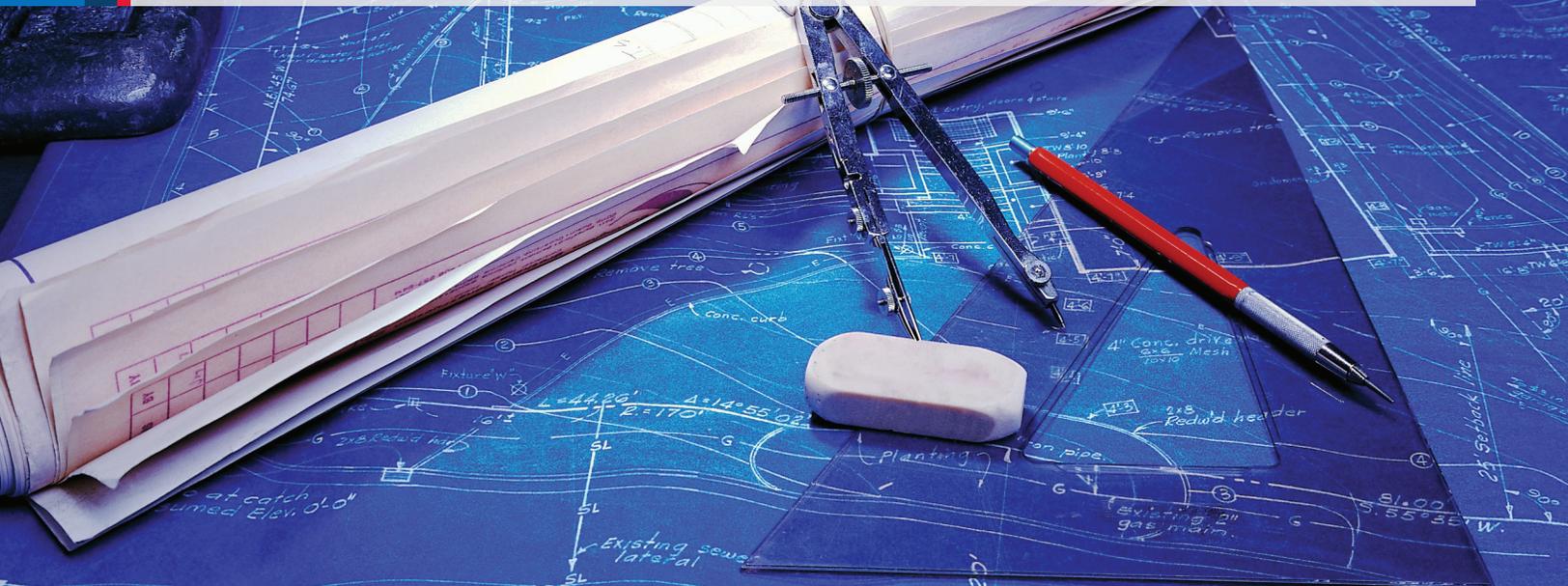


DOCUMENTING ENERGY EFFICIENCY: FROM DESIGN, TO CONSTRUCTION, TO OCCUPANCY

By Dr. Maria Spinu



Founded in 1993, U.S. Green Building Council (USGBC) has become the engine behind LEED® Green Building Rating System, the most widely recognized and widely used green building program across the globe. Launched in 2000, LEED® for New Construction & Major Renovations Projects certified nearly 9,600 buildings and registered nearly 19,000, and the number continues to grow. However, LEED® only looks at the building's projected energy use compared to a hypothetical, and potentially code-minimum, building. This is a major drawback, as the only way to know how you are doing, is to actually measure.

This case study for Ramona Apartments building provides a comparison between the designed parameters and the actual energy use, after the building was completed and occupied. The reason this case study is exceptional is because energy efficient design does not guarantee performance in use, and that the actual performance is rarely documented. Achieving energy efficient and sustainable buildings requires commitment all the way through the value chain of a building design and construction. It starts with a committed owner and investor, it continues with an energy efficient design and quality craftsmanship during the construction, and results in tangible dollar savings for the building occupants. One such example is Ramona Apartments, a 138-unit family-friendly building in the Pearl District, in Portland, Oregon, home to 133 children (and a total of 361 residents). The construction started in December of 2009 and was completed in March of 2011. What is remarkable about Ramona Apartments was, not only that the building was designed and built as energy efficient, but also that the performance has been validated after two years of occupancy and will continue to be recorded for at least the first five years of occupancy.

