

# **A Life Cycle Approach to Prioritizing Methods of Preventing Waste from the Residential Construction Sector in the State of Oregon**

**Phase 2 Report, Version 1.4 - Executive Summary**

*Prepared for DEQ by Quantis, Earth Advantage, and Oregon Home Builders Association*

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State of Oregon  
Department of  
Environmental  
Quality



## Project Team and Acknowledgements

The project team consisted of Jon Dettling, Amanda Pike and Dominic Pietro of Quantis; Bruce Sullivan, Indigo Teiwes, and Bill Jones of Earth Advantage; and Johnathan Balkema of the Oregon Home Builders Association. The Quantis staff conducted the LCA portions of the project. Earth Advantage provided the energy use modeling and a variety of other related research. The Oregon Home Builders Association modeled the standard and modified home structures and supplied realistic inventories of construction materials. Jordan Palmeri, Wendy Anderson and David Allaway of the Oregon Department of Environmental Quality provided valuable insight and information throughout the study. Sebastien Humbert and Olivier Joliet of Quantis provided quality control with regard to detailed technical aspects of the LCA. A 50-member external stakeholder panel reviewed initial findings and provided comments. In addition, a three-member panel of LCA experts, led by Dr. Arpad Horvath and including Dr. Greg Keoleian and Dr. Tom Gloria have provided a review based on the ISO LCA guidelines (ISO 14040), results of which are included as an appendix.

## Executive Summary

### Overview and Project Goals

The purpose of this project was to evaluate the environmental benefits of potential actions aimed at reducing material use and preventing waste during the design, construction, maintenance, and demolition of residential buildings within the state of Oregon. Within this report, the phrase waste prevention practices<sup>1</sup> is used to describe practices that reduce material use or reuse materials—and subsequently reduce waste generation.

Although the environmental benefits of the practices evaluated appear on the surface to be waste-related, much of the environmental benefit from many of these practices are gained not through the avoidance of needing to manage waste, but rather through avoided manufacturing and production of materials and/or the potential that some such practices may also reduce energy used by the

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<sup>1</sup> Waste prevention is distinguished throughout the report from such terms as “waste treatment” or “waste management,” which include such activities as recycling, incinerating and landfilling. These latter activities do not reduce the amount of waste that is created, but rather are means of managing it. The goals of this report are strictly to evaluate means of *preventing* waste from the residential construction sector.

home. It is therefore essential to consider benefits that may occur over the entire life cycle of residential homes and of the materials they contain.

The ultimate goal of this project is to support decisions by the Oregon Department of Environmental Quality and others in their efforts to form programs, policies, and actions to prevent waste generation from the residential building sector in a way that maximizes overall environmental benefits.

## Boundaries and Assumptions

This assessment considers production and manufacture of all materials comprising the structure of the home, transportation of these materials to and from the site of the home, construction, maintenance of the structure, use of the home (including heating and cooling energy, electricity use, and water use/heating), demolition, and management of all waste materials. The lifespan of the homes modeled in this project was 70 years. Given the highly variable nature of a home's lifespan, there was a sensitivity test conducted for this variable.

Generally, those items that would typically be included with a home when it is sold or rented are included (e.g. refrigerator, furnace, water heater). Not considered within the lifecycle are home furnishings, cleaning supplies, other materials or services purchased by the occupants, or the yard, fences, and driveways. Additionally, this study does not consider any impacts associated with the direct occupation of land area by the home, impacts associated with daily transportation of the residents, or any indirect effects through development patterns.

This project has been conducted to maximize applicability within the state of Oregon, and it should be noted that the assumptions made may limit the value of applying the results to other geographies.

The study is based on the best available information at the time the project was conducted. It should be recognized that the complexity of the systems in question and the necessity to predict unknown future conditions lead to a relatively large amount of uncertainty and the results shown should be considered to be scientific predictions rather than factual.

## Methodology

### Overview of Approach

The project is divided into two phases: The purpose of Phase 1 was to efficiently screen a list of candidate waste prevention practices to determine which ones to consider in more detail in Phase

2, which is the basis of this report. Phase 1 results can be found on DEQ’s website.<sup>2</sup> Practices chosen for Phase 2 evaluation were those that showed the greatest potential to prevent waste and provide overall environmental benefit, as well as those with complex issues not able to be fully explored in the first phase.

