

ENVIRONMENTAL PRODUCT DECLARATION

TYVEK® MECHANICALLY FASTENED AIR AND WATER BARRIER SYSTEM



DuPont™ Tyvek® Mechanically Fastened Air and Water Barrier Systems offer outstanding protection for gypsum, CMU, and many common sheathing substrat



DuPont Protection Solutions is a strategic business unit of DuPont, bringing dynamic science to the discovery and development of innovative products and services for commercial and residential construction. DuPont Protection Solutions is committed to increasing the performance of building systems and creating energy efficient and durable structures. DuPont is the only manufacturer to offer both Mechanically Fastened and mechanically fastened building wrap air and water barrier systems. DuPont™ Tyvek® commercial air and water barrier systems help effectively seal the building envelope. When you choose DuPont products for your next project, you get products that meet the highest performance standards and are backed by industry-leading building science and unrivaled industry support provided by the DuPont™ Tyvek® Specialists Network and the DuPont™ Building Knowledge Center.



ENVIRONMENTAL PRODUCT DECLARATION





TYVEK® MECHANICALLY FASTENED WEATHER BARRIER SYSTEMS
AIR BARRIER FOR COMMERCIAL CONSTRUCTION

According to ISO 14025

This declaration is an environmental product declaration (EPD) in accordance with ISO 14025. EPDs rely on Life Cycle Assessment (LCA) to provide information on a number of environmental impacts of products over their life cycle. Exclusions: EPDs do not indicate that any environmental or social performance benchmarks are met, and there may be impacts that they do not encompass. LCAs do not typically address the site-specific environmental impacts of raw material extraction, nor are they meant to assess human health toxicity. EPDs can complement but cannot replace tools and certifications that are designed to address these impacts and/or set performance thresholds – e.g. Type 1 certifications, health assessments and declarations, environmental impact assessments, etc. Accuracy of Results: EPDs regularly rely on estimations of impacts, and the level of accuracy in estimation of effect differs for any particular product line and reported impact. Comparability: EPDs are not comparative assertions and are either not comparable or have limited comparability when they cover different life cycle stages, are based on different product category rules or are missing relevant environmental impacts. EPDs from different programs may not be comparable.



| | | |
|---|--|--|
| PROGRAM OPERATOR | UL Environment | |
| DECLARATION HOLDER | DuPont | |
| DECLARATION NUMBER | 4787059050.102.1 | |
| DECLARED PRODUCT | Tyvek® Mechanically Fastened Air and Water Barrier Systems | |
| REFERENCE PCR | IBU Part B: Plastic and elastomer roofing and sealing sheet systems. With UL part A and part B addendum | |
| DATE OF ISSUE | June 21, 2017 | |
| PERIOD OF VALIDITY | 5 Years | |
| CONTENTS OF THE DECLARATION | Product definition and information about building physics Information about basic material and the material's origin Description of the product's manufacture Indication of product processing Information about the in-use conditions Life cycle assessment results Testing results and verifications | |
| The PCR review was conducted by: | Institut und Umwelt e.V. | |
| | Independent Expert Committee | |
| | info@ibu-epd.com | |
| This declaration was independently verified in accordance with ISO 14025 by Underwriters Laboratories <input type="checkbox"/> INTERNAL <input checked="" type="checkbox"/> EXTERNAL |  | |
| | Wade Stout, UL Environment | |
| This life cycle assessment was independently verified in accordance with ISO 14044 and the reference PCR by: |  | |
| | Thomas P. Gloria, Industrial Ecology Consultants | |



TYVEK® MECHANICALLY FASTENED AIR AND WATER BARRIER SYSTEM
AIR AND WATER BARRIER FOR COMMERCIAL CONSTRUCTION

According to ISO 14025

Product

Product Description

DuPont™ Tyvek® Mechanically Fastened Air and Water Barrier Systems provide the building envelope with an essential line of defense against air infiltration, water penetration and wasted energy. Mechanically fastened systems are available in residential and commercial grade. DuPont has been the industry leader since it invented the building wrap category more than 30 years ago. Today, the integrated mechanically fastened air and water barrier systems applies DuPont's expertise in building and material science deliver innovative solutions for the next generation of new construction and renovation of existing buildings, including:

- Sustainable building design and construction
- Superior protection
- Energy efficiency
- Ease of installation
- Enhanced durability
- Integrated solutions
- Expert support

Tyvek® Mechanically Fastened Air and Water Barrier Systems provide an ideal combination of air infiltration and bulk water penetration resistance with vapor permeability, allowing incidental moisture to escape so that the building envelope can dry out. Different project specifications dictate different installation scenarios, such as low-rise and high-performance systems, and require different combinations and quantities of component products. Products in the systems include:

- Tyvek® HomeWrap™
- Tyvek® CommercialWrap™
- 6" FlexWrap™
- 9" FlexWrap™
- 4" StraightFlash™
- 6" StraightFlash™ Versatile Flange (VF)
- 9" StraightFlash™
- 4" DuPont™ Flashing Tape
- 2" Tyvek® Tape
- 3" Tyvek® Tape
- 1" Wrap Cap Staples
- 2" Wrap Cap Screws

Application

Specific installation guidelines exist for specific construction types and performance requirements. Tyvek® Mechanically Fastened Air and Water Barrier Systems are installed from low-rise buildings, to high-rise, high-performance commercial projects. Following the installation guidelines for the specific project requirements is essential to achieving the intended performance.

Technical Data

Technical data for DuPont's wrap components are shown in Table 1. Separate values are provided for Tyvek® HomeWrap™ and Tyvek® CommercialWrap™ as these are respectively used in low-rise and high-performance installations.