THE PROJECT

Building Name

Ramona Apartments
(www.TheRamona.com)

Location

550 NW 14th Avenue, Portland, OR 97209

Owner

Nurture 247 Limited Partnership

Developer

Turtle Island Development LLC

Year Built

2011 (Construction started in 12/09 and completed in 3/11)

Size (SF)

230,760 GSF (including garage and commercial/educational spaces)

Cost/SF

Construction costs of \$127/GSF

LEED Level

Gold

Architect/Engineer/GC

- Architect - Ankrom Moisan Associated Architects
- Mechanical Engineer/Energy Modeling – PAE Consulting Engineers, Inc.
- Building Envelope – RDH Building Sciences Inc.
- GC - Walsh Construction Co.

THE DESIGN PHASE

The design team has used a cost effective approach to energy efficient design. It started with basic design features such as building form, orientation, and expression. The major component to meeting building envelope loads as efficiently and as cleanly as possible was the building envelope design. “Most of the energy efficiency at the Ramona can be attributed to focusing on the **building’s fundamentals, especially building an airtight and well-insulated envelope**”, says Ed McNamara, Principal at Turtle Island Development LLC. Building envelope airtightness was achieved with DuPont™ Tyvek®

CommercialWrap® continuous air barrier. At the time Ramona Apartments were designed, Oregon energy code required compliance with ASHRAE 90.1 2007 which did not even include a mandatory air barrier requirement. The continuous air barrier requirement was firstly introduced by ASHRAE 90.1 2010, so, from the start the design team went beyond minimum code requirements. Design strategies for energy efficiency are summarized in Figure 1.

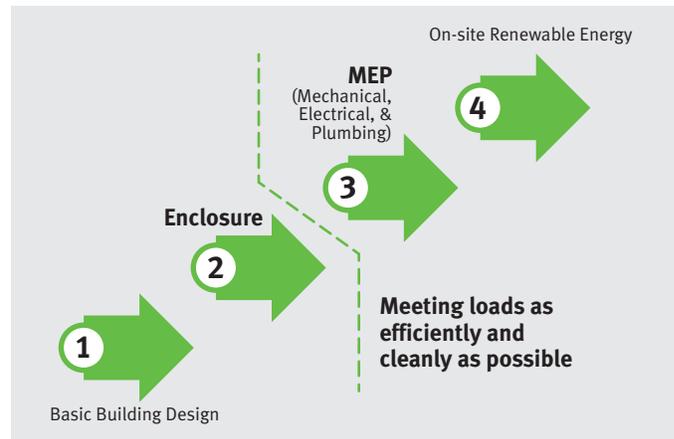


Figure 1. Energy Efficient Design Strategies for Ramona Apartments (Courtesy Walsh Construction Co.)

The design team analyzed and assessed numerous options for every aspect of energy efficiency. On-site energy generation was considered only after reducing demand as much as possible through basic building design, envelope loads and efficient fixtures and equipment. DuPont team was a partner from the design phase, and designing with a vapor permeable Tyvek® air barrier delivered a cost effective and durable building. This case study will emphasize the Building Envelope energy efficient measures, *specifically building envelope airtightness*.

Building Envelope Features:

- **Wall design:** 2x6 wood-framed wall with brick cladding with 1” airspace.
- **Air Barrier system:** DuPont™ Tyvek® CommercialWrap® continuous air barrier was installed over gypsum board exterior sheathing. The wall air barrier tied into the roof membrane.
- **Exterior Walls Insulation:** Blown-in fiberglass wall cavity insulation rated at R-23 at upper 5 floors.

THE CONSTRUCTION PHASE

During construction, all design features were carefully implemented. Walsh Construction Co. built a mock-up wall, and the entire design and construction team, including the owner, participated in the mock up demonstration using DuPont™ Tyvek® CommercialWrap® as a *continuous air barrier* (Figure 2). DuPont Technical Team and Commercial Tyvek® Specialist were involved with the design and construction team throughout the construction process. Figure 3 shows DuPont™ Tyvek® CommercialWrap® continuous air barrier being installed over gypsum board exterior sheathing. During construction, special attention was given to achieving continuity of the air barriers at the window-wall interface, transitions and penetrations.



Figure 2. Mock-up wall assembly for Ramona Apartments Roland Carson (left), the Commercial Tyvek® Specialist with Orepac was at the site during mock up demo



Figure 3. The Ramona Apartment: DuPont™ Tyvek® CommercialWrap® air Barrier was installed over the exterior gypsum board sheathing, with mechanical fasteners.

