Opportunities and Constraints for Townhouse Developments Meeting DOE's Zero Energy Ready Home Standard

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ABSTRACT

This paper discusses opportunities and various constraints that arise when attempting to meet the Department of Energy's (DOE) Zero Energy Ready Home (ZERH) Standard for townhouse developments. Besides a broader analysis of economical limits of performance for different consumption categories, the paper discusses the specific constraints that arise for production homebuilders when trying to meet this design goal. This study builds on findings that emerged from a submission to DOE's Race to Zero Student Competition and expands the application to constraints and opportunities for other climate zones. The submitted design proposal and analysis yielded interesting findings that can be of high relevance for other production builders looking into ZERH, as it identified focus areas of performance that are different to single family detached homes. The paper also discusses the modeling challenges and limitations of the software tools that are currently utilized to demonstrate that ZERH requirements are met.

BACKGROUND

High-Performance Buildings and the Production Home Builder

The trend towards energy efficient, high-performance homes has attracted various businesses across the housing market in hopes to benefit from the economic and marketing power of energy savings. Thus, it is no surprise that production builders are also trying to enter the high-performance building market and try to improve the typical standard homes they offer by featuring more energy efficient technologies. However, production builders, who typically construct homes in large quantities of similarly sized and designed houses within a community in a short time frame, face considerable challenges when making this transition. High-performance buildings require additional planning and processes, which includes building science analyses (e.g. for thermal and hygrothermal performance), customized framing, enhanced air sealing techniques, and advanced HVAC installation methods, all of which can disrupt critical schedules and budget constraints for production builders. Such changes and associated challenges are in general less strenuous for a custom homebuilder, where their project timelines are not necessarily governed by automated systems of procurement, production, and installation.

With such a vast amount of processes to ensure remain efficient, production builders have communicated the need for extra guidance and support towards designing and constructing high-performance homes. In an effort to help production builders with the transition into the high-performance building market, Pacific Northwest National Laboratory (PNNL) worked with several production home builders to identify the challenges typically faced by them when constructing to high-performance standards (Widder et al. 2013). Some of the common challenges encountered include difficulties faced during planning, implementation, and certification. In regards to planning, the scheduling and communication requirements with subcontractors were the biggest obstacle. Confusion over the need for schedule adjustments to accommodate new training for advanced construction techniques and critical installation activities was often missing or overlooked. Implementation was discussed as requiring the need for more building science support to optimize the construction process. Additionally, certification was an issue the builders discussed as another obstacle, specifically in regards to deciphering the HERS "black box", which refers to the score and energy consumption assessment and modeling tool REM/Rate, which is used to obtain design specific performance metrics. The builders believe that having more information and understanding for the weight/impact of various design characteristics that are written into and hidden in the energy consumption algorithms within the software, could assist with reaching certification goals more easily.

The lack of accuracy of HERS scores as compared to actually obtained performance numbers was also an issue. Many homes constructed and certified by the builders performed better than the predicted score when compared to actual utility bills, which has led to a loss of reliability in using HERS as a marketing tool. This result is consistent with a recent investigation, where the energy consumption of a large sample of high-performance multi-family building units were evaluated using observed utility use data compared against HERS estimated utility consumption data for the same units (McCoy et al. 2015). The results of the investigation revealed a significant overestimation of the HERS scores compared to actual usage data, with additional insight presented in regards to the variables and building technologies that may be driving the HERS score predictions.

In a similar attempt, specifically to identify common challenges production builders encounter when designing and constructing to high-performance building standards, and the Department of Energy's Zero Energy Ready Home (ZERH) standard in particular, a roundtable discussion of production builder executives organized a forum to gather relevant input and observations (Rashkin 2014). Key obstacles identified included a lack of software that can effectively capture the influences of high-performance technology contributions, and similar dissatisfaction with the inaccuracies of modeling tools predicting energy consumption data as discussed previously.

It is clear that there is still a learning curve and various barriers that exist for production builders transitioning into high-performance building design and manufacturing processes. Research and support that can remove these obstacles could help production builders with a faster and smoother transition into the high-performance building market, and assist them in achieving their high-performance building design goals with more ease.

U.S. Department of Energy Race to Zero Student Design Competition

The Race to Zero (RTZ) competition is an annual event, in which students and faculty teams from universities and other institutions of higher education across the country, including several international participants, compete to design a zero energy ready home (ZERH). The competition requires teams to abide by the DOE ZERH standard in their designs while also incorporating additional innovations and strategies the team deems fit to create a high-performance home. Designs are either original ideas developed by the team, or are based upon real-world scenarios by redesigning existing house plans that are typically provided by an actual homebuilder.

The Virginia Tech student team “Invent the Future” participated in this event in 2015 and submitted redesigned construction documents and building science analyses for a townhome development currently under development by a production homebuilder. Many of the rather small proposed changes, which could relatively easily have been implemented by a local custom home builder, had much larger impacts on the whole production and supply chain that is an integral part of the company structure for a production home builder. This collaboration between enthusiastic students and a large-scale, conservative production builder created a challenging yet interesting experience for the design team, and brought attention to key details that may be of value for other inquisitive production builders, who are planning to extend their product lines into the high-performance building market.

