 16", tooled joints both sides, includes mortar, excludes scaffolding, horizontal reinforcing, vertical reinforcing and grout	3.897	3.769	0.102	0.011	1.504
Furring, wood, on walls, on masonry, 1" x 3"	0.277	0.212	0.022	0.042	0.002
Perlite insulation, R2.7 per inch, poured in	1.810	1.660	0.118	0.016	0.020
Stucco, 3 coats, on masonry construction, incl. lath	1.265	1.222	0.034	0.006	0.003
Paints & Coatings, exterior, brick or concrete, primer + 2 coats, brushwork	0.223	0.190	0.021	0.008	0.005
Block masonry systems, 8" thick concrete block wall [3000]	21.034	19.436	1.062	0.397	1.740
Masonry reinforcing bars, truss type steel joint reinforcing, mill standard galvanized, 8" wide, 9 ga. sides, 9 ga. ties	0.483	0.452	0.023	0.001	0.005
Concrete block partitions, normal weight blocks, 2000 psi, 8" x 8" x 16", tooled joints both sides, includes mortar, excludes scaffolding, horizontal reinforcing, vertical reinforcing and grout	4.190	4.052	0.109	0.011	1.617
Furring, wood, on walls, on masonry, 1" x 3"	0.298	0.227	0.024	0.045	0.002
Perlite insulation, R2.7 per inch, poured in	1.946	1.785	0.127	0.017	0.021
Stucco, 3 coats, on masonry construction, incl. lath	1.360	1.314	0.037	0.006	0.003
Paints & Coatings, exterior, brick or concrete, primer + 2 coats, brushwork	0.240	0.204	0.022	0.009	0.006
Block masonry systems, 8" thick concrete block wall [3500]	23.288	21.518	1.176	0.439	1.926
Masonry reinforcing bars, truss type steel joint reinforcing, mill standard galvanized, 8" wide, 9 ga. sides, 9 ga. ties	0.534	0.501	0.026	0.001	0.006

Description	Total CO2 (tons)	CO2 (tons)	CH4 (tons)	N2O (tons)	HFC/PFC (tons)
Concrete block partitions, normal weight blocks, 2000 psi, 8" x 8" x 16", tooled joints both sides, includes mortar, excludes scaffolding, horizontal reinforcing, vertical reinforcing and grout	4.639	4.486	0.121	0.013	1.790
Furring, wood, on walls, on masonry, 1" x 3"	0.330	0.252	0.026	0.050	0.002
Perlite insulation, R2.7 per inch, poured in	2.154	1.976	0.141	0.019	0.024
Stucco, 3 coats, on masonry construction, incl. lath	1.506	1.455	0.041	0.007	0.003
Paints & Coatings, exterior, brick or concrete, primer + 2 coats, brushwork	0.266	0.226	0.025	0.009	0.006
Brick/stone veneer systems, red faced common brick [1500]	18.257	16.748	1.040	0.371	0.115
Masonry anchors, veneer wall ties, corrugated, galvanized, 22 ga., 7/8" x 7"	0.336	0.315	0.016	0.001	0.004
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.551	0.463	0.041	0.043	0.005
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.155	0.131	0.012	0.012	0.001
Brick veneer masonry, red brick, running bond, T.L. lots, 6.75/S.F., 4" x 2-2/3" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	5.570	5.238	0.299	0.027	0.024
1" x 4" pine, exterior trim, cornice board	0.043	0.033	0.003	0.007	0.000
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	0.237	0.217	0.015	0.002	0.003
Brick/stone veneer systems, red faced common brick [2000]	21.053	19.313	1.200	0.427	0.132
Masonry anchors, veneer wall ties, corrugated, galvanized, 22 ga., 7/8" x 7"	0.388	0.363	0.019	0.001	0.004
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.635	0.534	0.047	0.049	0.005
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.179	0.151	0.013	0.014	0.001

Description	Total CO2 (tons)	CO2 (tons)	CH4 (tons)	N2O (tons)	HFC/PFC (tons)
Brick veneer masonry, red brick, running bond, T.L. lots, 6.75/S.F., 4" x 2-2/3" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	6.423	6.040	0.345	0.032	0.028
1" x 4" pine, exterior trim, cornice board	0.050	0.038	0.004	0.008	0.000
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	0.273	0.251	0.018	0.002	0.003
Brick/stone veneer systems, red faced common brick [2450]	23.369	21.437	1.331	0.474	0.147
Masonry anchors, veneer wall ties, corrugated, galvanized, 22 ga., 7/8" x 7"	0.430	0.403	0.021	0.001	0.005
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.705	0.593	0.052	0.055	0.006
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.199	0.167	0.015	0.015	0.002
Brick veneer masonry, red brick, running bond, T.L. lots, 6.75/S.F., 4" x 2-2/3" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	7.129	6.704	0.383	0.035	0.031
1" x 4" pine, exterior trim, cornice board	0.055	0.042	0.004	0.008	0.000
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	0.303	0.278	0.020	0.003	0.003
Brick/stone veneer systems, red faced common brick [3000]	25.128	23.051	1.432	0.510	0.158
Masonry anchors, veneer wall ties, corrugated, galvanized, 22 ga., 7/8" x 7"	0.463	0.434	0.022	0.001	0.005
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.758	0.638	0.056	0.059	0.006
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.214	0.180	0.016	0.017	0.002
Brick veneer masonry, red brick, running bond, T.L. lots, 6.75/S.F., 4" x 2-2/3" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	7.666	7.209	0.412	0.038	0.033

Description	Total CO2 (tons)	CO2 (tons)	CH4 (tons)	N2O (tons)	HFC/PFC (tons)
1" x 4" pine, exterior trim, cornice board	0.059	0.045	0.005	0.009	0.000
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	0.326	0.299	0.021	0.003	0.004
Brick/stone veneer systems, red faced common brick [3500]	27.820	25.520	1.585	0.565	0.175
Masonry anchors, veneer wall ties, corrugated, galvanized, 22 ga., 7/8" x 7"	0.512	0.480	0.024	0.001	0.005
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.840	0.706	0.062	0.065	0.007
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.237	0.199	0.018	0.018	0.002
Brick veneer masonry, red brick, running bond, T.L. lots, 6.75/S.F., 4" x 2-2/3" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	8.487	7.981	0.456	0.042	0.037
1" x 4" pine, exterior trim, cornice board	0.066	0.050	0.005	0.010	0.000
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	0.361	0.331	0.024	0.003	0.004
Wood siding systems, 1" x 4" tongue & groove, redwood, vertical grain [1500]	15.425	13.583	0.968	0.773	0.104
Moldings, exterior, verge board, redwood, 1" x 4"	0.114	0.093	0.008	0.012	0.001
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.551	0.463	0.041	0.043	0.005
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.155	0.131	0.012	0.012	0.001
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	0.237	0.217	0.015	0.002	0.003
Wood Siding, Boards, board & batten, redwood, clear, vertical grain, 1" x 10"	3.683	3.000	0.265	0.402	0.019
Exterior wall framing systems, 2" x 4", 16" OC	0.213	0.179	0.016	0.016	0.002
Furring, wood, 1" x 3", 12" OC	0.209	0.160	0.017	0.032	0.001
Paints & Coatings, wood siding, primer + 1 coat, incl. puttying	0.113	0.096	0.010	0.004	0.003