After detailing the continuity of Tyvek® air barrier system, brick veneer was installed as exterior cladding, as shown in Figure 4. Figure 4 also shows other energy efficient features such as PV panels on the roof for on-site generation of renewable energy.

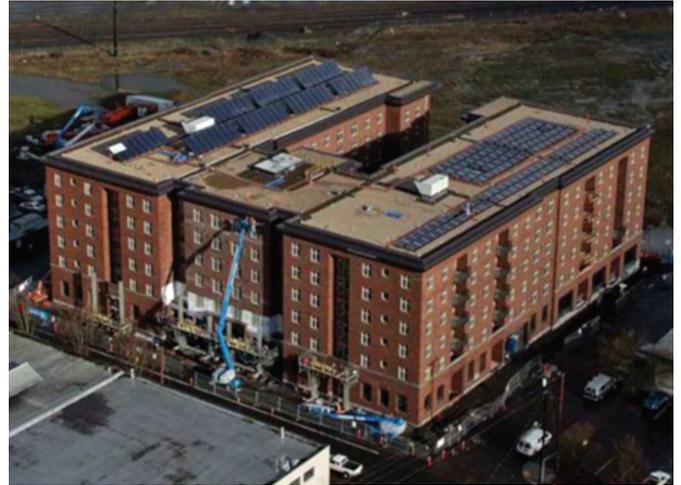


Figure 4. The Ramona Apartments: Brick veneer was installed as exterior cladding.

TESTING OF BUILDING ENVELOPE AIRTIGHTNESS

After the building envelope was complete, whole building testing was performed to ensure building envelope airtightness. At the time of testing, the construction was concluding interior finishes and was on track for LEED® Gold certification. The building was volunteered by Walsh Construction Co. to be tested as part of ASHRAE 1478-RP air-tightness research project and was tested on March 4, 2011. The ASHRAE 1478-Research Project was sponsored by DOE, ASHRAE and DuPont.

Testing Procedure and Results

During the Ramona Apartment's day-long testing, the team conducted building depressurization and pressurization with continuous data collection. The fans throughout the building were turned on, one by one, in order to slowly increase or decrease the building pressure to the required 75 Pa. The fans were controlled through a computer software program (Teclog2) so that single zone conditions were maintained for the entire exterior envelope. Throughout this period, the building was allowed to stabilize at benchmark pressures, and data were collected every minute. There was an extended team watching the test, comprised of those responsible for running the tests, the project team as well as test observers (Figure 5; a complete list of participants at the test is included in Appendix 1).



Figure 5. Whole Building Airtightness Testing – Watching the data collection.

The collected data points were plotted on a logarithmic scale, for depressurization and pressurization testing. The whole building airtightness expressed in cfm (cubic feet per minute) per square foot of enclosure at 75 Pa was calculated, using the following equation:

$$\text{Building Airtightness} = \frac{\text{Average Flow [cfm]}}{\text{Envelope Surface Area [sf]}}$$

Where:

- Average Flow = Results averaged from all tests, in cfm
- Envelope Surface Area = calculated surface area of four elevations and roof, in square feet (from design documents)
- Building Airtightness = average flow per square foot of the building envelope, in cfm per square foot @ 75 Pa pressure difference

The average air leakage rate for the enclosure of Ramona Apartment building was 0.22 cfm/ft² @ 75 Pa, exceeding the most stringent requirements to date, e.g. US Army Corps of Engineers and IgCC-2012 <0.25 cfm/ft² @ 75Pa), as well as GSA, IECC-2012 and 189.1-2009 standards <(0.40 cfm/ft² @ 75Pa).

LOCATING LEAKAGE SITES

Following the whole building airtightness test it was important to determine the sources of air leakage, even though the building has met the most stringent airtightness criteria. When the building is pressurized, leaks can be more readily seen from outdoors provided exterior walls have not been heated by radiation from the sun. When the building is depressurized, leaks can be more readily seen from the inside.

Thermal infrared and smoke detection were used to identify potential areas of further improvement in airtightness. The primary envelope issue noted was the seal at the roof-wall-soffit connection around the perimeter of the building. Additionally, air leakage was noticed at the attic ceiling level. None of these leakage sites are due to the imperfections of the wall air barrier, but rather the interface between the wall and the roof which is often difficult to detail. The IR imagery in Figure 6 clearly shows air leakage around the top perimeter of the wall-roof interface. The close up IR on the right shows the leakage into the soffit zone.