Zero Energy Ready Homes. To achieve the DOE ZERH standard it requires a home to attain a HERS score of approximately 55 or lower, which represents an energy performance improvement of 40%-50% beyond typical code requirements (DOE 2015). There are mandatory requirements prescribed to meet the ZERH standard through prescriptive or performance paths, which are specific to the climate and size of the home being designed and constructed. The requirements established by the DOE (2014) include the following:

- Compliance with the ENERGY STAR Qualified Homes Version 3 checklist
- Compliance with EPA Indoor airPLUS
- Compliance with the Renewable Energy Ready Home checklist
- Enclosure fenestration meets or exceeds ENERGY STAR requirements
- Enclosure insulation meets or exceeds 2012 IECC levels
- Ducts are located within the enclosure thermal and air barrier boundaries
- HVAC systems meets or exceeds 2012 IECC levels
- Minimized infiltration rates

- Hot water system meets EPA WaterSense conservation and energy efficiency requirements
- Lighting and appliances are ENERGY STAR qualified

To ensure that the home can become net zero if a photovoltaic (PV) system is installed, designing the size and selecting the characteristics (e.g. tilt and efficiency) of the PV system to determine the potential energy output and monetary value must also be accomplished. In this case, the annual kWh output of the proposed PV system should equal or exceed the projected annual energy consumption of the occupied home, and subsequently achieve an adjusted HERS score of "0", or below zero if surplus energy is being generated.

The Virginia Tech student design proposal was able to accomplish all of these goals to meet the ZERH requirements, all while successfully managing to address some important challenges faced with when collaborating with a production builder. The final design proposal submitted for the competition was named the TownHauZ.

The following sections provide a summary of the major project constraints that influenced the design, followed by the building science modeling challenges and analysis solutions conducted for the project, and discusses recommendations and opportunities towards designing net zero energy ready homes for production builders.

THE TOWNHAUZ PROJECT

A Net Zero Energy Ready Production Built Townhouse Development

For the RTZ Competition, the Virginia Tech student design team submitted a development proposal consisting of zero energy ready townhouses in Baltimore, Maryland. The partnership with a production builder allowed for the opportunity to engage with an actual townhouse development project in preparation, which provided typical initial design plans, and thus also provided the real-world context to apply advanced design objectives.

The project features a row of adjacent three-story units, each with approximately 1690 square feet of conditioned living area and 9 feet ceilings. Each unit has three bedrooms and two bathrooms on the third level, and an open living area and half bath on the second level. The first level is used for a one-car garage and a laundry room. This floor also provides ample space to convert the remaining unconditioned floor space into a recreational room at the homeowner's discretion, with additional rear space for potential additions to the home. The design of the TownHauZ project focused on an ultra-efficient enclosure system, high-performance HVAC systems, energy efficient lighting and appliances, and high quality comfort and control that can rival many high-performance homes available today. A summary of technical specifications for the townhomes as compared to the original standard design is listed in Table 1.

Table 1. Data & Technical Specifications: Proposed vs. Standard Design

Specifications	TOWNHAUZ	Standard Design
Project Location	Dundalk, Baltimore, MD	
IECC Climate Zone	IECC Climate Zone 4 (Mixed-Humid)	
Conditioned Area (sq.ft.)	1690	1690
HERS Score	39	106
HERS Score with PV	- 4	N/A
Monthly Energy Cost	$84.33	$192.75*
Wall Insulation	R-40	R-15
Foundation Insulation	R-10	R-10
Roof Insulation	R-60	R-49
Window Performance	R-7.6	R-3.5
Heating/Cooling	1.5 ton 16 SEER Heat Pump w/ Electric Backup	90% AFUE gas 13 SEER AC
Ventilation	Ductless Heat Recovery Ventilation	-
Dehumidification	ENERGY STAR 70H Dehumidifier	-
Water Heater	2.9 EF Hybrid Water Heater and PEX Distribution	Electric Storage Tank

**Based on Energy Information Administration (EIA) data for a standard home in Maryland*

Project Constraints

The overall project goals of making the townhouse development net zero energy ready with high-performance enclosure and building systems, and high levels of thermal comfort, faced two dominating challenges that became paramount for a successful design integration. These challenges were 1) to ensure that these homes with their high-performance enclosure system were designed appropriately for the moisture-laden climate, and 2), to design homes that are suitable for a production builder process, specifically in regards to construction limitations and marketability.

Production Builder Challenges. Discussions held with the production builder provided additional design constraints that had to be considered. In summary, it was found that

- the design needed to align with the manufacturing process and its limitations in the plant, e.g., the maximum height that fits under the production line bridge;
- the design needed to withstand the transportation process and thus limit the materials selection;
- changes of required labor on site can have significant impact on other processes, e.g. a change in duration of one process can disrupt other objects built on the same site. Additionally, for the particular production builder associated with this project, 7-9 of the townhomes are typically constructed at the same time, each house with a total schedule of 87 days, which includes quality inspections and customer walkthroughs. A design that compromises this would not be practical for the proposed type of builder;

- material selection can have a significant impact on worker health, which is one of the most valuable assets of a larger company, and thus can have long lasting impacts on a worker's productivity;
- there is a specific buyer's market, which can be challenging if you offer high-performance features only for a subset of units in a larger development, a path we suggested to implement as a demonstration project.

Due to these constraints, drastic changes and ambitious solutions proposed by the design team to alter the building enclosure and mechanical systems in an effort to achieve more energy efficient standards underwent significant scrutiny.

Climate Appropriate Design. The townhouse development was located in Baltimore, Maryland, which is classified as Climate Zone 4 according to the International Energy Conservation Code (IECC). This climate zone is predominantly a mixed-humid climate, with fairly mild temperatures that are experienced year round. The average annual temperature in Baltimore Country is 60.2 degrees Fahrenheit, with the highest temperatures observed in July (low 80s), and the coldest temperatures in January (mid to low 20s). An average of 41" of rainfall hits the Greater Baltimore area annually. Snow also adds to the mix of wet, but cold weather with an average of 22.7" of snow during the snowfall season.

Controlling moisture was an important goal for this design in particular in order to maintain quality and comfort, but also efficiency in energy and durability for the various building elements exposed to the challenges of a humid climate. More specifically, the highly insulated enclosure system with a resulting reduction of the HVAC loads created a scenario where dehumidification needs become the dominating variable that needs to be monitored and controlled. Market availability of such solutions has shown to be the biggest challenge to identify practical solutions.