The objectives of Phase 2 (this report) are to evaluate the impacts generated during the life cycle of (1) a typical home in Oregon under different construction scenarios and (2) the entire home population of Oregon. The latter includes all homes presently standing and those built until the end of 2030. In addition, a variety of improvements are made to the underlying data and methodology employed in the second phase.

### Waste Prevention Practices

The construction practices assessed in this report are listed below. The original list (which included about 30 practices in Phase 1) was generated by DEQ staff through a literature search and in consultation with numerous residential building professionals in Oregon. The list was revised at the initiation of both phases to include additional practices anticipated to provide important insight regarding the project goals.

**Table 1: Construction practices evaluated in this study.**

Home Size	Multi-Family Housing	Wall Framing
<ul style="list-style-type: none"> <li>• Extra-small (1149 sqft)</li> <li>• Small(1633 sqft)</li> <li>• Medium(2262 sqft)</li> <li>• Large(3424 sqft)</li> </ul>	<ul style="list-style-type: none"> <li>• 4-unit (2262 sqft)</li> <li>• 8-unit (1149 sqft)</li> <li>• 12-unit (1149 sqft)</li> </ul>	<ul style="list-style-type: none"> <li>• Intermediate Framing</li> <li>• Advanced Floor Framing</li> <li>• Advanced Framing (with drywall clips)</li> <li>• Double Wall</li> <li>• Insulating Concrete Forms (ICFs)</li> <li>• Staggered Stud</li> <li>• Strawbale Home</li> <li>• Structural Insulated Panels (SIPs)</li> </ul>
Multiple Waste Prevention Practices		Material Selection
<ul style="list-style-type: none"> <li>• Waste Prevention Home (including a combination of waste prevention practices)</li> </ul>		<ul style="list-style-type: none"> <li>• Durable Roofing, Flooring and Siding</li> </ul>
Material Reuse Scenarios		Benchmarks
<ul style="list-style-type: none"> <li>• Deconstruction, Restoration and Reuse (Moderate)</li> <li>• Deconstruction, Restoration and Reuse (High)</li> </ul>		<ul style="list-style-type: none"> <li>• Green Certified Home</li> <li>• High Performance Shell Home</li> <li>• Optimized End-of-Life, Reuse Excluded</li> </ul>

<sup>2</sup> <http://www.deq.state.or.us/lq/sw/wasteprevention/greenbuilding.htm>

## LCA Modeling Methodology

The evaluation of the building practices is accomplished using a combination of three models, as follows:

1. A CAD (computer aided design) model of the building structure created by the Oregon Home Builders Association to represent a standard Oregon home;
2. REM/Rate, commercially available software capable of estimating home energy use; and
3. A customized LCA-based calculation system created for this project in MS Excel. Supporting LCA work is conducted in the SimaPro commercial LCA software.

The building material lists provided by the OHBA model and the energy use provided by REM/Rate are used to characterize the building practice scenarios within the LCA modeling framework.

It should be recognized that this model uses a steady-state approach, implying that the quantity of annual impacts is assumed to be the same for each year of occupancy.

### The Individual Home Models

The *Medium Standard Home* is a theoretical residence whose characteristics are selected to represent a relatively standard new construction home of average size in Oregon which meets the minimal 2008 Oregon Energy Efficiency Specialty Code requirements. This standard residence is the baseline against which all waste prevention practices are evaluated.

The *Average Homes* are a series of home models developed by averaging the properties of homes across the state, specifically home size and building practices. Therefore, this model does not emulate a real home but an average of home properties in Oregon. *Average Homes* have been created in the four size categories defined, and for the three sizes of multi-family structures. In addition, different *Average Home* models are employed for new-construction (i.e., post-2010) and pre-existing (pre-2010) homes to reflect an expected difference in energy efficiency among these homes.