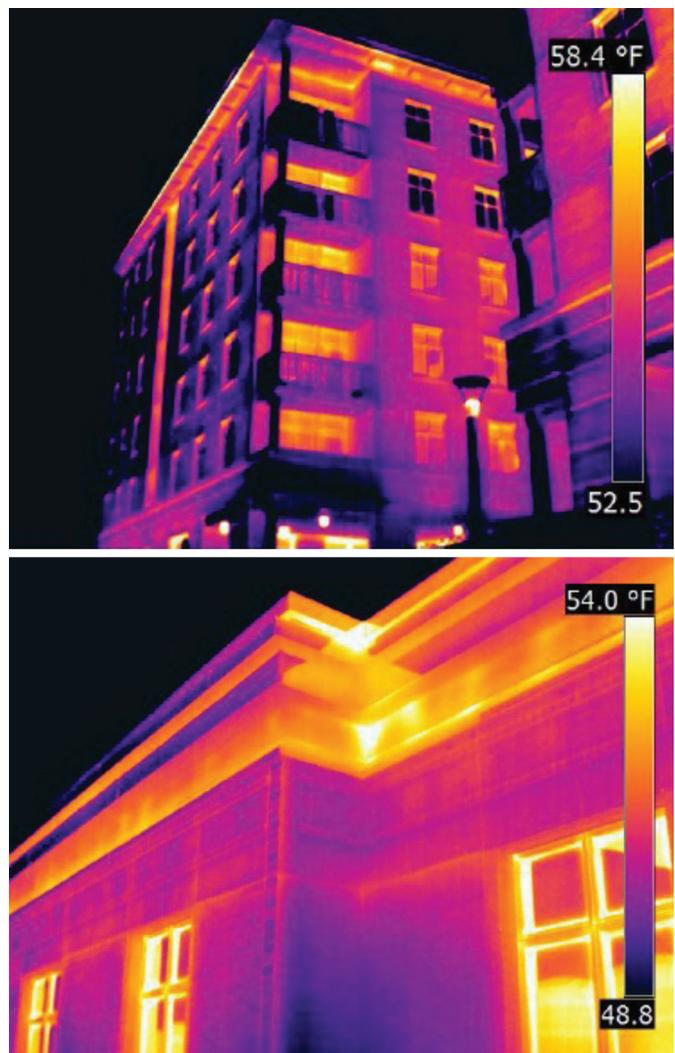


Figure 6. Thermal infrared pictures showing air leakage around the perimeter of the building (compliments of Mike Williams)



Figure 7. Use of tracer smoke to identify the location and severity of air leakage paths (Source: Ramona Apartments Building Envelope Inspection Report)

An air leakage detail at the attic ceiling level is shown in Figure 7. On the top, the friction fit insulation board was sealed top and bottom per the specs, but it leaks at the vertical truss connections. On the bottom, another leak near the air sealing work is evident. This pathway was probably missed because the installers lacked a fundamental understanding of air sealing and leakage pathways.

POST OCCUPANCY ENERGY USE

After two full years of operation, the Ramona Apartment building has exceeded its goals, outperforming not only the expected energy use but also the rigorous energy standards of Architecture 2030. This was the conclusion after two full years of monitoring and recording the energy use in the occupied building.

The Ramona achieved LEED-Gold Certification, but the Ramona's team wanted to go farther than just achieving a LEED rating. They adopted the Architecture 2030 Challenge as the benchmark for energy use.

The Architecture 2030 Challenge compares the building's Energy Use Intensity (EUI) to real buildings in a large database maintained by the Environmental Protection Agency (EPA). The EUI is measured by calculating all of the energy used at the site - therms of gas and kilowatt-hours of electricity - and converting those to British Thermal Units (BTUs).

The engineer's model for the Ramona predicted an EUI of 22.9 kBtu per SF per year –only 50% of the energy use by similar apartment buildings in the EPA's database. After two years, the building's actual performance beat those projections by more than 18% with an actual EUI of 18.7 kBtu/SF/year.