ANALYSIS FINDINGS

Modeling Methods

When analyzing the thermal and hygrothermal performance of the building enclosure, as well as the energy performance of the proposed townhomes, several modeling tools and evaluation methods were used to design an appropriate solution that abided by the proposed concept and goals. These tools and methods included THERM, WUFI, REM/Rate, and additional specific heat loss calculations. ASHRAE design temperatures were considered when sizing and designing the space conditioning and dehumidification systems, as well as an analysis of local heating and cooling needs using degree-days data.

THERM. Thermal bridges are caused by higher thermally conductive materials that "bridge" across the envelope. For example, studs are a simple form of a thermal bridge, spanning from gypsum on the inside to sheathing on the outside, and thus provide less resistance than the highly insulated cavities. Thermal bridging should be minimized as much as possible not only to reduce energy consumption but also to improve other thermal performance characteristics of enclosure assemblies, such as surface temperatures. To obtain more accurate input parameters for our energy analysis, the simulation tool THERM was used. THERM is a finite element method based heat transfer modeling tool developed by the Lawrence Berkeley National Laboratory (LBNL), and is used by many researchers and practitioners in the architecture, engineering, and construction domains to conduct heat-transfer analyses (LBNL 2015). THERM was used by the student design team to calculate more accurate U-Values of the enclosure assemblies, including additional assessment of losses through thermal bridges throughout various building component intersections.

WUFI. To investigate the hygrothermal performance of different wall assembly design alternatives under transient conditions, the software tool WUFI was used. WUFI can conduct dynamic heat and moisture transfer simulations for various wall material components exposed to different interior and exterior climate conditions (Fraunhofer IBP 2015). While the educational version only allows access to the standard ASHRAE material database, and limits simulation run-time scenarios to a maximum of two years, it provided enough insight into condensation risk tendencies for the local Baltimore climate.

REM/Rate. The energy modeling software tool REM/Rate is the standard tool defined by the DOE ZERH standard to obtain energy performance values, such as the HERS score, and it was thus used to calculate the score for the townhouse units with and without a photovoltaic system. The software additionally provided energy consumption estimates for the domains of heating, cooling, water heating, lighting and appliances. Developed by NORESCO LLC, REM/Rate was created specifically to meet the needs of HERS raters, and uses internal proprietary calculations to estimate the energy consumption of a building based upon the input of various housing characteristic variables such as R-values, climate, and domestic hot water and HVAC systems (NORESCO LLC 2015).

Additional Heat Loss Calculations. To further analyze the thermal performance of the enclosure system, different enclosure detail solutions in terms of their linear loss coefficients due to thermal bridging effects were assessed with detailed heat loss calculations. These analyses were again performed within THERM for validation. The results were also compared with REM/Rate energy performance results produced for the final design proposal in order to determine if thermal bridges are considered within the model, and if, to what degree.

Design Challenges and Modeling Limitations

Enclosure Thermal Performance. Various design alternatives of enclosure systems were evaluated in terms their thermal performance prior to selection of the final enclosure system design. Figure 1 depicts an example of a THERM simulation showing isotherms and flux vectors and the thermal bridging effect around studs of the original, cavity filled 2x4 stud wall prior to any design adjustments.

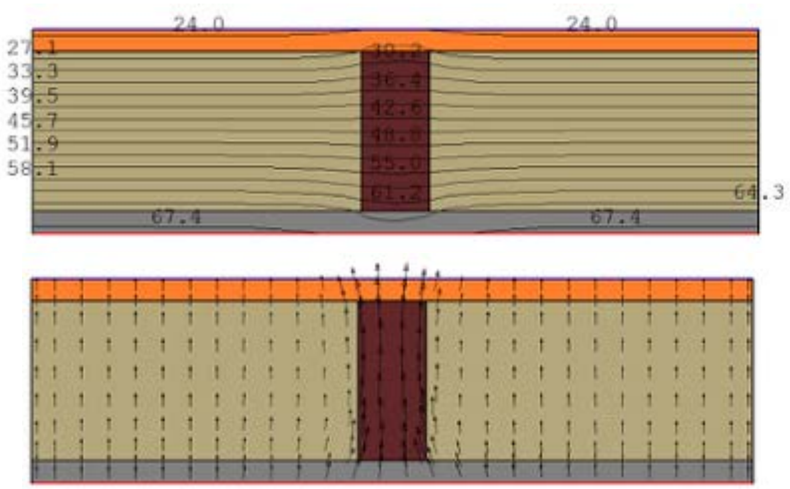


Figure 1. Isotherms and Flux Vectors of the original wall system

Initially, the design team began with the idea to improve the thermal performance of the original stud wall without the need to significantly change the construction process as currently carried out by the builder. The first step in this process was to increase the cavity by 2" and move to a 2x6 stud system, as it can be found in residential construction projects that are implementing advanced framing techniques. This concept of an increased thickness for the insulation cavity was then developed further to achieve even higher thermal performance. Eventually, a solution to break the thermal bridge of the studs was devised that not only improves the overall performance of the wall, but also achieves higher surface temperatures for thermal comfort.

Limited by a production height for wall panels in a manufacturing process, the preassembled panels could not be increased any further. However, since the builder already utilized blown in cellulose insulation in the roof assembly, the design team recommended using the same system for filling wall cavities. Utilizing this technology, the solution could be further improved by adding a 2" XPS insulation strip, e.g. ripped from larger boards, and attaching them directly to the studs.