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Table 1: Product Properties for Tyvek® Mechanically Fastened Air and Water Barrier

| Property | Value | Unit |
|--|--|--|
| Air Penetration Resistance - Material (ASTM E2178) Tyvek® HomeWrap™ Tyvek® CommercialWrap™ | <0.004 <0.001 | CFM/SF @ 75 Pa |
| Wall Assembly Air Penetration Resistance (ASTM E2357) Tyvek® HomeWrap™ ("low-rise" assembly) Tyvek® CommercialWrap™ ("high-performance" assembly) | N/A <0.01 | CFM/SF @ 75 Pa |
| Wall Assembly Air Penetration Resistance (ASTM E1677) Tyvek® HomeWrap™ ("low-rise" assembly) Tyvek® CommercialWrap™ ("high-performance" assembly) | Type 1 Type 1 | CFM/SF @ 75 Pa |
| Wall Assembly Air Penetration Resistance (ASTM E283) Tyvek® HomeWrap™ ("low-rise" assembly) Tyvek® CommercialWrap™ ("high-performance" assembly) | <0.04 <0.01 | CFM/SF @ 75 Pa |
| Water Penetration Resistance (ATTCC127) Tyvek® HomeWrap™ Tyvek® CommercialWrap™ | 250 280 | cm |
| Wall Assembly Water Penetration Resistance (ASTM E331) Tyvek® HomeWrap™ ("low-rise" assembly) Tyvek® CommercialWrap™ ("high-performance" assembly) | >0.56 PSF Tested to 15 PSF | No Leakage |
| Water Vapor Transmission (ASTM E05, Method B) Tyvek® HomeWrap™ Tyvek® CommercialWrap™ | 54 28 | Perms |
| AAMA 711-13, Self-Adhering Flashing Used for Installation of Exterior Wall Fenestration Products | Level 3 Thermal Exposure (80°C/176°F for 7 days) | Class A (no primer) |
| Ultraviolet Light Exposure (UV) – Accelerating Weathering (G155) Tyvek® HomeWrap™ ("low-rise" assembly) Tyvek® CommercialWrap™ ("high-performance" assembly) | 4 9 | months |
| Flame Propagation. Multiple Assemblies (NFPA 285) Tyvek® HomeWrap™ ("low-rise" assembly) Tyvek® CommercialWrap™ ("high-performance" assembly) | N/A Pass | N/A Multiple Assemblies |
| Surface Burning Characteristics (ASTM E84) Tyvek® HomeWrap™ Tyvek® CommercialWrap™ | Class A – 15/15 Class A - 10/10 | Class Flame Spread Index / Smoke Developed Index |
| Basis Weight (TAPPI T-410) Residential (Tyvek® HW) Commercial (Tyvek® CW) | 1.8 2.7 | oz./yd² |

Placing on the Market / Application Rules

The products considered in this EPD conform to the following technical specifications for Air and Water Resistive





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Barriers (WRB)

- Air Barriers: ASTM E2178-2008 (Standard Test Method for Air Permeance of Building Materials); ASTM E2357-2011 (Standard Test Method for Determining Air Leakage of Air Barrier Assemblies); ASTM E1677-2011, Standard Specification for Air Barrier (AB) Material or System for Low-Rise Framed Building Walls
- Water Resistive Barriers: ICC-ES AC38 (Acceptance Criteria For Water-Resistive Barriers); ASTM E331 (Wall Assembly Water Penetration Resistance); ASTM E96-2000/E96M-2005 (Test Methods for Water Vapor Transmission of Materials)
- Flashing: ASTM E-331 (Installed System Water Intrusion Testing); ASTM E-96 (Water Vapor Permeability)

Delivery Status

The majority of products are shipped in rolls of varying lengths.

Base Materials / Ancillary Materials

The products in Tyvek® Mechanically Fastened Air and Water Barrier Systems are primarily based on flashspun high-density polyethylene and, in the case of Tyvek® Tape and flashing products, adhesive for self-adhered application. Two scenarios are considered in this EPD—one for low-rise buildings and another for high-performance commercial buildings (Table 2). These two scenarios were chosen as they represent the majority of installations and allow DuPont to showcase their variety of offerings. High performance installations are defined as building envelope design requirements that exceed ASTM E 1677 (Standard Specification for Air Barrier Material or System for Low-Rise Framed Building Walls).

Table 2: Tyvek® Mechanically Fastened Air and Water Barrier system component products and materials

| Product | Sheet material | Adhesive | Low-rise: Mass % | High-performance: Mass % |
|----------------------------|---|--------------|------------------|--------------------------|
| Tyvek® HomeWrap™ WRB | Polyethylene | N/A | 60.8% | - |
| Tyvek® CommercialWrap™ WRB | Polyethylene | N/A | - | 45.1% |
| 6" FlexWrap™ | Polyethylene | Butyl rubber | 12.9% | - |
| 9" FlexWrap™ | Polyethylene | Butyl rubber | - | 10.6% |
| 4" DuPont™ Flashing Tape | Polyethylene | Butyl rubber | 13.2% | 11.1% |
| 2" Tyvek® Tape | Polypropylene | Acrylic | 2.47% | - |
| 3" Tyvek® Tape | Polypropylene | Acrylic | - | 0.898% |
| 4" StraightFlash™ | Polyethylene | Butyl rubber | - | 20.6% |
| 6" StraightFlash™ VF | Polyethylene | Butyl rubber | 4.62% | - |
| 9" StraightFlash™ | Polyethylene | Butyl rubber | - | 2.25% |
| 2" Wrap Cap Screws | Galvanized steel fastener with polyethylene cap | N/A | - | 9.36% |
| 1" Wrap Cap Staples | Galvanized steel fastener with polyethylene cap | N/A | 5.95% | - |

Low rise installation scenario - for installation on residential buildings and buildings less than 5 stories

High performance installation scenario - for installation on commercial buildings, buildings greater than 4 stories, and high performance installations of any height





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No base or ancillary materials are included in the Resource Conservation and Recovery Act (RCRA). For more information on these products, visit the Tyvek® Mechanically Fastened Air and Water Barrier System website.

Manufacture

Tyvek® Mechanically Fastened Air and Water Barrier System products are primarily flashspun polyethylene. Tyvek® tape and flashing products contain an adhesive. Products are then packaged for shipment.

Environment and Health during Manufacturing

DuPont has achieved zero landfill status in its Building Innovations business by reducing, reusing and recycling manufacturing byproducts and waste at manufacturing sites globally.

Product Processing/Installation

Tyvek® Mechanically Fastened Air and Water HomeWrap™ and CommercialWrap™ products are applied to building facades using Tyvek® Tape and flashing products as well as fasteners such as cap screws and staples.