Description	Total CO2 (tons)	CO2 (tons)	CH4 (tons)	N2O (tons)	HFC/PFC (tons)
Wood siding systems, 1" x 4" tongue & groove, redwood, vertical grain [2000]	17.787	15.663	1.116	0.891	0.120
Moldings, exterior, verge board, redwood, 1" x 4"	0.132	0.107	0.010	0.014	0.001
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.635	0.534	0.047	0.049	0.005
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.179	0.151	0.013	0.014	0.001
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	0.273	0.251	0.018	0.002	0.003
Wood Siding, Boards, board & batten, redwood, clear, vertical grain, 1" x 10"	4.247	3.459	0.306	0.463	0.022
Exterior wall framing systems, 2" x 4", 16" OC	0.246	0.206	0.018	0.019	0.002
Furring, wood, 1" x 3", 12" OC	0.241	0.184	0.019	0.036	0.001
Paints & Coatings, wood siding, primer + 1 coat, incl. puttying	0.130	0.111	0.012	0.005	0.003
Wood siding systems, 1" x 4" tongue & groove, redwood, vertical grain [2450]	19.744	17.386	1.239	0.989	0.133
Moldings, exterior, verge board, redwood, 1" x 4"	0.146	0.119	0.011	0.016	0.001
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.705	0.593	0.052	0.055	0.006
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.199	0.167	0.015	0.015	0.002
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	0.303	0.278	0.020	0.003	0.003
Wood Siding, Boards, board & batten, redwood, clear, vertical grain, 1" x 10"	4.714	3.840	0.340	0.514	0.024
Exterior wall framing systems, 2" x 4", 16" OC	0.273	0.229	0.020	0.021	0.002
Furring, wood, 1" x 3", 12" OC	0.268	0.205	0.021	0.040	0.001
Paints & Coatings, wood siding, primer + 1 coat, incl. puttying	0.144	0.123	0.013	0.005	0.004
Wood siding systems, 1" x 4" tongue & groove, redwood, vertical grain [3000]	21.230	18.694	1.332	1.064	0.143

Description	Total CO2 (tons)	CO2 (tons)	CH4 (tons)	N2O (tons)	HFC/PFC (tons)
Moldings, exterior, verge board, redwood, 1" x 4"	0.157	0.128	0.011	0.017	0.001
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.758	0.638	0.056	0.059	0.006
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.214	0.180	0.016	0.017	0.002
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	0.326	0.299	0.021	0.003	0.004
Wood Siding, Boards, board & batten, redwood, clear, vertical grain, 1" x 10"	5.069	4.129	0.365	0.553	0.026
Exterior wall framing systems, 2" x 4", 16" OC	0.293	0.246	0.022	0.023	0.002
Furring, wood, 1" x 3", 12" OC	0.288	0.220	0.023	0.044	0.002
Paints & Coatings, wood siding, primer + 1 coat, incl. puttying	0.155	0.132	0.014	0.006	0.004
Wood siding systems, 1" x 4" tongue & groove, redwood, vertical grain [3500]	23.504	20.697	1.475	1.178	0.158
Moldings, exterior, verge board, redwood, 1" x 4"	0.174	0.142	0.013	0.019	0.001
Gable end roof framing systems, 2" x 8" rafters, 16" OC, 4/12 pitch	0.840	0.706	0.062	0.065	0.007
Gable end roof fmg, ceiling joist, #2 or better, 2" x 8", 16" OC	0.237	0.199	0.018	0.018	0.002
Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	0.361	0.331	0.024	0.003	0.004
Wood Siding, Boards, board & batten, redwood, clear, vertical grain, 1" x 10"	5.612	4.571	0.404	0.612	0.029
Exterior wall framing systems, 2" x 4", 16" OC	0.324	0.273	0.024	0.025	0.003
Furring, wood, 1" x 3", 12" OC	0.319	0.244	0.025	0.048	0.002
Paints & Coatings, wood siding, primer + 1 coat, incl. puttying	0.172	0.146	0.016	0.006	0.004
Roof Strucure					
Gable end roofing, asphalt, roof shingles, class A [1500]	2.395	2.099	0.180	0.038	0.077

Description	Total CO2 (tons)	CO2 (tons)	CH4 (tons)	N2O (tons)	HFC/PFC (tons)
Moldings, exterior, verge board, sterling pine, 1" x 6"	0.015	0.012	0.001	0.002	0.000
Asphalt Shingles, standard strip shingles, inorganic, class A, 210-235 lb/sq	0.466	0.391	0.068	0.002	0.003
Asphalt Shingles, ridge shingles	0.042	0.035	0.006	0.000	0.000
Aluminum siding, soffit & fascia, vented, 1' overhang	0.262	0.214	0.012	0.001	0.035
Felt, asphalt, #15, 4 square per roll, no mopping	0.038	0.032	0.006	0.000	0.000
Aluminum downspouts, enameled, 2" x 3", .024" thick	0.052	0.042	0.002	0.000	0.007
Drip edge, galvanized, 5" wide	0.092	0.086	0.004	0.000	0.001
Aluminum gutters, stock units, enameled, 5" box, .027" thick	0.163	0.133	0.007	0.001	0.021
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	0.004	0.003	0.000	0.000	0.000
Gable end roofing, asphalt, roof shingles, class A [2000]	3.194	2.798	0.240	0.051	0.102
Moldings, exterior, verge board, sterling pine, 1" x 6"	0.020	0.016	0.001	0.002	0.000
Asphalt Shingles, standard strip shingles, inorganic, class A, 210-235 lb/sq	0.621	0.521	0.091	0.003	0.005
Asphalt Shingles, ridge shingles	0.056	0.047	0.008	0.000	0.000
Aluminum siding, soffit & fascia, vented, 1' overhang	0.349	0.285	0.016	0.002	0.046
Felt, asphalt, #15, 4 square per roll, no mopping	0.051	0.042	0.007	0.000	0.000
Aluminum downspouts, enameled, 2" x 3", .024" thick	0.069	0.056	0.003	0.000	0.009
Drip edge, galvanized, 5" wide	0.122	0.115	0.006	0.000	0.001
Aluminum gutters, stock units, enameled, 5" box, .027" thick	0.217	0.177	0.010	0.001	0.029
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	0.005	0.005	0.001	0.000	0.000
Gable end roofing, asphalt, roof shingles, class A [2450]	3.912	3.428	0.294	0.062	0.125
Moldings, exterior, verge board, sterling pine, 1" x 6"	0.025	0.020	0.002	0.003	0.000