### Modeling the Population of Homes

Using the results of the *Average Home* models and the population numbers for the state, the total impact of the housing sector in Oregon is computed to identify the magnitude impact or benefits that might result from waste prevention actions or policies when applied at the level of the entire state. When estimating statewide impacts, consideration is made of the proportion of homes in various size categories, single- and multi-family buildings (including multi-family buildings of various sizes), heating and cooling type, geographic zone, as well as distinguishing the energy efficiency of pre-existing and new construction homes. For this population of homes, impacts are assessed through the year 2210, at which point the great majority of homes existing as of 2030 are anticipated to have been demolished.

## Results

Principle results from this study are highlighted, as follows:

- For *Climate Change Impact*, the use of the home contributes about 86% of the total impact due to energy use (space and water heating, electricity consumption); materials production contributes 14%; followed by the construction, maintenance, and demolition phases which contribute a combined 2%; transportation of materials comprises less than 1%. Oregon's current waste management practices (recycling and energy recovery) for construction materials reduce the *Climate Change* impacts by about 4%.
- Energy use during the home's lifetime is the dominant contributor to most environmental impacts;
- Production of original and replacement materials are important contributors for several impact categories;
- Materials transport, construction, maintenance and demolition activities, and material end-of-life handling are relatively minor contributors in most impact categories;
- Only a small amount, approximately 6%, of the *Waste Generation* is predicted to occur during construction, with approximately 50% occurring during 70 years of use and maintenance and the remaining 44% occurring at the time of demolition;
- The combined practices of the waste prevention home show the greatest benefit in waste prevention, followed by material reuse, multi-family housing, small homes, green certification, and durable materials;
- Across all categories, the environmental impact of the *Extra-small Home (1149 sqft)* are reduced between 20% and 40% that of the *Medium Standard Home (2262 sqft)*, suggesting that home size is among the most important determinants of environmental impact;
- Depending on their design, multifamily homes are shown to be capable of providing benefit (10-15% reduction in impact) in comparison to equally sized single family homes;
- Material production impact alone is a relatively poor indicator of total environmental performance of building materials, especially those that influence home energy use;
- Carpeting, asphalt shingles, fiberglass insulation, drywall, wood, and appliances are identified as the chief contributors to environmental impacts in the *Medium Standard Home*;
- Metal components, some plastics, and fiberglass insulation are materials with high potential for benefit from reuse per kilogram of material. When considering indirect land use impacts, reusing wood can have substantial benefits.
- When material reuse is "high" (2/3 of the home is comprised of reused material that is reused at its end of life), most environmental impacts are substantially reduced, especially waste generation; and
- Negligible correlation exists between waste prevention and overall environmental impact of the alternative wall assemblies evaluated.