Packaging

Tyvek® Mechanically Fastened Air and Water Barrier system products are wound onto rolls and packaged in stretch wrap.

Condition of Use

DuPont™ Tyvek® Mechanically Fastened Air and Water Barrier Systems are specifically manufactured for above-grade, vertical walls. They should be covered with the facade within 4 months for low-rise systems and 9 months for high-performance systems to limit UV exposure.

Environment and Health during Use

Use of Tyvek® Mechanically Fastened Air and Water Barrier Systems can reduce building air leakage rates and, in turn, building energy consumption required for space heating and cooling (see “Other Environmental Information”). Tyvek® systems also can prevent risks associated with water intrusion and air infiltration.





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Reference Service Life

No use stage modules are reported; as such, declaration of the reference service life (RSL) is voluntary. An RSL has not been declared for the Tyvek® Mechanically Fastened Air and Water Barrier System.

Extraordinary Effects

Tyvek® Mechanically Fastened Air and Water Barrier System products conform to the following standards pertaining to extraordinary effects:

Fire

- NFPA 285 (Commercial Tyvek® Air and Water Barrier systems): Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Non-Load-Bearing Wall Assemblies Containing Combustible Components

Water

- AATCC-127, Hydrostatic Head Test for WRB measuring pressure to failure or time of failure at a given pressure; ASTM E331-2000, Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, And Curtain Walls by Uniform Static Pressure

Air Leakage Control

- ASTM E 2178-2008, Standard Test Method for Air Permeance of Building Materials; ASTM E 283-2004, Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen; ASTM E 2357-2011 Standard Test Method for Determining Air Leakage of Air Barrier Assemblies (for high-performance systems); ASTM E1677-2011, Standard Specification for Air Barrier (AB) Material or System for Low-Rise Framed Building Walls; ASTM E779-10 Standard Test Method for Determining Air Leakage Rate by Fan Pressurization (whole building).
- See the Other Environmental Information section for building energy savings.

Re-use Phase

Mechanically fastened products are not typically re-used after installation and use. Products are assumed to be disposed in a landfill

Disposal

Mechanically fastened products are typically not separated from construction waste and are assumed to be sent to a landfill.

Life Cycle Assessment Calculation Rules

Declared Unit

The declared unit for the Tyvek® Mechanically Fastened Air and Water Barrier system is 1 square meter (m²). The complete weatherization system consists of a weather barrier membrane and flashing, and flashing accessories, as





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well as the fastening materials. Table 3 below shows the reference flow of each component required for a low-rise building scenario and a high-performance building scenario.

Table 3: Product breakdown per declared unit for low-rise and high-performance scenarios

| Component | Amount per declared unit [kg / m ²] | Surface Density [kg / m ²] |
|--------------------------------|---|--|
| Low-rise system | | |
| Tyvek® HomeWrap™ WRB | 0.0669 | 0.110 |
| 6" FlexWrap™ | 0.0142 | |
| 4" DuPont™ Flashing Tape | 0.0145 | |
| 6" StraightFlash™ VF | 0.00506 | |
| 2" Tyvek® Tape | 0.00275 | |
| 1" Wrap Cap Staples | 0.00660 | |
| High-performance system | | |
| Tyvek® CommercialWrap™ WRB | 0.0992 | 0.220 |
| 9" FlexWrap™ | 0.0233 | |
| 4" StraightFlash™ | 0.0453 | |
| 9" StraightFlash™ | 0.00484 | |
| 4" DuPont™ Flashing Tape | 0.0244 | |
| 3" Tyvek® Tape | 0.000198 | |
| 2" Wrap Cap Screws | 0.0207 | |

System Boundary

Table 4: System boundary

| Production | | | Installation | | Use stage | | | | | | | End-of-Life | | | | Next product system |
|---------------------|---------------------------|---------------|----------------------------|----------------------------|-------------------|-------------|--------|-------------|---------------|------------------------|-----------------------|-----------------------------|--------------------------|---|----------|--|
| Raw material supply | Transport to manufacturer | Manufacturing | Transport to building site | Installation into building | Use / application | Maintenance | Repair | Replacement | Refurbishment | Operational energy use | Operational water use | Deconstruction / demolition | Transport to end-of-life | Waste processing for reuse, recovery or recycling | Disposal | Reuse, recovery or recycling potential |
| A1 | A2 | A3 | A4 | A5 | B1 | B2 | B3 | B4 | B5 | B6 | B7 | C1 | C2 | C3 | C4 | D |
| X | X | X | X | X | MND | MND | MND | MND | MND | MND | MND | MND | X | MND | X | X |

X = declared module; MND = module not declared





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The analysis includes all modules in the production and installation stages (A1 – A5), along with the transport (C2), disposal (C4), and credit (D) modules in the end-of-life stage. As such, it represents a “cradle to gate – with options” system boundary. Specific use stage impacts will vary substantially due to climate, building design, regional codes, energy fuel supplies, etc. Therefore, this stage of the life cycle (B1 - B7) is not included in the EPD. However, energy use during the use-stage can be significantly impacted by the reduction in air leakage rate available with the Mechanically Fastened product system relative to alternative construction. An evaluation of a typical US based application for the use stage operational energy use (B6) is presented in the Other Environmental Information section of this EPD.

Estimates and Assumptions

The complete weatherization systems consist of mechanically fastened weather barrier wraps, flashing, and flashing accessories, as well as fastening materials. Reference flows were calculated using a representative building, “Hotel, Small” prototype (Pacific Northwest National Laboratory, 2015), to determine the relative amounts required of each product. Once the masses of each product needed to seal the representative building were calculated, the numbers were scaled down to the functional unit of 1 m² using the building’s exterior wall surface area of 1,640 m². Total reference flows for the representative building were calculated to be 0.110 kg per m² and 0.220 kg per m² for the low-rise and high-performance systems, respectively.

EPD results omit use-stage impacts, which includes indirect energy consumption—that is, the share of a building’s operational energy consumption that can be causally attributed to the weatherization system. Given that most energy associated with a building’s life cycle is consumed during its operation, indirect energy consumption for the weatherization system is expected to represent a large fraction of the product’s cradle-to-grave environmental burden. This number, however, is also difficult to quantify with reasonable effort or certainty. Therefore, a payback period approach is used to illustrate the effect application of DuPont’s Tyvek® Mechanically Fastened Air and Water Barrier Systems can have on building operational energy consumption in the section Other Environmental Information. Users of this EPD are encouraged to consider Use-Stage impacts in the evaluation of mechanically fastened product systems for specific applications.