Description	Total CO2 (tons)	CO2 (tons)	CH4 (tons)	N2O (tons)	HFC/PFC (tons)
Asphalt Shingles, standard strip shingles, inorganic, class A, 210-235 lb/sq	0.761	0.638	0.111	0.004	0.006
Asphalt Shingles, ridge shingles	0.069	0.057	0.010	0.000	0.001
Aluminum siding, soffit & fascia, vented, 1' overhang	0.427	0.349	0.019	0.002	0.056
Felt, asphalt, #15, 4 square per roll, no mopping	0.062	0.052	0.009	0.000	0.000
Aluminum downspouts, enameled, 2" x 3", .024" thick	0.084	0.069	0.004	0.000	0.011
Drip edge, galvanized, 5" wide	0.150	0.141	0.007	0.000	0.002
Aluminum gutters, stock units, enameled, 5" box, .027" thick	0.266	0.217	0.012	0.001	0.035
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	0.007	0.006	0.001	0.000	0.000
Gable end roofing, asphalt, roof shingles, class A [3000]	4.791	4.197	0.359	0.076	0.154
Moldings, exterior, verge board, sterling pine, 1" x 6"	0.030	0.024	0.002	0.003	0.000
Asphalt Shingles, standard strip shingles, inorganic, class A, 210-235 lb/sq	0.931	0.781	0.137	0.005	0.007
Asphalt Shingles, ridge shingles	0.084	0.070	0.012	0.000	0.001
Aluminum siding, soffit & fascia, vented, 1' overhang	0.523	0.428	0.023	0.002	0.069
Felt, asphalt, #15, 4 square per roll, no mopping	0.076	0.064	0.011	0.000	0.001
Aluminum downspouts, enameled, 2" x 3", .024" thick	0.103	0.085	0.005	0.000	0.014
Drip edge, galvanized, 5" wide	0.184	0.172	0.009	0.000	0.002
Aluminum gutters, stock units, enameled, 5" box, .027" thick	0.325	0.266	0.015	0.001	0.043
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	0.008	0.007	0.001	0.000	0.000
Gable end roofing, asphalt, roof shingles, class A [3500]	5.589	4.897	0.419	0.089	0.179
Moldings, exterior, verge board, sterling pine, 1" x 6"	0.035	0.029	0.003	0.004	0.000
Asphalt Shingles, standard strip shingles, inorganic, class A, 210-235 lb/sq	1.087	0.912	0.159	0.006	0.008

Description	Total CO2 (tons)	CO2 (tons)	CH4 (tons)	N2O (tons)	HFC/PFC (tons)
Asphalt Shingles, ridge shingles	0.098	0.082	0.014	0.000	0.001
Aluminum siding, soffit & fascia, vented, 1' overhang	0.611	0.499	0.027	0.003	0.081
Felt, asphalt, #15, 4 square per roll, no mopping	0.088	0.074	0.013	0.000	0.001
Aluminum downspouts, enameled, 2" x 3", .024" thick	0.121	0.099	0.005	0.001	0.016
Drip edge, galvanized, 5" wide	0.214	0.201	0.010	0.000	0.002
Aluminum gutters, stock units, enameled, 5" box, .027" thick	0.380	0.310	0.017	0.002	0.050
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	0.010	0.008	0.001	0.000	0.000
Gable end roofing, wood, cedar shingles no. 1 perfections, 18" long [1500]	3.897	3.405	0.236	0.170	0.085
Moldings, exterior, verge board, sterling pine, 1" x 6"	0.015	0.012	0.001	0.002	0.000
Wood shingles, no. 1 red cedar perfections, 18" long, 5-1/2" exposure on roof	0.959	0.781	0.069	0.105	0.005
Wood shingles, ridge shakes or shingle wood	0.055	0.045	0.004	0.006	0.000
Aluminum siding, soffit & fascia, vented, 1' overhang	0.262	0.214	0.012	0.001	0.035
Felt, asphalt, #15, 4 square per roll, no mopping	0.038	0.032	0.006	0.000	0.000
Aluminum downspouts, enameled, 2" x 3", .024" thick	0.052	0.042	0.002	0.000	0.007
Drip edge, galvanized, 5" wide	0.092	0.086	0.004	0.000	0.001
Aluminum gutters, stock units, enameled, 5" box, .027" thick	0.163	0.133	0.007	0.001	0.021
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	0.004	0.003	0.000	0.000	0.000
Gable end roofing, wood, cedar shingles no. 1 perfections, 18" long [2000]	5.196	4.540	0.314	0.227	0.113
Moldings, exterior, verge board, sterling pine, 1" x 6"	0.020	0.016	0.001	0.002	0.000
Wood shingles, no. 1 red cedar perfections, 18" long, 5-1/2" exposure on roof	1.279	1.041	0.092	0.140	0.007

Description	Total CO2 (tons)	CO2 (tons)	CH4 (tons)	N2O (tons)	HFC/PFC (tons)
Wood shingles, ridge shakes or shingle wood	0.073	0.060	0.005	0.008	0.000
Aluminum siding, soffit & fascia, vented, 1' overhang	0.349	0.285	0.016	0.002	0.046
Felt, asphalt, #15, 4 square per roll, no mopping	0.051	0.042	0.007	0.000	0.000
Aluminum downspouts, enameled, 2" x 3", .024" thick	0.069	0.056	0.003	0.000	0.009
Drip edge, galvanized, 5" wide	0.122	0.115	0.006	0.000	0.001
Aluminum gutters, stock units, enameled, 5" box, .027" thick	0.217	0.177	0.010	0.001	0.029
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	0.005	0.005	0.001	0.000	0.000
Gable end roofing, wood, cedar shingles no. 1 perfections, 18" long [2450]	6.365	5.561	0.385	0.278	0.139
Moldings, exterior, verge board, sterling pine, 1" x 6"	0.025	0.020	0.002	0.003	0.000
Wood shingles, no. 1 red cedar perfections, 18" long, 5-1/2" exposure on roof	1.566	1.276	0.113	0.171	0.008
Wood shingles, ridge shakes or shingle wood	0.090	0.073	0.006	0.010	0.000
Aluminum siding, soffit & fascia, vented, 1' overhang	0.427	0.349	0.019	0.002	0.056
Felt, asphalt, #15, 4 square per roll, no mopping	0.062	0.052	0.009	0.000	0.000
Aluminum downspouts, enameled, 2" x 3", .024" thick	0.084	0.069	0.004	0.000	0.011
Drip edge, galvanized, 5" wide	0.150	0.141	0.007	0.000	0.002
Aluminum gutters, stock units, enameled, 5" box, .027" thick	0.266	0.217	0.012	0.001	0.035
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	0.007	0.006	0.001	0.000	0.000
Gable end roofing, wood, cedar shingles no. 1 perfections, 18" long [3000]	7.793	6.810	0.471	0.341	0.170
Moldings, exterior, verge board, sterling pine, 1" x 6"	0.030	0.024	0.002	0.003	0.000
Wood shingles, no. 1 red cedar perfections, 18" long, 5-1/2" exposure on roof	1.918	1.562	0.138	0.209	0.010

Description	Total CO2 (tons)	CO2 (tons)	CH4 (tons)	N2O (tons)	HFC/PFC (tons)
Wood shingles, ridge shakes or shingle wood	0.110	0.089	0.008	0.012	0.001
Aluminum siding, soffit & fascia, vented, 1' overhang	0.523	0.428	0.023	0.002	0.069
Felt, asphalt, #15, 4 square per roll, no mopping	0.076	0.064	0.011	0.000	0.001
Aluminum downspouts, enameled, 2" x 3", .024" thick	0.103	0.085	0.005	0.000	0.014
Drip edge, galvanized, 5" wide	0.184	0.172	0.009	0.000	0.002
Aluminum gutters, stock units, enameled, 5" box, .027" thick	0.325	0.266	0.015	0.001	0.043
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	0.008	0.007	0.001	0.000	0.000
Gable end roofing, wood, cedar shingles no. 1 perfections, 18" long [3500]	9.092	7.945	0.550	0.398	0.199
Moldings, exterior, verge board, sterling pine, 1" x 6"	0.035	0.029	0.003	0.004	0.000
Wood shingles, no. 1 red cedar perfections, 18" long, 5-1/2" exposure on roof	2.238	1.823	0.161	0.244	0.012
Wood shingles, ridge shakes or shingle wood	0.128	0.104	0.009	0.014	0.001
Aluminum siding, soffit & fascia, vented, 1' overhang	0.611	0.499	0.027	0.003	0.081
Felt, asphalt, #15, 4 square per roll, no mopping	0.088	0.074	0.013	0.000	0.001
Aluminum downspouts, enameled, 2" x 3", .024" thick	0.121	0.099	0.005	0.001	0.016
Drip edge, galvanized, 5" wide	0.214	0.201	0.010	0.000	0.002
Aluminum gutters, stock units, enameled, 5" box, .027" thick	0.380	0.310	0.017	0.002	0.050
Paints & Coatings, wood trim, primer + 1 coat, over 6" wide, incl. puttying	0.010	0.008	0.001	0.000	0.000
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [1500]	4.633	4.202	0.236	0.072	0.119
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	1.043	0.993	0.037	0.004	0.006