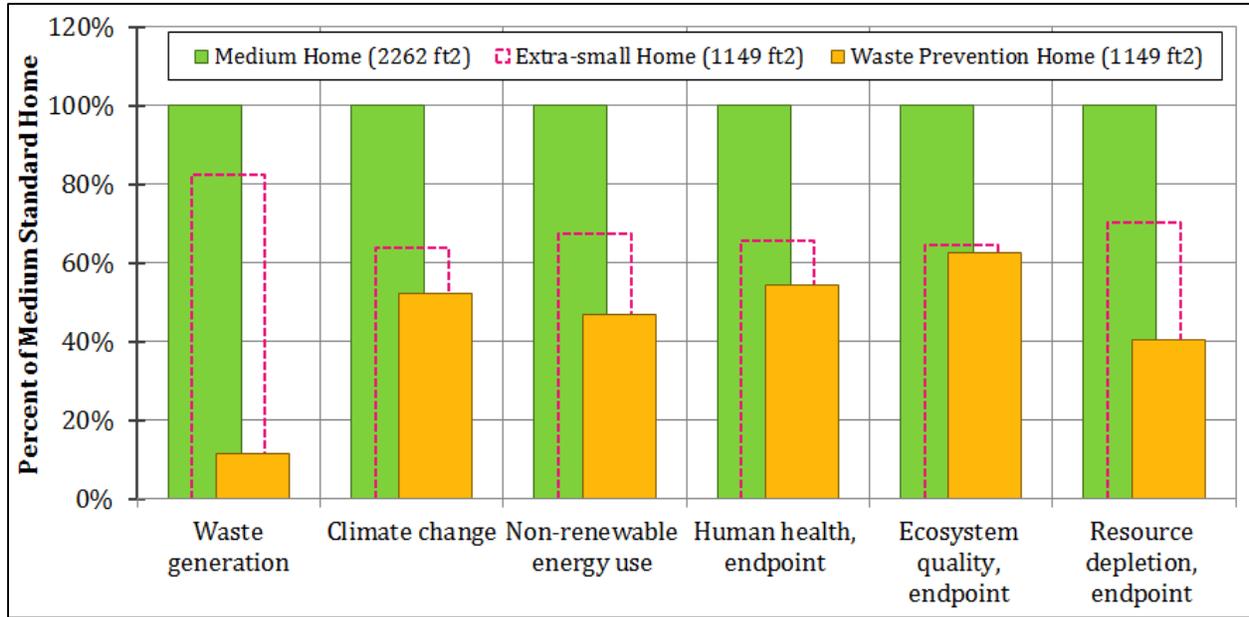


Figure 1: Summary of environmental benefits resulting from a home combining multiple waste prevention practices in comparison to a standard medium sized home and standard extra-small home