The challenge of this solution was that XPS would not provide a good mounting material for the interior finishing system, which is typically a drywall installation. In lieu of any existing product, it was proposed to utilize the ZIP system panels that can be ripped into 1.5" or 2" wide strips and can be easily mounted to the studs, while at the same time providing a mounting base for the gypsum boards. Obviously, the additional layers on the exterior of the ZIP system, which is typically used for other control functions, are overkill for this application, and a simpler/cheaper product would be desirable. In any case, adding additional cellulose is relatively cheap as compared to adding exterior insulation, and thus this wall assembly could serve as a viable alternative for a builder, achieving a total average R-Value of 25. This solution is shown in Figure 2.

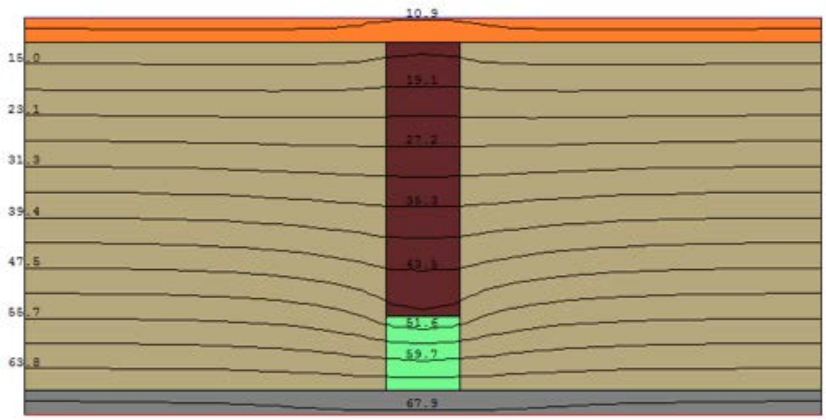


Figure 2. Alternative wall assembly achieving R-25

Considering the potential constraints that were voiced by the production builder, specifically those related to labor and construction processes with an unfamiliar product solution, the student design team looked into exterior insulation options. When adding exterior insulation, the previously proposed solution to increase the insulation cavity by adding XPS strips was determined to become less competitive for the builder since the added labor would not offset the same performance gain than just increasing the exterior insulation by the same thickness.

A cost versus performance gain analysis conducted by the team showed that exterior insulation levels beyond 3” bring no significant energy consumption savings for townhouse projects, which have on average a smaller enclosure/floor-area ratio than comparable single-family detached homes. However, for this project the team decided to use 4” of exterior XPS foam insulation to increase thermal comfort and to come closer to the typical performance of walls following the PassivHaus Standard.

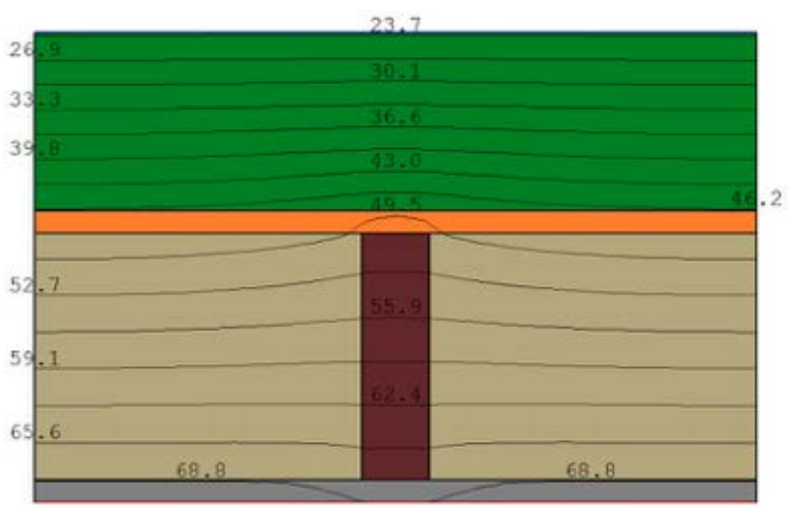


Figure 3. High performance wall system achieving R-40

The final proposed assembly is shown in Figure 3, and is composed of 1⁄2" gypsum board, a 2x6 stud system with 5 1/2" of blown-in cellulose in its cavities, 1⁄2" OSB as structural sheathing, 4" XPS exterior insulation, 3/8" strapping for a capillary break, and vinyl siding. This proposed wall system achieves R-40 and can thus significantly increase the interior surface temperatures during colder days.

Hygrothermal Performance of the Enclosure System. The wall assembly shown in Figure 3 comes close to the "perfect wall" as it is often referred to and published by the Building Science Corporation (Lstiburek 2008). For comparative reasons the project team analyzed different approaches of modelling and compliance as they can be found in different international hygrothermal standards and codes.

When checking the condensation risk of this assembly under steady-state conditions during winter months as required by German standards, interstitial condensation can be anticipated when the exterior temperature is below 20°F and interior relative humidity is above 35% as shown in Figure 4. This is significantly lower than the 50% required by German standards, and would trigger interstitial condensation at the OSB board. Now, it is still debatable if 35% interior humidity under cold weather conditions with more or less continuous heating is a reasonable long-term interior condition. However, if it is assumed that the proposed enclosure follows airtight building standards, and the home has a rather high occupancy rate (e.g. 4 BRs) compared to the total square area (actually volume), these relative humidity rates become more likely, which in turn increases the condensation risk.

Admittedly, the German DIN Standard applied in the analysis shown in Figure 4 is based on a very low-risk modeling approach that is applied as a blanket solution for the German climate. This method is applicable in moderate climates with no significant humidity levels in summer, which in turn allow for longer periods of evaporation of eventual accumulated condensation amounts during colder periods.