Description	Total CO2 (tons)	CO2 (tons)	CH4 (tons)	N2O (tons)	HFC/PFC (tons)
Aluminum siding, soffit & fascia, vented, 1' overhang	0.694	0.567	0.031	0.003	0.092
Felt, asphalt, #15, 4 square per roll, no mopping	0.044	0.037	0.006	0.000	0.000
Sheet metal flashing, stainless steel, flexible sheets, .018" thick, 26 gauge, including up to 4 bends	0.124	0.116	0.006	0.000	0.001
Drip edge, galvanized, 5" wide	0.135	0.126	0.006	0.000	0.001
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [2000]	6.142	5.569	0.312	0.096	0.158
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	1.390	1.324	0.049	0.006	0.008
Aluminum siding, soffit & fascia, vented, 1' overhang	0.925	0.756	0.041	0.004	0.122
Felt, asphalt, #15, 4 square per roll, no mopping	0.058	0.049	0.009	0.000	0.000
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	0.134	0.126	0.006	0.000	0.001
Drip edge, galvanized, 5" wide	0.180	0.168	0.009	0.000	0.002
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [2450]	7.524	6.822	0.383	0.118	0.194
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	1.703	1.622	0.060	0.007	0.010
Aluminum siding, soffit & fascia, vented, 1' overhang	1.133	0.926	0.051	0.005	0.150
Felt, asphalt, #15, 4 square per roll, no mopping	0.071	0.060	0.010	0.000	0.001
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	0.164	0.154	0.008	0.000	0.002
Drip edge, galvanized, 5" wide	0.220	0.206	0.011	0.000	0.002

Description	Total CO2 (tons)	CO2 (tons)	CH4 (tons)	N2O (tons)	HFC/PFC (tons)
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [3000]	9.213	8.353	0.468	0.144	0.237
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	2.086	1.986	0.073	0.009	0.013
Aluminum siding, soffit & fascia, vented, 1' overhang	1.387	1.134	0.062	0.006	0.183
Felt, asphalt, #15, 4 square per roll, no mopping	0.088	0.073	0.013	0.000	0.001
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	0.201	0.189	0.010	0.000	0.002
Drip edge, galvanized, 5" wide	0.269	0.252	0.013	0.001	0.003
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [3500]	10.748	9.745	0.546	0.168	0.277
Concrete Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	2.433	2.317	0.085	0.010	0.015
Aluminum siding, soffit & fascia, vented, 1' overhang	1.619	1.323	0.072	0.007	0.214
Felt, asphalt, #15, 4 square per roll, no mopping	0.102	0.086	0.015	0.001	0.001
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	0.235	0.220	0.011	0.000	0.003
Drip edge, galvanized, 5" wide	0.314	0.294	0.015	0.001	0.003
Built-up roof, asphalt, organic, 4-ply, insulated deck [1500]	3.966	3.580	0.287	0.066	0.034
2" x 6" miscellaneous wood blocking, to wood construction	0.019	0.014	0.001	0.003	0.000
Wood framing, roof cants, split, 4" x 4"	0.017	0.013	0.001	0.003	0.000
Roof Deck Insulation, fiberglass, 1-1/16" thick, R4.17	1.340	1.229	0.087	0.012	0.015

Description	Total CO2 (tons)	CO2 (tons)	CH4 (tons)	N2O (tons)	HFC/PFC (tons)
Built-up roofing systems, asphalt flood coat with gravel/slag surfacing, coated & saturated base sheet, 4-plies #15 asphalt felt, mopped, excl. insulation, flashing or wood nailers	0.558	0.468	0.082	0.003	0.004
Sheet metal flashing, aluminum, flexible, mill finish, .040" thick, including up to 4 bends	0.183	0.171	0.009	0.000	0.002
Built-up roof, asphalt, organic, 4-ply, insulated deck [2000]	5.288	4.774	0.383	0.088	0.045
2" x 6" miscellaneous wood blocking, to wood construction	0.025	0.019	0.002	0.004	0.000
Wood framing, roof cants, split, 4" x 4"	0.023	0.018	0.002	0.003	0.000
Roof Deck Insulation, fiberglass, 1-1/16" thick, R4.17	1.787	1.639	0.117	0.016	0.020
Built-up roofing systems, asphalt flood coat with gravel/slag surfacing, coated & saturated base sheet, 4-plies #15 asphalt felt, mopped, excl. insulation, flashing or wood nailers	0.744	0.624	0.109	0.004	0.006
Sheet metal flashing, aluminum, flexible, mill finish, .040" thick, including up to 4 bends	0.244	0.228	0.012	0.000	0.003
Built-up roof, asphalt, organic, 4-ply, insulated deck [2450]	6.478	5.848	0.469	0.108	0.055
2" x 6" miscellaneous wood blocking, to wood construction	0.031	0.023	0.002	0.005	0.000
Wood framing, roof cants, split, 4" x 4"	0.028	0.021	0.002	0.004	0.000
Roof Deck Insulation, fiberglass, 1-1/16" thick, R4.17	2.189	2.008	0.143	0.019	0.024
Built-up roofing systems, asphalt flood coat with gravel/slag surfacing, coated & saturated base sheet, 4-plies #15 asphalt felt, mopped, excl. insulation, flashing or wood nailers	0.911	0.764	0.134	0.005	0.007
Sheet metal flashing, aluminum, flexible, mill finish, .040" thick, including up to 4 bends	0.299	0.280	0.014	0.001	0.003
Built-up roof, asphalt, organic, 4-ply, insulated deck [3000]	7.933	7.161	0.574	0.132	0.067
2" x 6" miscellaneous wood blocking, to wood construction	0.038	0.029	0.003	0.006	0.000

Description	Total CO2 (tons)	CO2 (tons)	CH4 (tons)	N2O (tons)	HFC/PFC (tons)
Wood framing, roof cants, split, 4" x 4"	0.034	0.026	0.003	0.005	0.000
Roof Deck Insulation, fiberglass, 1-1/16" thick, R4.17	2.680	2.459	0.175	0.024	0.029
Built-up roofing systems, asphalt flood coat with gravel/slag surfacing, coated & saturated base sheet, 4-plies #15 asphalt felt, mopped, excl. insulation, flashing or wood nailers	1.116	0.936	0.164	0.006	0.008
Sheet metal flashing, aluminum, flexible, mill finish, .040" thick, including up to 4 bends	0.366	0.343	0.017	0.001	0.004
Built-up roof, asphalt, organic, 4-ply, insulated deck [3500]	9.255	8.354	0.670	0.154	0.079
2" x 6" miscellaneous wood blocking, to wood construction	0.044	0.034	0.003	0.007	0.000
Wood framing, roof cants, split, 4" x 4"	0.040	0.031	0.003	0.006	0.000
Roof Deck Insulation, fiberglass, 1-1/16" thick, R4.17	3.127	2.868	0.204	0.027	0.034
Built-up roofing systems, asphalt flood coat with gravel/slag surfacing, coated & saturated base sheet, 4-plies #15 asphalt felt, mopped, excl. insulation, flashing or wood nailers	1.302	1.092	0.191	0.007	0.010
Sheet metal flashing, aluminum, flexible, mill finish, .040" thick, including up to 4 bends	0.426	0.400	0.020	0.001	0.005
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [1500]	7.860	7.194	0.432	0.108	0.134
ClayTiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	3.263	3.068	0.175	0.016	0.014
Aluminum siding, soffit & fascia, vented, 1' overhang	0.694	0.567	0.031	0.003	0.092
Felt, asphalt, #15, 4 square per roll, no mopping	0.044	0.037	0.006	0.000	0.000
Sheet metal flashing, stainless steel, flexible sheets, .018" thick, 26 gauge, including up to 4 bends	0.124	0.116	0.006	0.000	0.001
Drip edge, galvanized, 5" wide	0.135	0.126	0.006	0.000	0.001

