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Fort Devens: Cold Climate, Energy-Efficient, Market-Rate Townhomes

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Consortium for Advanced Residential Buildings

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Unless otherwise noted, all tables were created by CARB.

Definitions

ACH50	Air changes per house at a pressure difference of 50 Pascal between the inside and outside
AFUE	Annual Fuel Utilization Efficiency
BA Benchmark	Building America Benchmark 2010 home
BEopt	Building Energy Optimization software
C7A	Cambridge Seven Architects
CARB	Consortium for Advanced Residential Buildings
CFL	Compact fluorescent lamp
ccSPF	Closed-cell spray polyurethane foam
DHW	Domestic hot water
EEM	Energy efficiency measure
EF	Energy factor
HERS	Home Energy Rating System
o.c.	On center
PV	Photovoltaic
RDI	Rural Development, Inc.
SEER	Seasonal Energy Efficiency Ratio
SHGC	Solar heat gain coefficient

Executive Summary

Advanced planning and design considerations can leverage market-present technologies to yield high performance, marketable homes. Developing appropriate strategies based on location and site conditions early in architectural design and building specification is critical. In the Northeast, the first priority is often a tight high performance building envelope to reduce the heating load up front. By combining energy-conscious site and building planning with cutting-edge but market-ready products and techniques, the Consortium for Advanced Residential Buildings (CARB) developed effective strategies to reduce the overall building energy use in line with Building America goals in this modestly priced market rate project.

In 2009, MassDevelopment issued a request for qualifications and subsequent request for proposals for teams to develop moderately priced high efficiency homes on two sites in the Devens Regional Enterprise Zone. MassDevelopment, a Massachusetts agency that owns the Devens site (formerly Fort Devens Army Base, in Harvard, Massachusetts), set a goal of producing a replicable example of current and innovative sustainable building practices with a near-zero energy potential (see Figure 1). Metric Development, as primary developer and construction manager, formed one of the successful teams that included CARB and Cambridge Seven Architects (C7A).

Figure 1. Development sign at Devens

The performance goals were to reach a target Home Energy Rating System (HERS) Index of 40 (to meet the MassDevelopment requirements) and 30% source energy savings over the Building America (BA) Benchmark 2010. Combining these aggressive goals with affordability and replicability dictated that the process begin in the basic planning stages and incorporate site

design for solar access and building planning for simplicity of design and ease of construction. The resulting design called for four triplex two-story townhomes, each containing two bedrooms and 1900 ft^2 of space, including basements. Performance optimization studies were performed using BEopt software, which determined the insulation levels, overall airtightness, fenestration specifications, and other thermal enclosure attributes. The developer's marketing requirements meant that conventional, although highly efficient, mechanical systems were specified. Design integration kept all systems, including heating, ventilation, and air conditioning (HVAC) ducts within conditioned space.

A conventional vented attic with loose fill cellulose insulation formed the ceiling plane thermal boundary. Arriving at the final wall assembly (R-38, double-wall with dense pack cellulose) required more effort, as the initial design with 3 in. of closed-cell foam was deemed too expensive.

With the elimination of the foam insulation, the air sealing protocol for the vertical walls became critical. Specifically advocated by CARB and adopted by Metric Development is the use of the exterior sheathing plane as the primary vertical air barrier. All the panel butt joints were treated with proprietary butyl/polyurethane tape; and the panel edges, terminations, and penetrations with low-expansion foam to meet the aggressive air sealing target of 2.0 ACH50.

Conclusions and Recommendations

The energy efficiency measures (EEMs) implemented at the Devens triplex surpass the anticipated energy performance target. Examining the costs of the energy-efficient upgrades reveals the most- and least-effective measures. In the Devens end unit, the enclosure improvements cost the most, but also saved the most energy in the biggest end use category. (The middle unit enclosure upgrades were less costly by virtue of the reduced surface area relative to the end units). Lighting and appliances were the most cost effective in terms of payback period and provided the simplest changes, but also yield limited energy savings. Mechanical improvements struck a balance between the moderate price and substantial energy savings. The overall improvements cost $7,804 and saved 46.06 MBtu/yr for a payback period of 13.44 years. This package of improvements proved to be cost effective with a short payback period and relatively low first cost for significant energy savings.