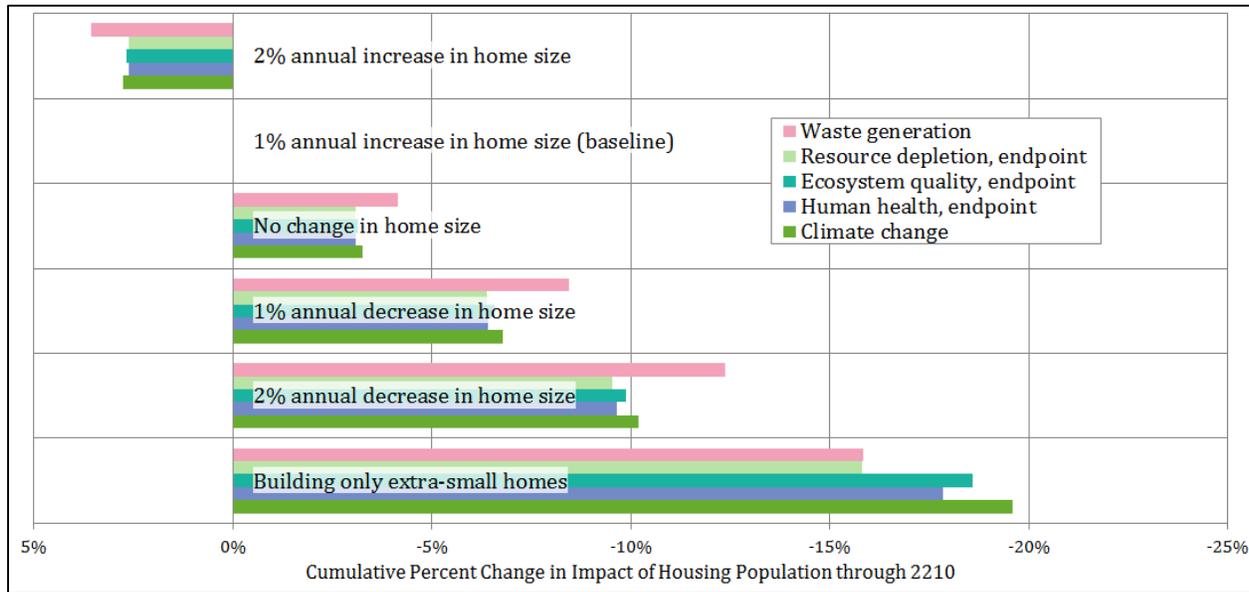
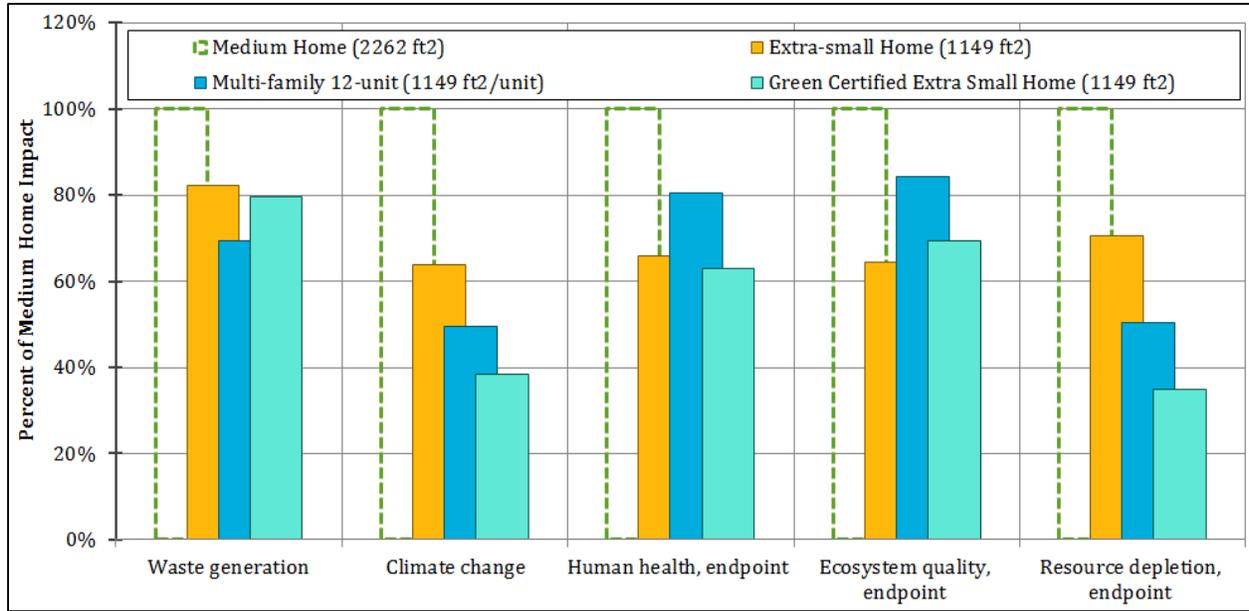
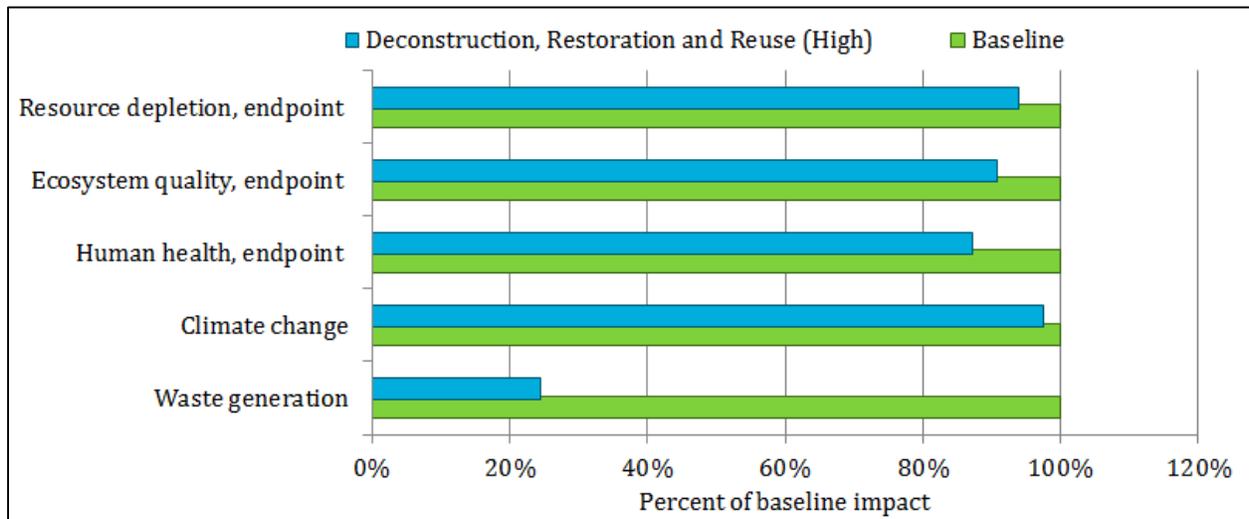