Description	Total CO2 (tons)	CO2 (tons)	CH4 (tons)	N2O (tons)	HFC/PFC (tons)
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [2000]	10.443	9.558	0.574	0.144	0.178
ClayTiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	4.350	4.091	0.234	0.021	0.019
Aluminum siding, soffit & fascia, vented, 1' overhang	0.925	0.756	0.041	0.004	0.122
Felt, asphalt, #15, 4 square per roll, no mopping	0.058	0.049	0.009	0.000	0.000
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	0.134	0.126	0.006	0.000	0.001
Drip edge, galvanized, 5" wide	0.180	0.168	0.009	0.000	0.002
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [2450]	12.793	11.709	0.704	0.177	0.218
ClayTiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	5.329	5.011	0.286	0.026	0.023
Aluminum siding, soffit & fascia, vented, 1' overhang	1.133	0.926	0.051	0.005	0.150
Felt, asphalt, #15, 4 square per roll, no mopping	0.071	0.060	0.010	0.000	0.001
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	0.164	0.154	0.008	0.000	0.002
Drip edge, galvanized, 5" wide	0.220	0.206	0.011	0.000	0.002
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [3000]	15.665	14.337	0.862	0.217	0.267
ClayTiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	6.525	6.136	0.351	0.032	0.028
Aluminum siding, soffit & fascia, vented, 1' overhang	1.387	1.134	0.062	0.006	0.183

Description	Total CO2 (tons)	CO2 (tons)	CH4 (tons)	N2O (tons)	HFC/PFC (tons)
Felt, asphalt, #15, 4 square per roll, no mopping	0.088	0.073	0.013	0.000	0.001
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	0.201	0.189	0.010	0.000	0.002
Drip edge, galvanized, 5" wide	0.269	0.252	0.013	0.001	0.003
Clay Tiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories [3500]	18.276	16.727	1.005	0.253	0.311
ClayTiles, shakes, all colors, nailed to wood deck, 90 per square, 950 lb per square, 13" x 16-1/2", incl. installation of accessories	7.613	7.159	0.409	0.037	0.033
Aluminum siding, soffit & fascia, vented, 1' overhang	1.619	1.323	0.072	0.007	0.214
Felt, asphalt, #15, 4 square per roll, no mopping	0.102	0.086	0.015	0.001	0.001
Sheet metal flashing, copper, flexible, under 1,000 lbs, 16 ounce sheets, including up to 4 bends	0.235	0.220	0.011	0.000	0.003
Drip edge, galvanized, 5" wide	0.314	0.294	0.015	0.001	0.003

APPENDIX G

GHG EMISSIONS TOTALS RESULTS

Size - 1 story		1500					2000				
		Total CO_2	CO_2	CH_4	N_2O	HFC PFC	Total CO_2	CO_2	CH_4	N_2O	HFC PFC
Baseline		140.08	131.01	5.66	2.42	1.91	174.57	163.41	6.95	3.00	2.46
Material Combinations		**GHG Emissions Results (baseline values included) [ton]**									
Stucco	Asphalt Shingle	157.33	146.43	6.77	2.91	2.16	194.53	181.22	8.24	3.55	2.77
Stucco	Wood	160.34	149.04	6.88	3.18	2.18	198.53	184.71	8.39	3.91	2.79
Stucco	Build Up	160.48	149.39	6.98	2.97	2.07	198.72	185.17	8.53	3.63	2.65
Stucco	Concrete Tile	161.81	150.63	6.88	2.98	2.24	200.43	186.76	8.39	3.64	2.88
Stucco	Clay Tile	168.26	156.62	7.27	3.05	2.27	209.03	194.74	8.91	3.74	2.92
8" Painted Block	Asphalt Shingle	158.77	148.05	6.73	2.76	3.22	199.49	186.12	8.37	3.46	4.20
8" Painted Block	Wood	161.77	150.66	6.84	3.03	3.24	203.49	189.60	8.52	3.81	4.22
8" Painted Block	Build Up	161.91	151.01	6.94	2.82	3.13	203.67	190.07	8.66	3.53	4.08
8" Painted Block	Concrete Tile	163.24	152.25	6.84	2.83	3.30	205.38	191.66	8.51	3.55	4.31
8" Painted Block	Clay Tile	169.70	158.24	7.23	2.91	3.33	213.98	199.64	9.04	3.65	4.35
Brick	Asphalt Shingle	164.80	153.42	7.17	2.96	2.20	207.53	193.29	8.96	3.71	2.84
Brick	Wood	167.80	156.03	7.28	3.22	2.21	211.53	196.77	9.11	4.07	2.86
Brick	Build Up	167.94	156.38	7.39	3.01	2.11	211.72	197.24	9.25	3.79	2.72
Brick	Concrete Tile	169.28	157.63	7.28	3.02	2.28	213.43	198.83	9.11	3.80	2.95
Brick	Clay Tile	175.73	163.61	7.68	3.10	2.31	222.03	206.81	9.63	3.90	2.99
Wood Shingles	Asphalt Shingle	163.41	151.60	7.18	3.37	2.20	204.66	189.95	8.91	4.23	2.83
Wood Shingles	Wood	166.41	154.21	7.29	3.64	2.21	208.66	193.43	9.06	4.58	2.85
Wood Shingles	Build Up	166.55	154.56	7.39	3.43	2.11	208.85	193.90	9.20	4.30	2.71
Wood Shingles	Concrete Tile	167.89	155.80	7.29	3.44	2.28	210.55	195.49	9.06	4.32	2.94
Wood Shingles	Clay Tile	174.34	161.79	7.68	3.51	2.31	219.16	203.47	9.58	4.41	2.98