The correct assessment and remedy of any condensation risk is essential to achieving a viable and durable high-performance enclosure system for climate appropriate designs. Knowledge on how to assess this risk is a building science fundamental that can prove invaluable to a builder. Enhanced thermal performance and airtight construction is only half the battle in designing an ultra-efficient enclosure. Failing to acknowledge the potential for moisture to impede on the durability of the system could lead to costly and hazardous undesired results.

The proposed wall assembly was then investigated more closely under transient conditions with the software tool WUFI. Figures 5 – 6 first show the hygrothermal performance of the original regular 2x4 stud wall for the Baltimore climate to demonstrate the performance variability that can be captured through this tool.

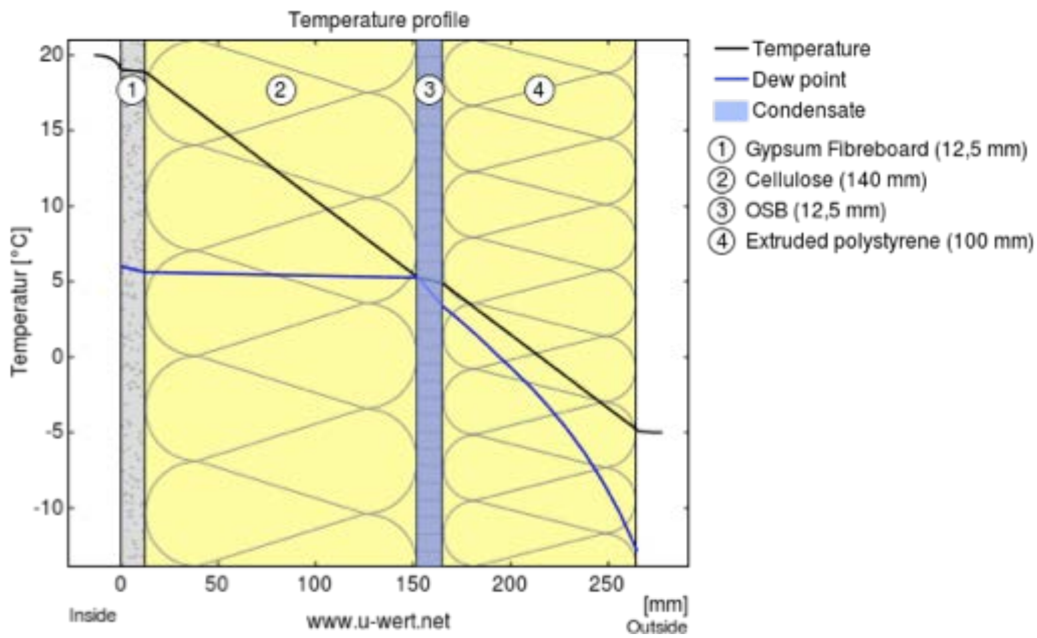
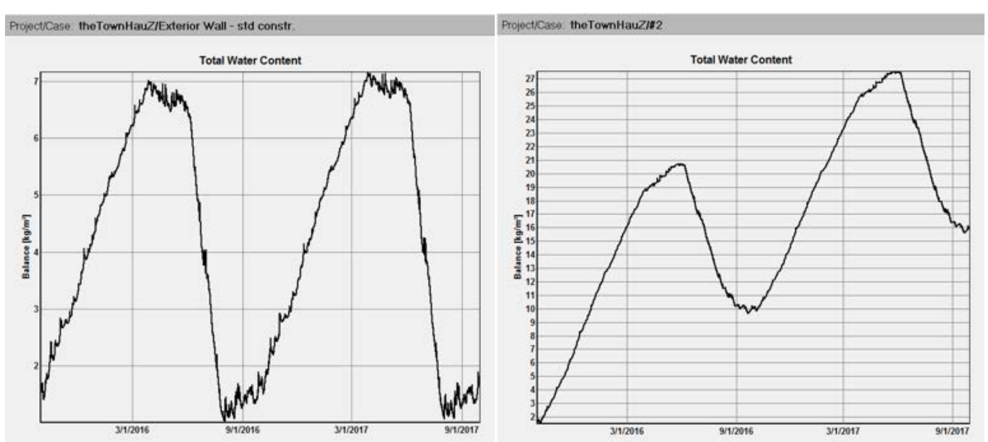
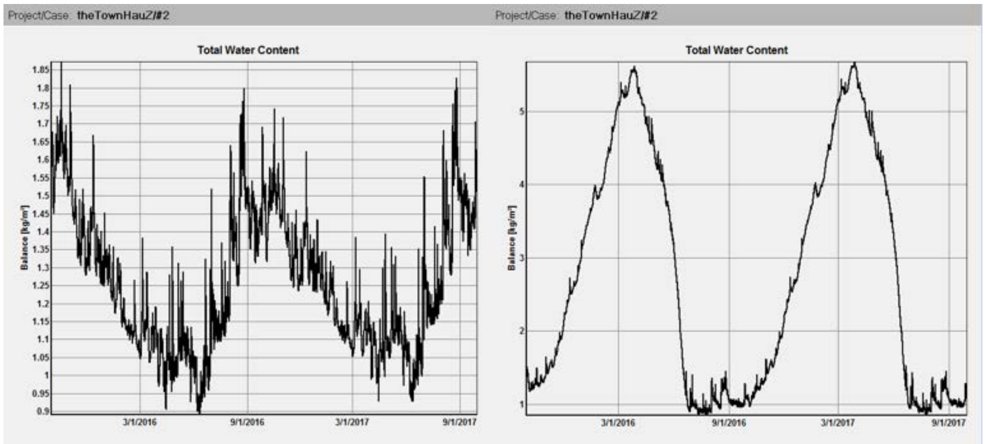


Figure 4. Hygrothermal performance under steady state conditions of 35% interior relative humidity in winter climate.