Figure 2: Summary of environmental benefits achieved over the entire home population life cycle by a given reduction in new home construction size for population of homes existing in 2010 or built before 2030



**Figure 3: Summary of additional environmental benefit or impact of multi-family homes and homes with green certification in comparison to a home of similar size (extra-small) and a medium sized home**



**Figure 4: Summary of environmental benefits over their entire lifecycle achieved by salvaging and reusing 67% of materials in all Oregon homes existing in 2010 or built prior to 2030 through a program of deconstruction, restoration and material reuse**

## Implications, Conclusions and Recommendations

These results have important implications for policy-making in Oregon, particularly the following:

- Waste prevention practices that noticeably affect a home's energy use show the most potential to reduce other environmental impacts;
- Many of the waste prevention practices, especially those regarding home design, may have a long delay between their implementation and the realization of the reduction in material entering the waste stream although the benefits associated with reduced material production and reduction in operational energy use may be seen more immediately;
- Reducing home size is among the best tier of options for reducing waste generation in the Oregon housing sector, while simultaneously achieving a large environmental benefit across many categories of impact. Increased density and fewer home possessions were not explicitly included in the scope of this study and could further contribute to the benefit of small homes;
- Policies that reverse the trend in increasing house size would be extremely beneficial for both waste prevention and a broad range of environmental impacts and even modest decreases in home size are likely to produce important environmental outcomes;
- Families who choose or require more living space may mitigate a larger home's impact by adding green building practices. The relationship between home size and environmental impacts suggests that larger homes be held to a more stringent building standard;
- Reduction in home size is a significant leverage point for impact reduction and may be a more effective measure than achieving minimum levels of "green certification";
- If "larger" homes are still desired, one could consider designing an Accessory Dwelling Unit (ADU) directly into the new home. Providing flexibility and adaptability for different family configurations over time can provide more density of people within the home, thereby reducing the overall impacts of the home on a per person basis. Additionally, ADUs can be income generating rentals which may be an attractive option to homebuyers in today's market
- Depending on building design and materials, there could be an environmental benefit to promoting multi-family housing relative to single family homes;
- Reusing certain materials and selecting environmentally preferable materials can improve environmental performance, however, both require thorough analysis of individual materials and components;
- When selecting or substituting materials, each stage of a material's life cycle must be assessed to understand the relative environmental benefit;
- Wall framing practices should be selected based on overall environmental profile rather than being solely based on their ability to reduce material use or reuse materials due to their strong influence to operational energy use;
- A combination of numerous waste prevention practices show a potential for both a high level of reduction in waste generation as well as in a broad range of environmental impacts;

The implications above can be used to guide the Oregon DEQ and interested parties in better understanding environmental impacts associated with a wide variety of waste prevention practices applicable to residential buildings. The use of LCA provides a comprehensive view of the environmental implications of more than 30 building-related practices, in addition to several benchmarking activities.

The results indicate that the most beneficial action for overall improvement in environmental performance of the housing stock, while preventing waste, is to reverse the past trend toward increasing the size of homes. Similarly, multi-family housing presents a substantial level of environmental benefit.

To achieve maximum waste prevention and environmental benefits, a wide variety of practices that prevent waste generation, as exemplified by the Waste Prevention Home examined here, could be promoted and adopted.

Beyond preventing the use of materials, it is possible to address the environmental impact of those materials that are used by selecting materials for environmental performance and by reusing materials. While material substitution may be logistically simple in many cases, material selection is a very complicated manner. Better data and a thorough analysis are needed in each case to determine material preference. The LCA framework contained in the International Standards Organization (ISO) standards, and employed here, provide a roadmap for handling material selection. Selecting on the basis of product attributes alone, such as durability does not guarantee a high overall environmental performance.

Those building materials effecting energy use require an analysis that considers the entire life cycle of the home. The case of wall framing, examined in detail here, is shown to be an issue for which waste prevention is not a good guide for selecting the best environmentally performing options.

Material reuse, though clearly having the potential for environmental benefits, presents logistical challenges and presents some risks for added environmental impact. If promoted, it should be done aggressively to ensure that good information on this topic is produced and circulated and that infrastructure exists to allow efficient collection and transport of materials.