Size - 1 story		2450					3000				
		Total CO_2	CO_2	CH_4	N_2O	HFC PFC	Total CO_2	CO_2	CH_4	N_2O	HFC PFC
Baseline		204.28	191.24	8.10	3.54	2.95	240.52	225.18	9.51	4.18	3.55
Material Combinations		**GHG Emissions Results (baseline values included) [ton]**									
Stucco	Asphalt Shingle	227.33	211.80	9.59	4.17	3.32	267.09	248.87	11.24	4.89	3.99
Stucco	Wood	232.24	216.07	9.77	4.60	3.34	273.10	254.10	11.46	5.42	4.02
Stucco	Build Up	232.46	216.64	9.94	4.26	3.17	273.38	254.80	11.67	5.00	3.82
Stucco	Concrete Tile	234.55	218.59	9.77	4.28	3.45	275.94	257.18	11.46	5.03	4.16
Stucco	Clay Tile	245.09	228.36	10.41	4.40	3.50	288.84	269.15	12.25	5.17	4.22
8" Painted Block	Asphalt Shingle	234.81	219.06	9.83	4.10	5.08	277.89	259.25	11.63	4.86	6.16
8" Painted Block	Wood	239.71	223.33	10.02	4.53	5.11	283.90	264.47	11.86	5.39	6.20
8" Painted Block	Build Up	239.94	223.90	10.18	4.19	4.94	284.17	265.17	12.06	4.97	5.99
8" Painted Block	Concrete Tile	242.03	225.85	10.01	4.21	5.22	286.73	267.56	11.85	5.00	6.33
8" Painted Block	Clay Tile	252.57	235.63	10.65	4.33	5.27	299.64	279.53	12.64	5.14	6.39
Brick	Asphalt Shingle	244.66	227.84	10.56	4.41	3.41	289.96	270.00	12.53	5.24	4.12
Brick	Wood	249.57	232.11	10.75	4.84	3.44	295.96	275.22	12.75	5.77	4.15
Brick	Build Up	249.79	232.68	10.91	4.50	3.27	296.24	275.93	12.96	5.35	3.95
Brick	Concrete Tile	251.88	234.63	10.74	4.52	3.55	298.80	278.31	12.74	5.38	4.29
Brick	Clay Tile	262.42	244.41	11.38	4.64	3.60	311.71	290.28	13.53	5.52	4.35
Wood Shingles	Asphalt Shingle	240.46	223.14	10.46	5.01	3.40	284.12	263.63	12.35	5.94	4.10
Wood Shingles	Wood	245.36	227.41	10.64	5.44	3.42	290.13	268.86	12.58	6.47	4.13
Wood Shingles	Build Up	245.59	227.98	10.81	5.10	3.26	290.41	269.56	12.78	6.06	3.92
Wood Shingles	Concrete Tile	247.68	229.93	10.63	5.12	3.53	292.97	271.95	12.57	6.08	4.26
Wood Shingles	Clay Tile	258.22	239.71	11.28	5.24	3.58	305.87	283.91	13.36	6.23	4.32

Size - 1 story		3500				
		Total CO_2	CO_2	CH_4	N_2O	HFC PFC
Baseline		270.30	253.01	10.69	4.74	4.10
Material Combinations		**GHG Emissions Results (baseline values included) [ton]**				
Stucco	Asphalt Shingle	304.94	283.92	12.93	5.69	4.63
Stucco	Wood	311.95	290.02	13.19	6.31	4.67
Stucco	Build Up	312.27	290.83	13.43	5.82	4.43
Stucco	Concrete Tile	315.26	293.62	13.18	5.85	4.82
Stucco	Clay Tile	330.32	307.58	14.10	6.02	4.89
8" Painted Block	Asphalt Shingle	313.90	292.76	13.17	5.53	7.14
8" Painted Block	Wood	320.90	298.86	13.43	6.15	7.18
8" Painted Block	Build Up	321.23	299.68	13.67	5.66	6.94
8" Painted Block	Concrete Tile	324.21	302.46	13.42	5.69	7.33
8" Painted Block	Clay Tile	339.27	316.42	14.34	5.86	7.40
Brick	Asphalt Shingle	327.98	305.30	14.21	5.97	4.75
Brick	Wood	334.98	311.40	14.47	6.59	4.79
Brick	Build Up	335.31	312.22	14.71	6.10	4.55
Brick	Concrete Tile	338.29	315.00	14.46	6.13	4.95
Brick	Clay Tile	353.35	328.96	15.38	6.30	5.02
Wood Shingles	Asphalt Shingle	320.66	297.43	13.97	6.77	4.72
Wood Shingles	Wood	327.66	303.52	14.23	7.39	4.76
Wood Shingles	Build Up	327.99	304.34	14.47	6.90	4.52
Wood Shingles	Concrete Tile	330.98	307.12	14.23	6.93	4.92
Wood Shingles	Clay Tile	346.03	321.09	15.14	7.10	4.99

Size - 2 story		1500					2000				
		Total CO_2	CO_2	CH_4	N_2O	HFC PFC	Total CO_2	CO_2	CH_4	N_2O	HFC PFC
Baseline		102.08	94.23	4.92	2.17	1.47	119.83	110.69	5.70	2.56	1.69
Material Combinations		**GHG Emissions Results (baseline values included) [ton]**									
Stucco	Asphalt Shingle	116.24	106.94	5.79	2.58	1.63	137.19	126.26	6.78	3.06	1.90
Stucco	Wood	117.74	108.24	5.85	2.71	1.64	139.19	128.00	6.85	3.24	1.91
Stucco	Build Up	117.81	108.42	5.90	2.61	1.59	139.28	128.24	6.92	3.10	1.84
Stucco	Concrete Tile	118.47	109.04	5.85	2.61	1.67	140.13	129.03	6.85	3.10	1.95
Stucco	Clay Tile	121.70	112.03	6.04	2.65	1.69	144.44	133.02	7.11	3.15	1.97
8" Painted Block	Asphalt Shingle	119.76	110.45	5.87	2.50	2.81	140.65	129.77	6.83	2.94	3.25
8" Painted Block	Wood	121.26	111.76	5.93	2.63	2.82	142.65	131.51	6.91	3.12	3.26
8" Painted Block	Build Up	121.33	111.93	5.98	2.52	2.77	142.74	131.75	6.98	2.98	3.19
8" Painted Block	Concrete Tile	122.00	112.55	5.93	2.53	2.85	143.60	132.54	6.90	2.99	3.31
8" Painted Block	Clay Tile	125.22	115.55	6.12	2.57	2.87	147.90	136.53	7.17	3.04	3.33
Brick	Asphalt Shingle	122.73	113.08	6.14	2.58	1.66	144.08	132.80	7.14	3.04	1.92
Brick	Wood	124.23	114.38	6.19	2.71	1.67	146.08	134.54	7.22	3.21	1.94
Brick	Build Up	124.30	114.56	6.25	2.61	1.62	146.17	134.78	7.28	3.07	1.87
Brick	Concrete Tile	124.97	115.18	6.19	2.61	1.70	147.03	135.57	7.21	3.08	1.98
Brick	Clay Tile	128.20	118.17	6.39	2.65	1.72	151.33	139.56	7.48	3.13	2.00
Wood Shingles	Asphalt Shingle	119.90	109.91	6.07	2.98	1.65	140.81	129.15	7.06	3.50	1.91
Wood Shingles	Wood	121.40	111.22	6.12	3.11	1.66	142.81	130.89	7.13	3.68	1.92
Wood Shingles	Build Up	121.47	111.39	6.17	3.01	1.61	142.91	131.13	7.20	3.54	1.85
Wood Shingles	Concrete Tile	122.14	112.01	6.12	3.01	1.69	143.76	131.92	7.13	3.55	1.97
Wood Shingles	Clay Tile	125.36	115.01	6.32	3.05	1.71	148.06	135.91	7.39	3.59	1.99