Figure 5 shows on the left that as long as the enclosure is built to regular standards (ACH~2.0), there will be enough drying potential during the summer, which theoretically would allow for any condensate accumulated during winter to evaporate through diffusion. However, relatively high total amounts of water content accumulate and are stored in the assembly, which can be a concern to some building materials. Once more airtight construction is implemented (ACH<1), this drying potential is gone (Figure 5 right). This issue can be resolved in two ways: a) through introduction a vapor retarder on the interior side to reduce the overall diffusion rate as shown in Figure 6 on the left, or b) control for humidity levels on the interiors side (i.e. actively dehumidify) to increase the evaporation potential again (Figure 6 right).

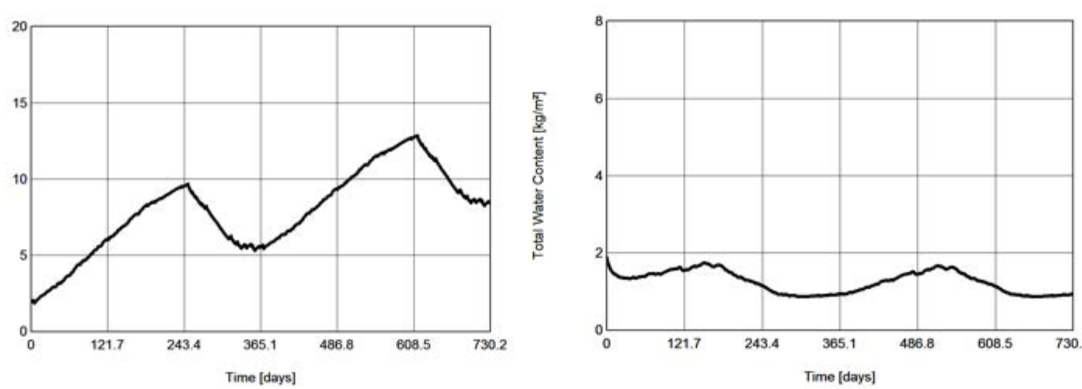


Figures 5. Left: Standard 2x4 wall assembly. Right: 2x4 wall assembly - airtight



**Figures 6. Left: 2x4 wall assembly, airtight, with additional vapor barrier on the interior
Right: 2x4 wall assembly, airtight, with controlled interior dehumidification**

A WUFI analysis assessing the condensation risk of the proposed R-40 wall would also face some condensation issues if airtight construction is assumed and interior humidity levels are not actively controlled and maintained (Figure 7 left). This scenario was then compared with a proposed active dehumidification system that could hold the interior humidity levels below 50% during the summer months. Figure 7 shows the simulated total water content in this wall assembly over two years on the right, and it appears to have enough drying potential under these conditions.



**Figures 7. Left: Exterior wall without vapor barrier and without interior humidity control
Right: Exterior wall without vapor barrier but with active interior humidity control**

The introduction of a vapor-retarding layer on the interior side of the wall assembly was subsequently investigated as an additional measure to evaluate its impact on the water content. Figure 8, shows on the left how the vapor control layer can successfully achieve the same as a system controlling for interior humidity, which still is an energy intensive process. One challenge with two vapor-retarding layers, such as the retarder on the interior side and the OSB board in the center, is to prevent larger amounts of moisture (e.g. rain during construction) being trapped between these layers. The biggest challenge for this solution is the correct installation of this layer and translating the importance of this function to construction practice without errors. This process may require additional training and coordination, which is often not necessarily feasible for established schedules and budgets set by a builder. With this in mind, an evaluation of the wall assembly including a vapor retarder while also actively controlling for interior humidity was performed. This strategy results in better hygrothermal performance and built-in redundancy, which reduces the risk of errors on either side, be it construction process or system failures (compare Figure 8 right).

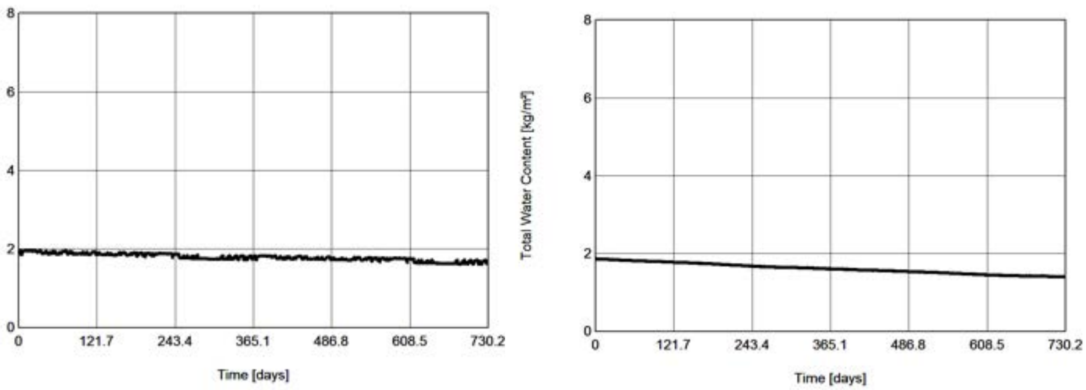


Figure 8. Left: Exterior wall with added vapor barrier but without interior humidity control Right: Exterior wall with added vapor barrier and active interior humidity control

As shown in Figure 9, the ultimately proposed solution for the exterior wall system even meets the stringent German standards, which requires reduction of the condensation risk based on a constant interior relative humidity of 50% over 90 winter days.