Energy Highlights:

- Performance compared to energy model – The energy model projected an EUI of 22.9 kBtu/GSF/year. The actual performance of 18.7 kBtu for the first year (from 7/1/11 to 6/30/12) and 18.9 kBtu for the second year was 46.8% of west regional average of 40 and was 18.5% better than the energy simulation model had predicted. The energy simulation model included air leakage control as one of the critical simulation parameters.
- Data Collection –Tracking the energy use for the whole building and for the individual apartments is planned for 5 years. The apartment energy use is being tracked by floor (to assess the stack effect) and by geographic orientation. An energy “dashboard” was added in all apartments on the 4th floor and the electricity use in those units is being compared to the floors above and below.

SUMMARY & CONCLUSIONS

This is the first case I am aware of, where building energy performance was documented from design, to construction, to occupancy, and actually measured. Most energy efficiency at Ramona can be attributed to focusing on the building's fundamentals, especially building an airtight and well-insulated envelope. There has been extensive discussion in the industry about the impact of airtightness on building's energy efficiency and the effectiveness of a continuous air barrier in achieving an airtight envelope. However, this has been received with skepticism, since most research to date documenting energy savings from airtightness is based on energy simulation models which compare the energy performance of an airtight building with a “leaky” building, often code minimum. This case study documents not only how a continuous air barrier could achieve an airtight building envelope, but also how an airtight building envelope can

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reduce the energy use. The actual energy use is close to that predicted by energy simulation models, which included air leakage control as one of the critical energy efficiency measures. Based on experience with previous buildings, the design team had assumed an infiltration rate of 0.16 ACH in energy model simulations. Blower door tests conducted on 36 of the apartments at Ramona, in addition to whole building airtightness testing described above, averaged an air leakage rate of 0.14 ACH.

Further monitoring for the next 5 years will provide additional information on maintaining building envelope airtightness years after its initial installation. No such data exist in the industry.

ACKNOWLEDGEMENTS

Special thanks to the entire Ramona Project Team for sharing the design, construction details and post-occupancy energy monitoring; ASHRAE 1478-RP project team for sharing the whole building airtightness test report and for inviting DuPont to participate on the project; Personal thanks to Mike Steffen at Walsh Construction Co. for involving the DuPont Team on the project at the very early stages, for volunteering the building for airtightness testing, for sharing the energy use data with us and allowing us to use these data.

ABOUT THE AUTHOR

Dr. Spinu received a Masters Degree in Chemical Engineering and Ph.D. in Polymer Science and Engineering from Virginia Tech. She joined DuPont Central Research & Development (CR&D) in Wilmington, Delaware in 1990 as a Research Chemist. In 1995 she was promoted to Research Manager, and in 2000 she joined DuPont Building Innovations as a New Business Development Manager. She currently leads Building Science and Sustainability initiatives in DuPont Building Innovations.

Dr. Spinu has been a member of the 90.1 ASHRAE Committee and Envelope subcommittee (2004-2012), BEC (Building Envelope Council), AIA/BEC, CSI, ABAA, and other professional and trade organizations. She has published many papers in technical journals and trade organizations, is the author of 16 patents and has been an invited speaker at many regional, national and international conferences on building science.

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APPENDIX 1

The following individuals were present and participated in the building air leakage test.

Name	Organization	Responsibility
Wei Lam	WJE Associates, Inc.	Run Teclog2 during testing
Ashley Wisse	WJE Associates, Inc.	Label mechanical equipment for seal removal during experimental testing
Gary Nelson	Energy Conservatory	
Collin Olson	Energy Conservatory	Ensure proper teclog set-up
Larry Harmon	Air Barrier Solutions	Identify air barrier issues
Steven Shewach	Pete Fowler	
Michael Bonn	Ankrom Moisan Associated Architects	
Mark Koller	Interface Engineering	
Vanessa Cass	Waterleaf Architecture	
Dave Deress	WJE Associates, Inc.	Equipment Set-up
Maria Spinu	DuPont	Observe Testing
Pete Ryan	WJE Associates, Inc.	Equipment Set-up
Craig Stewart	Ecotope	
Amanda Ayour	Portland Energy Conservation, Inc.	
Mike Williams	White Glove Building Maintenance	Thermography
Mike Steffen	Walsh Construction	Observe Testing
Martin Houston	Walsh Construction	Observe Testing / Thermography
Logan Cravens	SERA Architects	
Jasha Kistler	Façade Group	
Rob Kistler	Façade Group	
Ed McNamara		
Dave Young	RDH Group	
Ariel Levy	RDH Group	
Bob Davis	Ecotope	
Craig Stewart	Ecotope	
Sean O'Shea	WJE Associates, Inc.	Equipment Set-up