Size – 2 story		2450					3000				
		Total CO_2	CO_2	CH_4	N_2O	HFC PFC	Total CO_2	CO_2	CH_4	N_2O	HFC PFC
Baseline		143.47	132.53	6.83	3.05	1.95	185.81	171.67	8.80	3.94	2.43
Material Combinations		**GHG Emissions Results (baseline values included) [ton]**									
Stucco	Asphalt Shingle	163.62	150.60	8.08	3.63	2.19	208.86	192.33	10.24	4.60	2.72
Stucco	Wood	166.07	152.73	8.18	3.85	2.21	211.86	194.95	10.35	4.87	2.74
Stucco	Build Up	166.18	153.02	8.26	3.67	2.12	212.00	195.30	10.46	4.66	2.63
Stucco	Concrete Tile	167.23	153.99	8.17	3.68	2.26	213.28	196.49	10.35	4.67	2.80
Stucco	Clay Tile	172.50	158.88	8.49	3.74	2.29	219.73	202.47	10.74	4.75	2.83
8" Painted Block	Asphalt Shingle	166.95	154.04	8.11	3.48	3.69	211.63	195.30	10.22	4.42	4.32
8" Painted Block	Wood	169.40	156.17	8.21	3.70	3.71	214.63	197.92	10.34	4.68	4.34
8" Painted Block	Build Up	169.51	156.46	8.29	3.53	3.62	214.77	198.27	10.44	4.47	4.24
8" Painted Block	Concrete Tile	170.56	157.43	8.20	3.54	3.76	216.05	199.46	10.33	4.49	4.41
8" Painted Block	Clay Tile	175.83	162.32	8.53	3.60	3.78	222.50	205.44	10.73	4.56	4.44
Brick	Asphalt Shingle	170.76	157.40	8.46	3.59	2.22	215.72	198.92	10.59	4.53	2.74
Brick	Wood	173.21	159.53	8.55	3.80	2.23	218.73	201.53	10.71	4.80	2.76
Brick	Build Up	173.32	159.82	8.63	3.63	2.15	218.87	201.88	10.81	4.59	2.66
Brick	Concrete Tile	174.37	160.79	8.55	3.64	2.29	220.15	203.07	10.70	4.60	2.82
Brick	Clay Tile	179.64	165.68	8.87	3.70	2.31	226.60	209.06	11.10	4.67	2.85
Wood Shingles	Asphalt Shingle	167.13	153.35	8.37	4.10	2.21	211.83	194.56	10.49	5.08	2.73
Wood Shingles	Wood	169.58	155.48	8.46	4.32	2.22	214.83	197.17	10.61	5.35	2.74
Wood Shingles	Build Up	169.70	155.77	8.54	4.15	2.14	214.97	197.53	10.71	5.14	2.64
Wood Shingles	Concrete Tile	170.74	156.74	8.46	4.16	2.27	216.25	198.72	10.60	5.15	2.81
Wood Shingles	Clay Tile	176.01	161.63	8.78	4.22	2.30	222.70	204.70	11.00	5.22	2.84

Size - 2 story		3500				
		Total CO_2	**CO_2**	**CH_4**	**N_2O**	**HFC PFC**
Baseline		188.38	174.00	8.97	4.01	2.46
Material Combinations		**GHG Emissions Results (baseline values included) [ton]**				
Stucco	Asphalt Shingle	214.59	197.48	10.60	4.75	2.79
Stucco	Wood	218.09	200.53	10.73	5.06	2.81
Stucco	Build Up	218.25	200.94	10.85	4.82	2.69
Stucco	Concrete Tile	219.75	202.33	10.73	4.83	2.88
Stucco	Clay Tile	227.27	209.31	11.19	4.92	2.92
8" Painted Block	Asphalt Shingle	217.26	200.41	10.56	4.53	4.56
8" Painted Block	Wood	220.76	203.46	10.69	4.84	4.58
8" Painted Block	Build Up	220.92	203.87	10.81	4.60	4.46
8" Painted Block	Concrete Tile	222.42	205.26	10.69	4.61	4.66
8" Painted Block	Clay Tile	229.95	212.24	11.15	4.70	4.69
Brick	Asphalt Shingle	221.79	204.41	10.97	4.66	2.81
Brick	Wood	225.29	207.46	11.10	4.97	2.83
Brick	Build Up	225.46	207.87	11.22	4.72	2.71
Brick	Concrete Tile	226.95	209.26	11.10	4.74	2.91
Brick	Clay Tile	234.48	216.24	11.56	4.82	2.94
Wood Shingles	Asphalt Shingle	217.47	199.59	10.86	5.27	2.79
Wood Shingles	Wood	220.98	202.64	10.99	5.58	2.81
Wood Shingles	Build Up	221.14	203.05	11.11	5.34	2.69
Wood Shingles	Concrete Tile	222.63	204.44	10.99	5.35	2.89
Wood Shingles	Clay Tile	230.16	211.42	11.45	5.44	2.92

APPENDIX H

PaLATE RESULT PER LANE-MILE

Phase	Mat. Course	Energy [MJ]	CO2 [kg]	NOx [g]	PM_{10} [g]	SO2 [g]	CO [g]	VOC [g]
				Local (Urban) Layer Specifications				
C - Mat. Product.	Wearing Course 1	3,537,818	301,805	311,233	654,924	553,371	905,381	27,729
C - Mat. Product.	Wearing Course 2	4,245,382	362,166	403,733	785,909	664,045	1,086,458	33,275
C - Mat. Product.	Subbase 1	1,290,653	90,207	134,617	20,331	200,537	256,049	0
C - Mat. Product.	Embkt & Shoulder	0	0	0	0	0	0	0
C - Mat. Product.	**Total**	**9,073,854**	**754,178**	**849,583**	**1,461,165**	**1,417,953**	**2,247,888**	**61,005**
C - Mat. Transp.	Wearing Course 1	281,772	21,065	1,122,271	215,544	67,336	93,523	0
C - Mat. Transp.	Wearing Course 2	338,127	25,278	1,346,726	258,693	80,804	112,227	0
C - Mat. Transp.	Subbase 1	313,831	23,462	1,249,958	243,650	74,998	104,163	0
C - Mat. Transp.	Embkt and Shoulder	0	0	0	0	0	0	0
C - Mat. Transp.	**Total**	**933,730**	**69,805**	**3,718,956**	**717,886**	**223,137**	**309,913**	**0**
C - Process (equip.)	Wearing Course 1	6,610	496	11,567	6,905	765	2,493	2,057,178
C - Process (equip.)	Wearing Course 2	7,932	595	13,881	996	918	2,991	2,468,613
C - Process (equip.)	Wearing Course 3	0	0	0	0	0	0	0
C - Process (equip.)	Subbase 1	53,883	4,044	81,017	9,586	5,358	17,458	0
C - Process (equip.)	Subbase 3	0	0	0	0	0	0	0
C - Process (equip.)	**Total**	**68,424**	**5,136**	**106,464**	**17,488**	**7,040**	**22,941**	**4,525,791**
M - Mat. Product.	Wearing Course 1	353,782	30,181	33,644	65,492	55,337	90,538	2,773
M - Mat. Product.	Wearing Course 2	424,538	36,217	40,373	78,591	66,405	108,646	3,328
M - Mat. Product.	Embkt and Shoulder	0	0	0	0	0	0	0
M - Mat. Product.	**Total**	**778,320**	**66,397**	**74,018**	**144,083**	**121,742**	**199,184**	**6,100**
M - Mat. Transp.	Wearing Course 1	28,177	2,107	112,227	22,086	6,734	9,352	0
M - Mat. Transp.	Wearing Course 2	33,813	2,528	134,673	26,253	8,080	11,223	0
M - Mat. Transp.	Wearing Course 3	0	0	0	0	0	0	0
M - Mat. Transp.	Embkt and Shoulder	0	0	0	0	0	0	0
M - Mat. Transp.	**Total**	**61,990**	**4,634**	**246,900**	**48,339**	**14,814**	**20,575**	**0**
M - Process (equip.)	Wearing Course 1	1,342	101	2,348	187	155	506	205,718
M - Process (equip.)	Wearing Course 2	1,610	121	2,818	201	186	607	246,861
M - Process (equip.)	Wearing Course 3	0	0	0	0	0	0	0
M - Process (equip.)	Embkt and Shoulder	0	0	0	0	0	0	0
M - Process (equip.)	Total	**2,952**	**222**	**5,166**	**388**	**342**	**1,113**	**452,579**