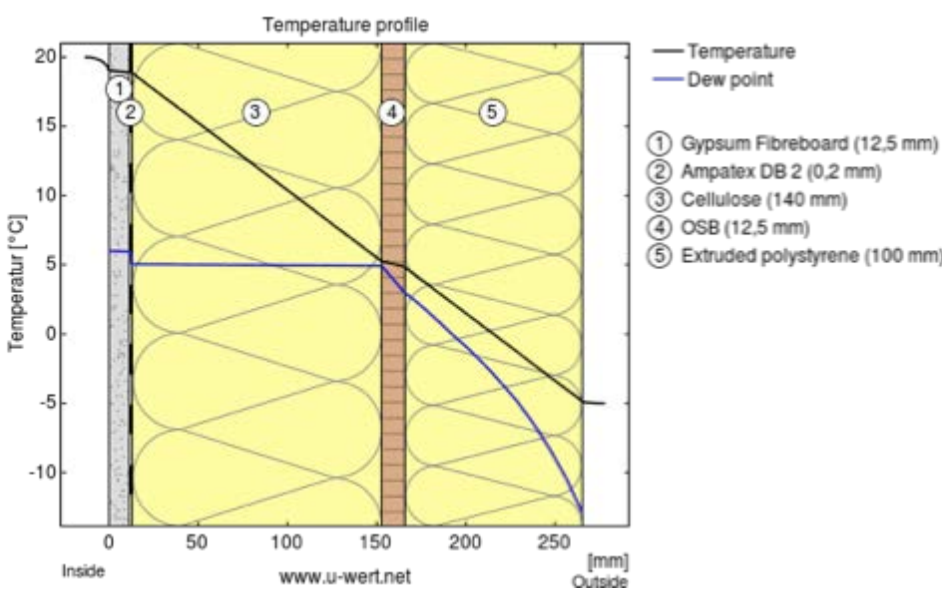


Figure 9. The TOWNHAUZ R-40 exterior wall system

Thermal Bridges and Window Integration. To analyze the thermal performance of the enclosure system further, different detail solutions were investigated in terms of their linear loss coefficients due to their thermal bridging effects. This analysis was carried out with spreadsheet based heat loss models and calculations. It was found that REM/Rate, which was used for our energy analysis, does not account for thermal bridges, even though thermal bridges can have a significant impact on energy performance in high performance enclosure systems.

After conducting an individual energy analysis of the original wall assembly with simulations for a single façade of one level, the difference between the analysis a) without considering thermal bridges (1,731 BTUh) and b) an alternative solution that considered the effects of double and triple studs below windows, in corners, and the window frame installation (1,818 BTUh) were compared. The difference between the two approaches came to 12.6% of the total losses for a typical façade segment. These analyses were again performed using THERM for verification.

Thermal bridges are specifically critical around window installation details. The project team thus evaluated different installation methods and processes to improve these thermal bridges. The original window is shown in in Figure 10, while the proposed window installation design shown in Figure 11 moved the window installation pane from the exterior close to the center axis of the enclosure system. The OSB provides a sufficient mounting basis, and allows for reaching 2” over the edge of the raw opening formed by the surrounding studs and headers. This additional space can now be filled with solid insulation while the remaining gap will be filled with spray foam. This option allows for a thermal bridge free construction, bringing the linear thermal loss coefficient around the perimeter of the window close to zero.

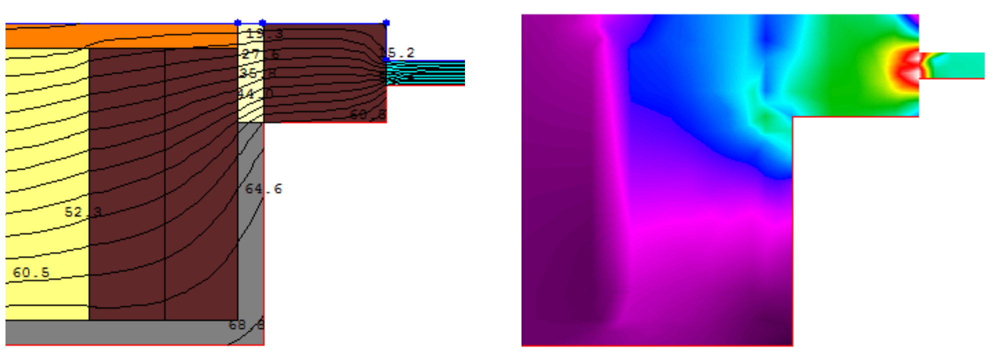


Figure 10. Original window detail

The analysis of the final wall assembly carried out in the spreadsheet model, which also includes windows that have a 40% better performance, showed that the total heat losses could be considerably reduced, namely from 1,818 BTUh down to 711.8 BTUh, which represents a 60% reduction.