Cut-off Criteria

No cut-off criteria were applied in this study. All reported data was incorporated and modeled using best available Life Cycle Inventory (LCI) data.

Background Data

Background datasets for upstream and downstream data are representative of the years 2009 – 2015 and were obtained from the GaBi 2016 databases (thinkstep, 2016).

Data Quality

A variety of tests and checks were performed throughout the project to ensure high quality of the completed LCA. Checks included an extensive review of project-specific LCA models as well as the background data used.

Data included first-hand industry data from DuPont in combination with consistent background life cycle inventory information from the GaBi 2016 databases. The data are representative of DuPont’s flashspun Tyvek® system products produced in the United States in 2015.

Period under Review

Data are representative of manufacturing during 2015.



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Allocation

No allocation was necessary for primary data collected from DuPont’s manufacturing facilities.

Comparability

A comparison or an evaluation of EPD results is only possible if all results to be compared were created using the same background data and according to the same guidelines, including EN 15804 (CEN, 2013) and the PCR (IBU, 2014). Additionally, the building context and product-specific performance characteristics should be considered, particularly air infiltration reduction potential, the potential to reduce building energy use relative to a baseline building design with no effective air leakage control, as well as the potential to increase levels of envelope leakage control established by common industry standards.

Life Cycle Assessment Scenarios and Additional Technical Information

Information relevant to the life cycle modules included in this study are summarized in the following tables.

Table 5: Transport to building site (A4)

| Property | Value | Unit |
|---|-------|------------|
| Liters of fuel | 39 | L / 100 km |
| Transport distance | 805 | km |
| Capacity utilization (including empty runs) | 78 | % |

Table 6: Installation at building site (A5)

| Property | Low-rise | High-performance | Unit |
|-----------------|----------|------------------|------|
| Material loss | 5 | 5 | % |
| Packaging waste | 0.00570 | 0.00956 | kg |

Table 7: End-of-life (C1-C4)

| Property | Low-rise | High-performance | Unit |
|---------------------------------------|----------|------------------|------|
| Collected as mixed construction waste | 0.11 | 0.22 | kg |
| Landfilling | 0.11 | 0.22 | kg |





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Life Cycle Assessment Results

Results for 1 m² of installed Tyvek® Mechanically Fastened Air and Water Barrier Systems are presented below.

| ENVIRONMENTAL IMPACTS: LOW RISE SCENARIO | | | | | | | |
|--|--|----------|----------|----------|----------|----------|-----------|
| CML 2001 (Apr 2013) | | | | | | | |
| Parameter | Unit | A1-A3 | A4 | A5 | C2 | C4 | D |
| GWP | [kg CO ₂ eq.] | 4.97E-01 | 7.02E-03 | 2.90E-02 | 2.68E-04 | 4.93E-03 | -3.44E-04 |
| ODP | [kg CFC-11 eq.] | 1.18E-06 | 5.78E-14 | 5.88E-08 | 2.20E-15 | 9.43E-14 | -1.04E-13 |
| AP | [kg SO ₂ eq.] | 1.32E-03 | 2.60E-05 | 7.91E-05 | 9.91E-07 | 2.13E-05 | -9.29E-07 |
| EP | [kg PO ₄ ³ eq.] | 1.25E-04 | 6.71E-06 | 9.78E-06 | 2.56E-07 | 2.72E-06 | -5.62E-08 |
| POCP | [kg C ₂ H ₄ eq.] | 2.68E-04 | 3.10E-06 | 1.68E-05 | 1.18E-07 | 2.16E-06 | -6.02E-08 |
| ADPE | [kg Sb eq.] | 2.48E-07 | 1.05E-09 | 1.26E-08 | 4.00E-11 | 1.89E-09 | -7.85E-11 |
| ADPF | [MJ] | 1.10E+01 | 9.87E-02 | 5.60E-01 | 3.76E-03 | 7.45E-02 | -4.18E-03 |
| TRACI 2.1 | | | | | | | |
| Parameter | Unit | A1-A3 | A4 | A5 | C2 | C4 | D |
| GWP | [kg CO ₂ eq.] | 4.97E-01 | 7.02E-03 | 2.90E-02 | 2.68E-04 | 4.93E-03 | -3.44E-04 |
| ODP | [kg CFC-11 eq.] | 1.17E-06 | 6.15E-14 | 5.88E-08 | 2.34E-15 | 1.00E-13 | -1.11E-13 |
| AP | [kg SO ₂ eq.] | 1.31E-03 | 3.41E-05 | 8.31E-05 | 1.30E-06 | 2.30E-05 | -8.83E-07 |
| EP | [kg N eq.] | 6.32E-05 | 3.17E-06 | 5.37E-06 | 1.21E-07 | 1.28E-06 | -3.75E-08 |
| SFP | [kg O ₃ eq.] | 1.83E-02 | 1.08E-03 | 1.04E-03 | 4.13E-05 | 4.47E-04 | -8.46E-06 |