Phase	Mat. Course	Energy [MJ]	CO2 [kg]	NOx [g]	PM_{10} [g]	SO2 [g]	CO [g]	VOC [g]
		Collector (Urban) Layer Specifications						
C - Mat. Product.	Wearing Course 1	4,354,238	371,452	383,057	806,061	681,072	1,114,316	34,129
C - Mat. Product.	Wearing Course 2	5,551,654	473,602	527,958	1,027,728	868,367	1,420,752	43,514
C - Mat. Product.	Subbase 1	1,886,339	131,841	196,747	29,715	293,092	374,225	0
C - Mat. Product.	Embkt and Shoulder	0	0	0	0	0	0	0
C - Mat. Product.	**Total**	**11,792,231**	**976,895**	**1,107,762**	**1,863,503**	**1,842,531**	**2,909,294**	**77,642**
C - Mat. Transp.	Wearing Course 1	346,796	25,926	1,381,257	265,285	82,875	115,105	0
C - Mat. Transp.	Wearing Course 2	442,165	33,056	1,761,103	338,290	105,666	146,759	0
C - Mat. Transp.	Subbase 1	458,676	34,290	1,826,862	356,104	109,612	152,239	0
C - Mat. Transp.	Embkt and Shoulder	0	0	0	0	0	0	0
C - Mat. Transp.	**Total**	**1,247,638**	**93,272**	**4,969,222**	**959,679**	**298,153**	**414,102**	**0**
C - Process (equip.)	Wearing Course 1	8,135	611	14,236	8,498	941	3,068	2,531,911
C - Process (equip.)	Wearing Course 2	10,372	778	18,151	1,303	1,200	3,911	3,228,187
C - Process (equip.)	Subbase 1	78,752	5,911	118,409	14,011	7,830	25,515	0
C - Process (equip.)	Embkt and Shoulder	0	0	0	0	0	0	0
C - Process (equip.)	**Total**	**97,259**	**7,300**	**150,797**	**23,812**	**9,972**	**32,494**	**5,760,098**
M - Mat. Product.	Wearing Course 1	435,424	37,145	41,408	80,606	68,107	111,432	3,413
M - Mat. Product.	Wearing Course 2	555,165	47,360	52,796	102,773	86,837	142,075	4,351
M - Mat. Product.	Embkt and Shoulder	0	0	0	0	0	0	0
M - Mat. Product.	**Total**	**990,589**	**84,505**	**94,204**	**183,379**	**154,944**	**253,507**	**7,764**
M - Mat. Transp.	Wearing Course 1	34,680	2,593	138,126	27,182	8,288	11,510	0
M - Mat. Transp.	Wearing Course 2	44,217	3,306	176,110	34,331	10,567	14,676	0
M - Mat. Transp.	Embkt and Shoulder	0	0	0	0	0	0	0
M - Mat. Transp.	**Total**	**78,896**	**5,898**	**314,236**	**61,513**	**18,854**	**26,186**	**0**
M - Process (equip.)	Wearing Course 1	1,651	124	2,890	234	191	623	253,191
M - Process (equip.)	Wearing Course 2	2,106	158	3,685	263	244	794	322,819
M - Process (equip.)	Embkt and Shoulder	0	0	0	0	0	0	0
M - Process (equip.)	**Total**	**3,757**	**282**	**6,575**	**497**	**435**	**1,417**	**576,010**

Phase	Mat. Course	Energy [MJ]	CO2 [kg]	NOx [g]	PM_{10} [g]	SO2 [g]	CO [g]	VOC [g]
				Major Arterial (Urban) Layer Specifications				
C - Mat. Product.	Wearing Course 1	5,714,937	487,531	502,762	1,057,955	893,907	1,462,539	44,794
C - Mat. Product.	Wearing Course 2	7,048,423	601,289	670,300	1,304,811	1,102,485	1,803,798	55,246
C - Mat. Product.	Subbase 1	2,035,261	142,249	212,280	32,061	316,231	403,769	0
C - Mat. Product.	Embkt and Shoulder	0	0	0	0	0	0	0
C - Mat. Product.	**Total**	**14,798,621**	**1,231,069**	**1,385,341**	**2,394,827**	**2,312,624**	**3,670,107**	**100,039**
C - Mat. Transp.	Wearing Course 1	455,170	34,028	1,812,900	348,186	108,774	151,075	0
C - Mat. Transp.	Wearing Course 2	561,377	41,968	2,235,910	429,496	134,155	186,326	0
C - Mat. Transp.	Subbase 1	494,887	36,997	1,971,088	384,217	118,265	164,257	0
C - Mat. Transp.	Embkt and Shoulder	0	0	0	0	0	0	0
C - Mat. Transp.	**Total**	**1,511,434**	**112,994**	**6,019,899**	**1,161,900**	**361,194**	**501,658**	**0**
C - Process (equip.)	Wearing Course 1	10,677	801	18,685	11,154	1,236	4,026	3,323,133
C - Process (equip.)	Wearing Course 2	13,169	988	23,045	1,654	1,524	4,966	4,098,531
C - Process (equip.)	Subbase 1	84,969	6,377	127,757	15,117	8,448	27,530	0
C - Process (equip.)	Embkt and Shoulder	0	0	0	0	0	0	0
C - Process (equip.)	**Total**	**108,815**	**8,167**	**169,487**	**27,925**	**11,208**	**36,522**	**7,421,664**
M - Mat. Product.	Wearing Course 1	571,494	48,753	54,349	105,795	89,391	146,254	4,479
M - Mat. Product.	Wearing Course 2	704,842	60,129	67,030	130,481	110,249	180,380	5,525
M - Mat. Product.	Embkt and Shoulder	0	0	0	0	0	0	0
M - Mat. Product.	**Total**	**1,276,336**	**108,882**	**121,379**	**236,277**	**199,639**	**326,634**	**10,004**
M - Mat. Transp.	Wearing Course 1	45,517	3,403	181,290	35,677	10,877	15,108	0
M - Mat. Transp.	Wearing Course 2	56,138	4,197	223,591	43,587	13,415	18,633	0
M - Mat. Transp.	Embkt and Shoulder	0	0	0	0	0	0	0
M - Mat. Transp.	**Total**	**101,655**	**7,600**	**404,881**	**79,264**	**24,293**	**33,740**	**0**
M - Process (equip.)	Wearing Course 1	2,167	163	3,793	301	251	817	332,313
M - Process (equip.)	Wearing Course 2	2,673	201	4,678	334	309	1,008	409,853
M - Process (equip.)	Embkt and Shoulder	0	0	0	0	0	0	0
M - Process (equip.)	**Total**	**4,841**	**363**	**8,471**	**635**	**560**	**1,825**	**742,166**