Final testing of the initial prototype resulted in a HERS Index of 39, exceeding the targeted 40. Pricing the incremental cost increases for each upgraded system from standard practice determined cost effectiveness of the final prototype as compared to the specifications and costs of the BA Benchmark. Based on these outcomes, Metric Development is moving forward with the next buildings with no significant changes to plans and specifications.

1 Introduction and Background

MassDevelopment, a Massachusetts agency that owns the Devens Regional Enterprise Zone, (formerly Fort Devens Army Base in Harvard, Massachusetts) issued a request for qualifications in 2009 and a subsequent request for proposals for teams to develop moderately priced high efficiency homes on two sites in the enterprise zone (see Figure 2). Metric Development, as primary developer and construction manager, formed one of the successful teams that included CARB and C7A. MassDevelopment's goal was to produce a replicable example of current and innovative sustainable building practices with a near-zero energy potential. The homes, to be built and marketed in a mostly working class area north of Boston, are intended to showcase how they could be built and sold profitably, and that the results can be scaled to much larger developments and to infill opportunities.

Figure 2. Photo of the prototype triplex nearing completion

CARB's objective was to demonstrate and document how advanced planning and design considerations, as well as optimized whole-house technology, can leverage market-present technologies and yield high performance, marketable homes. CARB's performance target was to improve efficiency levels to 30% better than Building America House Simulation Protocols for new homes (Hendron and Engebrecht 2010). MassDevelopment's performance requirements are actually even higher, and therefore formed the project's overall performance goals. Initially

intended to be capable of net zero-energy performance (after photovoltaic [PV] arrays were installed), the team looked at efficiency levels balanced against projected costs and available roof area for PV and arrived at a target HERS of 40. The final agreement between the developer and MassDevelopment included HERS 41 as a minimum performance level to trigger the land purchase incentives. This contractual requirement ensured that the developer remained committed and helped to focus the design and planning activities.

The planning process started with a nearly clean sheet of paper, requiring 12 homes to be constructed on the flat 1-acre infill site. The homes were to be priced at $225,000–$350,000 and provide a reasonable return to the developer. To achieve these goals, basic planning decisions were paramount. A design charrette with the architect, developer, and CARB research team was conducted to develop and evaluate planning options and refine the most promising ones. From this exercise the basic two-story triplex building configuration was selected for economy of construction, marketability, enclosure-to-floor-area ratio, and solar site planning.

The simple compact form results in four rectilinear triplexes and allows all homes to be placed with direct southern exposures for passive solar gain and for future placement of roof-mounted PV arrays. With the townhouse triplex form, the high floor area to thermal enclosure area results in economy of construction and allows high-R wall strategies to be incorporated with lower incremental cost increases. The compact townhome form is also a traditional staple of New England that was thought to enhance marketability. Lastly, the design enhances energy performance by optimizing usable floor area relative to thermal enclosure area.

The energy strategy was to reduce the thermal loads as much as practical through enclosure efficiency, and then apply efficient, low capacity systems to meet those reduced loads. CARB used lessons learned from previous Building America cold-climate research to incorporate several of the enclosure strategies developed with Rural Development Inc. (RDI), including the double-frame walls and dense-pack cellulose fill (Aldrich 2012). These homes are meant to be "market rate" not definitionally "affordable," so two major departures from the successful RDI homes were incorporated: fully insulated and semi-conditioned basements and traditional HVAC systems. (For cost savings the RDI homes were insulated at the first floor framing, leaving the basement unconditioned, and conventional HVAC systems were omitted, instead relying on a single unit heater in each dwelling for space heating). The insulated basements used strategies that were researched and developed by CARB during side-by-side testing analysis completed in Chicago in 2004 (Aldrich and Zuluaga 2006) and included in a recent CARB implementation guide. (Aldrich et al. 2012) In this instance R-13 aluminum faced polyisocyanurate boards were adhered directly to the interior concrete surfaces.

Ensuring the enclosure assemblies would perform at their intended levels meant that extreme care was given to air sealing. CARB provided on-site contractor training, observation, quality control, technical installation support, and verification. Following project completion, CARB conducted the final test-out and building commissioning. The target HERS Index of 40 was surpassed at each unit. MassDevelopment intends to build three more triplexes based on the lessons learned from the completed prototype.