| ENVIRONMENTAL IMPACTS: HIGH PERFORMANCE SCENARIO | | | | | | | |
|--|--|----------|----------|----------|----------|----------|-----------|
| CML 2001 (Apr 2013) | | | | | | | |
| Parameter | Unit | A1-A3 | A4 | A5 | C2 | C4 | D |
| GWP | [kg CO ₂ eq.] | 9.42E-01 | 1.39E-02 | 5.41E-02 | 5.35E-04 | 9.86E-03 | -5.70E-04 |
| ODP | [kg CFC-11 eq.] | 3.54E-06 | 1.15E-13 | 1.77E-07 | 4.41E-15 | 1.89E-13 | -1.72E-13 |
| AP | [kg SO ₂ eq.] | 2.54E-03 | 5.16E-05 | 1.49E-04 | 1.98E-06 | 4.27E-05 | -1.54E-06 |
| EP | [kg PO ₄ ³ eq.] | 2.47E-04 | 1.33E-05 | 1.84E-05 | 5.11E-07 | 5.45E-06 | -9.30E-08 |
| POCP | [kg C ₂ H ₄ eq.] | 6.36E-04 | 6.15E-06 | 3.76E-05 | 2.36E-07 | 4.33E-06 | -9.97E-08 |
| ADPE | [kg Sb eq.] | 1.72E-06 | 2.08E-09 | 8.64E-08 | 8.00E-11 | 3.78E-09 | -1.30E-10 |
| ADPF | [MJ] | 2.11E+01 | 1.96E-01 | 1.07E+00 | 7.52E-03 | 1.49E-01 | -6.93E-03 |
| TRACI 2.1 | | | | | | | |
| Parameter | Unit | A1-A3 | A4 | A5 | C2 | C4 | D |
| GWP | [kg CO ₂ eq.] | 9.43E-01 | 1.39E-02 | 5.41E-02 | 5.35E-04 | 9.86E-03 | -5.70E-04 |
| ODP | [kg CFC-11 eq.] | 3.55E-06 | 1.22E-13 | 1.77E-07 | 4.69E-15 | 2.01E-13 | -1.83E-13 |
| AP | [kg SO ₂ eq.] | 2.51E-03 | 6.77E-05 | 1.56E-04 | 2.60E-06 | 4.60E-05 | -1.46E-06 |
| EP | [kg N eq.] | 1.22E-04 | 6.29E-06 | 9.92E-06 | 2.42E-07 | 2.56E-06 | -6.21E-08 |
| SFP | [kg O ₃ eq.] | 3.61E-02 | 2.15E-03 | 2.03E-03 | 8.26E-05 | 8.94E-04 | -1.40E-05 |

GWP = Global warming potential; ODP = Depletion potential of the stratospheric ozone layer; AP = Acidification potential of land and water; EP = Eutrophication potential; POCP = Formation potential of tropospheric ozone photochemical oxidants; ADPE = Abiotic depletion potential for non-fossil resources; ADPF = Abiotic depletion potential for fossil resources; SFP = Smog formation potential

| RESOURCE USE: LOW RISE SCENARIO | | | | | | | |
|---------------------------------|-------------------|----------|----------|----------|----------|----------|-----------|
| Parameter | Unit | A1-A3 | A4 | A5 | C2 | C4 | D |
| PERE | [MJ] | 1.76E-01 | 1.64E-03 | 9.16E-03 | 6.25E-05 | 4.84E-03 | -4.47E-04 |
| PERM | [MJ] | 8.26E-02 | - | 4.13E-03 | - | - | - |
| PERT | [MJ] | 2.59E-01 | 1.64E-03 | 1.33E-02 | 6.25E-05 | 4.84E-03 | -4.47E-04 |
| PENRE | [MJ] | 7.20E+00 | 9.92E-02 | 3.69E-01 | 3.78E-03 | 7.65E-02 | -5.11E-03 |
| PENRM | [MJ] | 4.44E+00 | - | 2.22E-01 | - | - | - |
| PENRT | [MJ] | 1.16E+01 | 9.92E-02 | 5.91E-01 | 3.78E-03 | 7.65E-02 | -5.11E-03 |
| SM | [kg] | - | - | - | - | - | - |
| RSF | [MJ] | - | - | - | - | - | - |
| NRSF | [MJ] | - | - | - | - | - | - |
| FW | [m ³] | 1.75E-03 | 2.01E-05 | 9.00E-05 | 7.66E-07 | 1.18E-05 | -1.62E-06 |





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| RESOURCE USE: HIGH PERFORMANCE SCENARIO | | | | | | | |
|---|------|----------|----------|----------|----------|----------|-----------|
| Parameter | Unit | A1-A3 | A4 | A5 | C2 | C4 | D |
| PERE | [MJ] | 3.55E-01 | 3.25E-03 | 1.83E-02 | 1.25E-04 | 9.69E-03 | -7.40E-04 |
| PERM | [MJ] | 1.38E-01 | - | 6.92E-03 | - | - | - |
| PERT | [MJ] | 4.93E-01 | 3.25E-03 | 2.52E-02 | 1.25E-04 | 9.69E-03 | -7.40E-04 |
| PENRE | [MJ] | 1.53E+01 | 1.97E-01 | 7.81E-01 | 7.56E-03 | 1.53E-01 | -8.46E-03 |
| PENRM | [MJ] | 6.86E+00 | - | 3.43E-01 | - | - | - |
| PENRT | [MJ] | 2.21E+01 | 1.97E-01 | 1.12E+00 | 7.56E-03 | 1.53E-01 | -8.46E-03 |
| SM | [kg] | - | - | - | - | - | - |
| RSF | [MJ] | - | - | - | - | - | - |
| NRSF | [MJ] | - | - | - | - | - | - |
| FW | [m³] | 3.38E-03 | 3.99E-05 | 1.73E-04 | 1.53E-06 | 2.36E-05 | -2.68E-06 |

PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; PENRM = Use of non-renewable primary energy resources used as raw materials; PENRT = Total use of non-renewable primary energy resources; SM= Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Use of net fresh water

| OUTPUT FLOWS AND WASTE CATEGORIES: LOW RISE SCENARIO | | | | | | | |
|--|------|----------|----------|----------|----------|----------|-----------|
| Parameter | Unit | A1-A3 | A4 | A5 | C2 | C4 | D |
| HWD | [kg] | 1.77E-08 | 1.26E-10 | 8.99E-10 | 4.80E-12 | 1.46E-10 | -2.80E-12 |
| NHWD | [kg] | 5.16E-03 | 3.49E-06 | 4.25E-03 | 1.33E-07 | 1.10E-01 | -1.55E-06 |
| RWD | [kg] | 2.42E-04 | 2.09E-07 | 1.22E-05 | 7.96E-09 | 7.78E-07 | -3.62E-07 |
| CRU | [kg] | - | - | - | - | - | - |
| MFR | [kg] | - | - | - | - | - | - |
| MER | [kg] | - | - | - | - | - | - |
| EEE | [MJ] | - | - | - | - | - | - |
| EET | [MJ] | - | - | - | - | - | - |