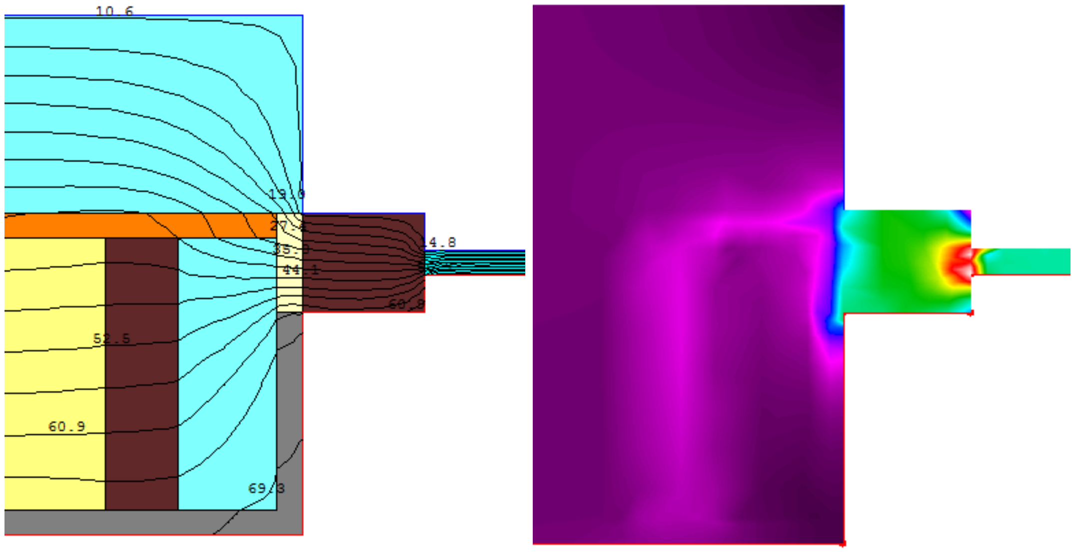


Figure 11. Thermal-bridge free window detail

Energy Analysis: To achieve the ultimate energy consumption reduction goals required to meet the ZERH standard, the design team first tried to cut down on energy loads in a way that was still feasible to the construction process of a production builder and cost efficient in material selection and systems operations. Initial strides were made through the enclosure design as discussed in the previous analysis section. This was done through a combined effort of reducing thermal transmission and infiltration, thermal bridge free details, enhancing insulation levels, and ensuring airtight construction.

However, specifically for townhouse developments, where enclosure to floor area ratios are rather low for mid units, the enclosure alone is not enough to meet the ZERH energy goals. Additional attention must be paid to the HVAC system, hot water heating system, lighting loads and appliance selections specified for the home in order to identify high-performance systems that meet the new load reduction requirements. Ultimately, the HERS score for this development could be drastically reduced and came in below the initial target score of 50.

For a project like this, a renewable source of energy is needed to achieve real net zero energy consumption. To supply the total remaining annual energy consumption balance here, 27,500 kBTU of energy must be produced annually on site. The site orientation and location in regard to the potential for harnessing adequate solar radiation play a significant role when determining the size of a photovoltaic (PV) system. Using the NREL PVWatts Calculator, the team could show that an array of 20 PV panels, each with an output of 320 Watts, resulting in a total array size of slightly larger than 6 kW can make the project net zero. Using this data in the energy models for the project generated a final HERS rating of -4.

Applicability in Across Different Climate Zones

The analysis and findings discussed in this paper are relevant for developments in the hot-humid climate zone found along the eastern coastal states of the U.S. While these are rather densely populated regions, where townhouse developments are quite common, the same results for developments in other climate zones are not immediately applicable. To elaborate, humidity levels during summer months (if not directly controlled through the HVAC system) and average exterior temperatures during winter months can have a significant impact on the hygrothermal performance solution shown in this paper.

At the same time, the rather mild mid-Atlantic climate seen in Baltimore made the enclosure system play a less significant role than it would receive in mid central climates, where many more days are below freezing temperatures. It can be anticipated that additional insulation levels beyond the utilized thicknesses presented here can be economically feasible.

CONCLUSION

The design and eventual construction of production builder friendly and climate appropriate high-performance townhouses can be a complex task, where many variables must be considered in order to create viable, efficient, durable, and ultimately profitable solutions for all involved stakeholders. As presented in this paper, meticulous planning and analysis is essential when selecting appropriate materials and constructions methods to achieve a successful product. Failure to do so could result in costly scheduling and installation mistakes, as well as long-term durability issues, which are not only detrimental to a builders bottom-line and reputation, but can become an additional hazard to the health and financial well-being of their homebuyers.

This paper provided specific building science analysis insights and recommendations for production builders planning to or already transitioning into the high-performance building market. Some of the main obstacles mentioned by production builders as discussed herein, such as challenges with planning, implementation, certification, and marketing can be summarized in the following takeaways that are key elements for a successful implementation of high-performance building standards and processes.

Key Takeaways. Builders and designers must not overlook the potential impacts technology solution decisions can have on labor, specifically in regards to the importance of necessary training investments to properly install unfamiliar high-performance construction systems and details. Implementing fail-safes (e.g. controlled dehumidification and correct vapor diffusion design) is an additional strategy that can help mitigate the risk of failures due to possible implementation issues.

Building science fundamentals such as thermal and hygrothermal performance understanding are essential knowledge elements that should become mandatory across all stakeholders. This means horizontal knowledge integration across the different design and management domains, and vertical dissemination across supply chains and the building construction industry, starting from CEOs recognizing the risks, project managers understanding the issue, and construction trades executing details.

As demonstrated in this paper, modeling and simulation analyses can be conducted to ensure decisions are appropriate for short-term and long-term goals of cost efficiency and durability. Once the underlying principals are understood, the actual procedures are comparatively simple for individuals in the architecture and building construction industries, and they can quickly become proficient with minimal time investment. Furthermore, optimizing for comfort is another benefit to performing building science analyses that can be used as a marketing tool for customers interested in the additional benefits of their investments.

It is important to note that when applying these strategies in other climates, appropriate adjustments must be made to ensure a solution is still effective. While it may be tempting to apply the same design to multiple project locations in order to maintain established schedules and training competencies, high-performance buildings are not a one size fits all model. An understanding for the processes and design strategies that will need to change for successful implementation in various locations is fundamental to a successful application across different climate zones. .

Finally, the “blind” use of energy modeling and scoring tools, such as the HERS rating tool can lead to a lack of attention to critical construction details. Thermal bridges are often not captured well in available energy modeling tools, which can skew energy consumption estimates and/or result in local condensation issues. Identifying thermal performance problem areas in the design phase can allow for more accurate estimation of thermal losses, and can additionally help with the optimization of the thermal boundary layer. Presenting this information to customers in a way that can explain possible discrepancies between HERS scores and actual energy consumption could potentially be a powerful design and marketing tool, which exemplifies the builders rigor beyond simply abiding by the construction standard.

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