| OUTPUT FLOWS AND WASTE CATEGORIES: HIGH PERFORMANCE SCENARIO | | | | | | | |
|--|------|----------|----------|----------|----------|----------|-----------|
| Parameter | Unit | A1-A3 | A4 | A5 | C2 | C4 | D |
| HWD | [kg] | 2.42E-08 | 2.50E-10 | 1.24E-09 | 9.60E-12 | 2.93E-10 | -4.64E-12 |
| NHWD | [kg] | 9.03E-03 | 6.92E-06 | 7.18E-03 | 2.66E-07 | 2.21E-01 | -2.57E-06 |
| RWD | [kg] | 4.21E-04 | 4.14E-07 | 2.11E-05 | 1.59E-08 | 1.56E-06 | -6.00E-07 |
| CRU | [kg] | - | - | - | - | - | - |
| MFR | [kg] | - | - | - | - | - | - |
| MER | [kg] | - | - | - | - | - | - |
| EEE | [MJ] | - | - | - | - | - | - |
| EET | [MJ] | - | - | - | - | - | - |

HWD = Hazardous waste disposed; NHWD = Non-hazardous waste disposed; RWD = Radioactive waste disposed; CRU = Components for re-use; MFR = Materials for recycling; MER = Materials for energy recovery; EEE = Exported electrical energy; EET = Exported thermal energy

Interpretation

The results represent the cradle-to-gate and end-of-life environmental performance of the Tyvek® Mechanically Fastened Air and Water Barrier Systems. For all impact categories, the manufacturing stage (modules A1-A3) is the dominant contributor to life cycle impact. Installation impact is associated with the production of additional wrap that represents installation waste.





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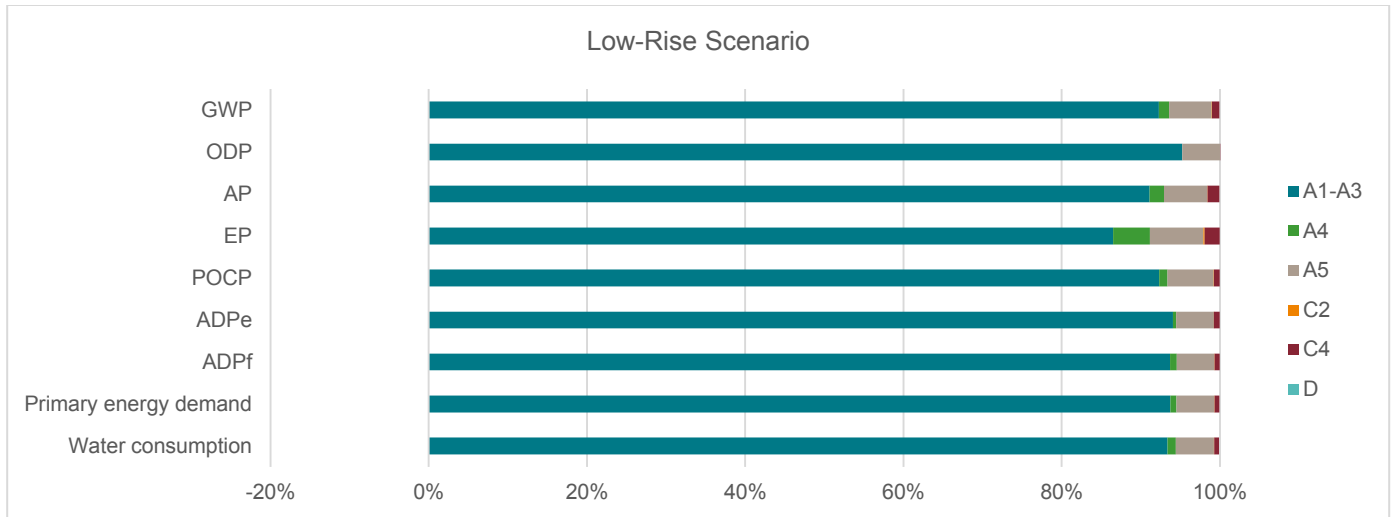


Figure 1: CML 2001 (April 2013) impact category results for low-rise scenario

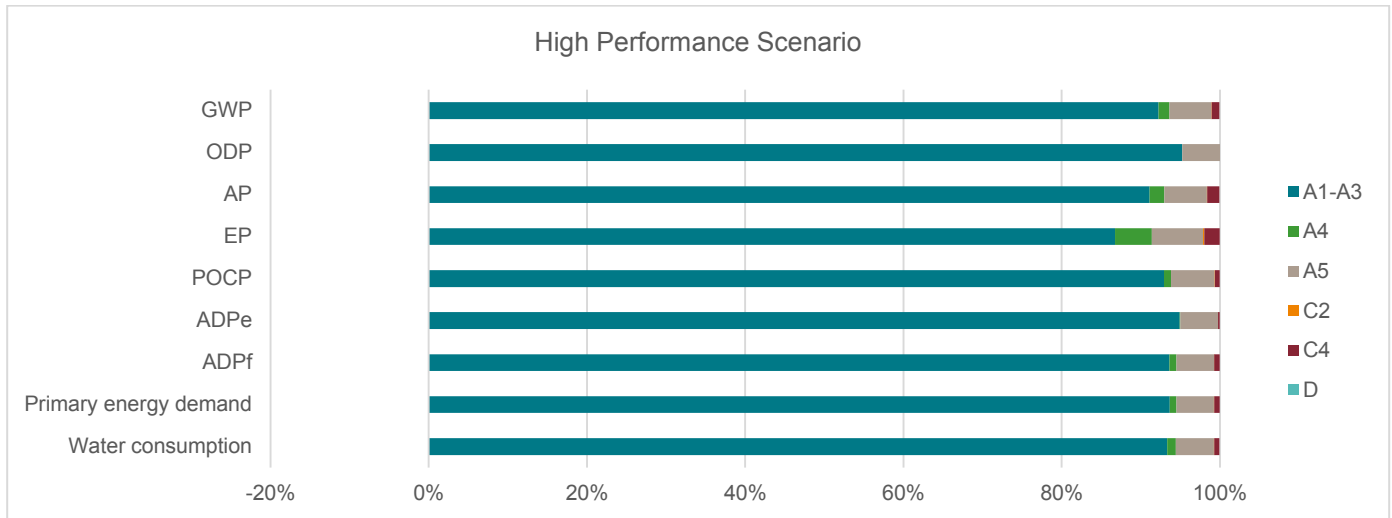


Figure 2: CML 2001 (April 2013) impact category results for high performance scenario

Requisite Evidence

No requisite evidence is required for Tyvek® Mechanically Fastened Air and Water Barrier systems.





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Other Environmental Information

Building Use Stage Benefits

The EPD analysis focuses on the production, installation, and disposal of the Tyvek® Mechanically Fastened Weather Barrier System. However, it does not provide a complete picture of the overall environmental impact associated with the weatherization system as it omits the building use stage. Use of DuPont’s Tyvek® Mechanically Fastened Weather Barrier Systems reduces building air leakage rates, which in turn lowers building energy consumption required for space heating and cooling. As a result, during the building use the Air and Water Barrier system will actually contribute to “energy savings” which could significantly surpass the “energy cost” required to manufacture, install, and dispose DuPont™ Tyvek® Mechanically Fastened Weather Barrier Systems. The energy savings during the building operational phase should have a net positive impact on the WRB’s cradle-to-grave environmental footprint.

A payback period approach is used to compare the “energy cost” with the “energy savings” that DuPont™ Tyvek® Mechanically Fastened Weather Barrier System could contribute due to savings in building operational energy consumption. A U.S. average case is used to estimate the time needed to “payback” the energy and greenhouse gas impacts associated with manufacturing, installing and disposing of the Tyvek® Mechanically Fastened WB System. For payback times shorter than the building service life, the use of a weather barrier system would result in net impact reductions in the building’s environmental footprint relative to a baseline option without such a system.

Since energy requirements will vary based on numerous factors, including building design, regional weather, temperature control systems, building heating and cooling sources, code requirements, etc. the calculations are performed for a U.S. average case, using average energy savings across all climates for a representative building. The “Hotel, Small” prototype or a similar building is used as a representative building to estimate space heating and cooling energy savings, as well as to calculate weatherization system energy demand.

The small hotel characteristics are shown in Table 9. Based on these characteristics, 1,640 m² of weatherization system are required to seal the building envelope. The associated total primary energy demand for both the low-rise and high-performance systems is shown in Table 8.

Table 8: Total weatherization system primary energy demand

| Scenario | Primary Energy Demand [MJ / m ²] | Primary Energy Demand [MJ / 1640 m ²] |
|------------------|--|---|
| Low-rise | 12.7 | 20,800 |
| High performance | 24.1 | 39,500 |

Table 9: Small hotel building characteristics

| Property | Value (Imperial) | Value (metric) |
|---|-------------------------|----------------------|
| Building height | 38 ft. | 11.6 m |
| Number of stories | 4 | 4 |
| Floor space | 43,200 ft. ² | 4,010 m ² |
| Exterior wall area (covered by membrane system) | 17,700 ft. ² | 1,640 m ² |

Estimating reduction in space heating and cooling energy consumption associated with reduction in air leakage is





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somewhat more complicated due to lack of data and appropriate guidelines for air infiltration input into whole-building energy simulation models. An overview of the methodology is as follows:

- 1) Define air leakage rates for a baseline building and airtight building.
- 2) Using whole building energy simulations, calculate percent energy savings for an average commercial building, based on meeting different air leakage rates defined in (1).
- 3) Translate percent energy savings to an absolute value based on commercial sector annual energy consumption for space heating and cooling.
- 4) Calculate energy savings per 1,000 square feet of building floor space based on total floor space for the commercial sector.
- 5) Calculate energy savings for the representative building based on results from (4) and building floor area from Table 9.
- 6) The final result represents annual energy savings for the representative building and can be combined with weatherization system energy demand to calculate the payback period.

These calculations are briefly summarized below.

(1) The following air leakage rates were used for this analysis:

- *Baseline building*: **1.00 CFM/SF @ 75Pa** (0.3 in. w.c.) based on whole building tests of existing buildings, measured as part of USACE (US Army Corps of Engineers) air barrier program
- *Airtight building* - two different standards were used: **0.40 CFM/SF @ 75Pa** (0.3 in. w.c.) based on ASHRAE 90.1-2013 Appendix G, and **0.25 CFM/SF @ 75Pa** (0.3 in. w.c.) based on USACE requirements

It is possible to achieve Whole Building air tightness using the DuPont's Tyvek® Mechanically Fastened Air and Water Barrier Systems that exceeds the 0.25 CFM/SF @ 75 Pa standard. Both the low-rise and high-performance systems can be specified and installed to achieve the 0.40 CFM/SF ASHRAE 90.1-2013 standard. To achieve Whole Building air tightness at or below the 0.25 CFM/SF USACE, the high-performance scenario is best suited to meet those specifications. If a whole building airtightness test results are available for a given building, the actual value could be inputted in the energy model to calculate the energy savings for a specific project.

(2) Whole building energy simulation data from (Zhivov, 2013) provides percent energy savings for the two air leakage rates 0.25 CFM/SF and 0.4 CFM/SF as compared to a baseline air leakage rate of 1.0 CFM/SF (all measured at 75 Pa). This information is then combined with building construction volume for each ASHRAE climate zone (Jarnagin & Bandyopadhyay, 2010) in order to calculate weighted average energy savings across all climate zones (shown in Table 10, second column).

(3) Next, total energy used for space heating and cooling for all commercial buildings was obtained from the 2011 Buildings Energy Data Book (US Department of Energy, 2012). Energy used for space heating and cooling was calculated based on commercial sector energy consumption in BEDB Table 3.1.3 and on percent of that energy used for space heating and cooling in BEDB Tables 3.1.4 and 3.1.5. Calculated percent energy savings was then applied to space heating and cooling energy consumption to calculate the amount of energy saved. Results based on BEDB 2010 calculations and 2015 projections are shown in Table 10.



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Table 10: Annual primary energy consumption and energy savings for all US commercial buildings

| Air tightness standard @ 75 Pa | Weighted % energy savings | Commercial energy end use for space heating & cooling [10 ¹⁵ Btu] | | Commercial energy savings for space heating and cooling [10 ¹⁵ Btu] | |
|--------------------------------|---------------------------|--|--------------|--|--------------|
| | | 2010 primary | 2015 primary | 2010 primary | 2015 primary |
| 1.0 CFM/SF | 0% (baseline) | 5.77 | 4.13 | 0 | 0 |
| 0.4 CFM/SF | 6.5% | 5.77 | 4.13 | 0.38 | 0.27 |
| 0.25 CFM/SF | 12.3% | 5.77 | 4.13 | 0.71 | 0.51 |

(4) Commercial building primary energy savings associated with space heating and cooling from Table 10 are then divided by the total floor area of all commercial buildings (also from (US Department of Energy, 2012)) to calculate energy savings per 1,000 SF of floor space. These normalized results are shown in Table 11.

(5) Finally, energy savings associated with the representative building are calculated based on the representative building’s floor space in Table 9. The results are shown in the last two columns in Table 11 for 2010 and 2015.

Table 11: Annual energy savings for representative building

| Air tightness standard @ 75 Pa | Floor space [10 ⁹ SF] | | Commercial energy savings for space heating and cooling, normalized by floor area [MMBtu / 1,000 SF] | | Representative building energy savings for space heating and cooling [MMBtu / yr.] | |
|--------------------------------|----------------------------------|------|--|--------------|--|--------------|
| | 2010 | 2015 | 2010 primary | 2015 primary | 2010 primary | 2015 primary |
| 1.0 CFM/SF | 81.1 | 84.1 | 0 | 0 | 0 | 0 |
| 0.4 CFM/SF | 81.1 | 84.1 | 4.6 | 3.2 | 200 | 140 |
| 0.25 CFM/SF | 81.1 | 84.1 | 8.8 | 6.0 | 380 | 260 |

(6) Energy payback period is calculated based on weatherization system energy demand as it compares to annual energy savings from Table 11. Results in Table 12 indicate that payback period is on the order of months; therefore, most of the energy required to manufacture, install, and dispose DuPont’s Tyvek® Mechanically Fastened Air and Water Barrier Systems is recovered within the first four months of building use due to lower space heating and cooling energy consumption. No payback period results are provided for the low-rise scenario at an air tightness standard of 0.25 CFM/SF as the scenario is not designed to meet this standard.

Table 12: Energy payback period calculation for small hotel building prototype

| Air tightness standard @ 75 Pa | 1.0 CFM/SF | 0.4 CFM/SF | | 0.25 CFM/SF | |
|---|------------|------------|------------|--------------|------------|
| | Baseline | Low-rise | High perf. | Low-rise | High perf. |
| Product primary energy demand [GJ] | 0 | 20.8 | 39.5 | 20.8 | 39.5 |
| Weighted % energy savings | 0% | 6.5% | | 12.3% | |
| 2010 building energy savings [GJ / yr.] | 0 | 210 | | 400 | |
| 2010 payback period [months] | N/A | 1.2 months | 2.2 months | 0.62 months* | 1.2 months |
| 2015 building energy savings [GJ / yr.] | 0 | 150 | | 270 | |
| 2015 payback period [months] | N/A | 1.7 months | 3.2 months | 0.92 months* | 1.7 months |

* While the low-rise scenario can meet the USACE airtightness standard of 0.25 CFM/SF, the high-performance scenario is the recommended option for this standard.





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(7) Likewise, global warming potential payback period can be calculated using the same methodology (since energy savings lead to greenhouse gas emissions reduction) and the results are summarized in Table 13. Total CO₂ emissions used to calculate payback period were obtained from Table 3.4.2 and 3.4.3 in the Building Energy Data Book (US Department of Energy, 2012).

Table 13: Global warming payback period calculation for small hotel building prototype

| Air tightness standard @ 75 Pa | 1.0 CFM/SF | 0.4 CFM/SF | | 0.25 CFM/SF | |
|--|------------|------------|------------|--------------|-------------|
| | Baseline | Low-rise | High perf. | Low-rise | High perf. |
| Product carbon emissions [kg CO ₂ e] | 0 | 890 | 1,700 | 890 | 1,700 |
| Weighted % energy savings | 0% | 6.5% | | 12.3% | |
| 2010 building GWP reduction [kg CO ₂ e / yr.] | 0 GJ | 10,800 | | 20,300 | |
| 2010 payback period [months] | N/A | 0.98 month | 1.9 months | 0.52 months* | 0.99 months |
| 2015 building GWP reduction [kg CO ₂ e / yr.] | 0 GJ | 7,300 | | 13,800 | |
| 2015 payback period [months] | N/A | 1.5 months | 2.7 months | 0.76 months* | 1.5 months |

* While the low-rise scenario can meet the USACE airtightness standard of 0.25 CFM/SF, the high-performance scenario is the recommended option for this standard.

The potential global warming impact during manufacture, installation, and disposal of DuPont’s Tyvek® Mechanically Fastened Air and Water Barrier Systems is “cancelled” within the first two months of building use due to lower space heating and cooling energy consumption. Since energy savings and global warming potential reduction from building envelope airtightness are expected throughout the building life (>50 years), Tyvek® Mechanically Fastened Air and Water Barriers are expected to have a net environmental benefit over the remaining of the building life.

Other Air and Water Barrier Benefits

In addition to energy savings which were quantified in this analysis through whole building energy simulations, Tyvek® systems provide substantial additional benefits by preventing risks associated with water intrusion and air infiltration. Potential risks associated with water intrusion can range from health risks (due to mold and dampness which could affect the IEQ), to building envelope durability/materials degradation (such as rotting of wood or corrosion of metals), to materials performance (such as loss of insulation R-value). Potential risks associated with air infiltration include impact on the occupant’s comfort (e.g. cold drafts) and transport of outdoor contaminants into the conditioned space, affecting the IEQ. A continuous WRB system is a cost-effective measure for avoiding risks associated with water intrusion and air infiltration. While these additional WRB benefits are more difficult to quantify because moisture intrusion and air infiltration events are unpredictable, the impact on building envelope durability/longer building life (which will obviously impact materials resources), as well as comfort and health of the building occupants could be significant.





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