Through the prototype, the additional costs beyond the baseline home have been gathered and evaluated, and research gaps have been identified. This research provides valuable data on best-

in-class whole-house solutions with the potential to meet the source energy savings goals. Working on a prototype test building also allowed training opportunities for the developer and contractor for better installation when the techniques used are replicated in the remaining triplexes and in future projects.

2 Research Methods and Questions

The following research questions will be answered by this project and represent a continuation of CARB's work with RDI.

- What solution package can be readily implemented in cold climate homes to achieve at least 30% energy savings compared to the BA Benchmark?
- Is that solution package commercially viable? Where are opportunities to reduce costs in this solution package?
- What are the specific gaps to achieving the solution package at a production scale (cost, risk adversity, implementation complexity, etc.)?
- Based on the results of this test home, what other alternative energy efficiency solution packages should be considered?
- What are the market interest and consumer reactions, developer and builder reactions and feedback loops, and stakeholder enthusiasm for replicating the package?
- How effectively does each EEM meet its specific cost and performance targets? How effective is each when integrated into a whole-house package?
- How effectively and cost effectively does the double wall solution provide R-35 plus performance? What is the medium-term moisture performance of this assembly in a northern climate? (This last question will not be answered in this report but will be the subject of a study in a follow-up report.)

The team approached these questions by identifying the largest energy end uses, and therefore the most potential savings, weighing the costs and benefits of each EEM, and determining the point at which further improvements to a particular building component were warranted or if diminishing returns came into play.

3 Technical Specifications

Building components were chosen for their local market availability, improvement over the BA Benchmark, and cost effectiveness. Table 1 summarizes the EEMs implemented at the end unit of the Devens triplex prototype, compared to the BA Benchmark. The 1,975-ft^2 attached townhome has two levels plus an unfinished insulated basement, two bedrooms, and 1.5 bathrooms. Figure 3 through Figure 5 show floor plans of the prototype triplex. Figure 6 shows the triplex under construction.

Table 1. Prototype Building Specifications

Component	BA Benchmark 2010	Prototype Specification
Foundation Assembly	Uninsulated basement slab; R-10 (2-in. extruded polystyrene at R-5/in.) at exterior **OR** R-19 (5.5-in. fiberglass batt insulation) on interior of basement cavity wall	Uninsulated basement slab; R-13 (2-in. polyisocyanurate at R-6.5/in.) at interior side of foundation wall
Above-Grade Exterior Walls	Wood 2 × 4 stud frame, 16 in. o.c.[a]; R-13 (3.5 in. fiberglass batt) + R-5 continuous insulation (1 in. extruded polystyrene at R-5/in.)	Wood 2 × 4 double stud frame walls, 16 in. o.c., R-38 (10 in. dense pack cellulose at R-3.8/in.)
Ceiling Assembly	R-38 fiberglass batt insulation	R-59 loose fill cellulose (16 in. at R-3.6/in.)
Window Glazing	U-0.35, SHGC[b]-0.35, double pane, non-ENERGY STAR®	U-0.24, SHGC-0.22, double pane, vinyl
Cooling System	1.5-ton air conditioner, SEER[c] 13	1.5-ton air conditioner, SEER 16, programmable thermostat
Heating System	78% AFUE[d] gas furnace	96.5% AFUE condensing gas furnace
Water Heating	Non-ENERGY STAR gas storage water heater, 40-gal tank, EF[e] 0.59	96% condensing gas tankless water heater, EF 0.96
Lighting	66% incandescent, 21% CFL[f], 13% T-8 fluorescent	0% incandescent, 95% CFL, 5% T-8 fluorescent
Appliances	Non-ENERGY STAR appliances	ENERGY STAR
Air Sealing	7.4 ACH50	1.6 ACH50
Ducts	In conditioned space, R-0	In conditioned space, R-8, 0 LTO[g], 85 TL[h]

[a] On center
[b] Solar heat gain coefficient
[c] Seasonal Energy Efficiency Ratio
[d] Annual Fuel Utilization Efficiency
[e] Energy factor
[f] Compact fluorescent lamp
[g] Leakage to outside
[h] Total leakage

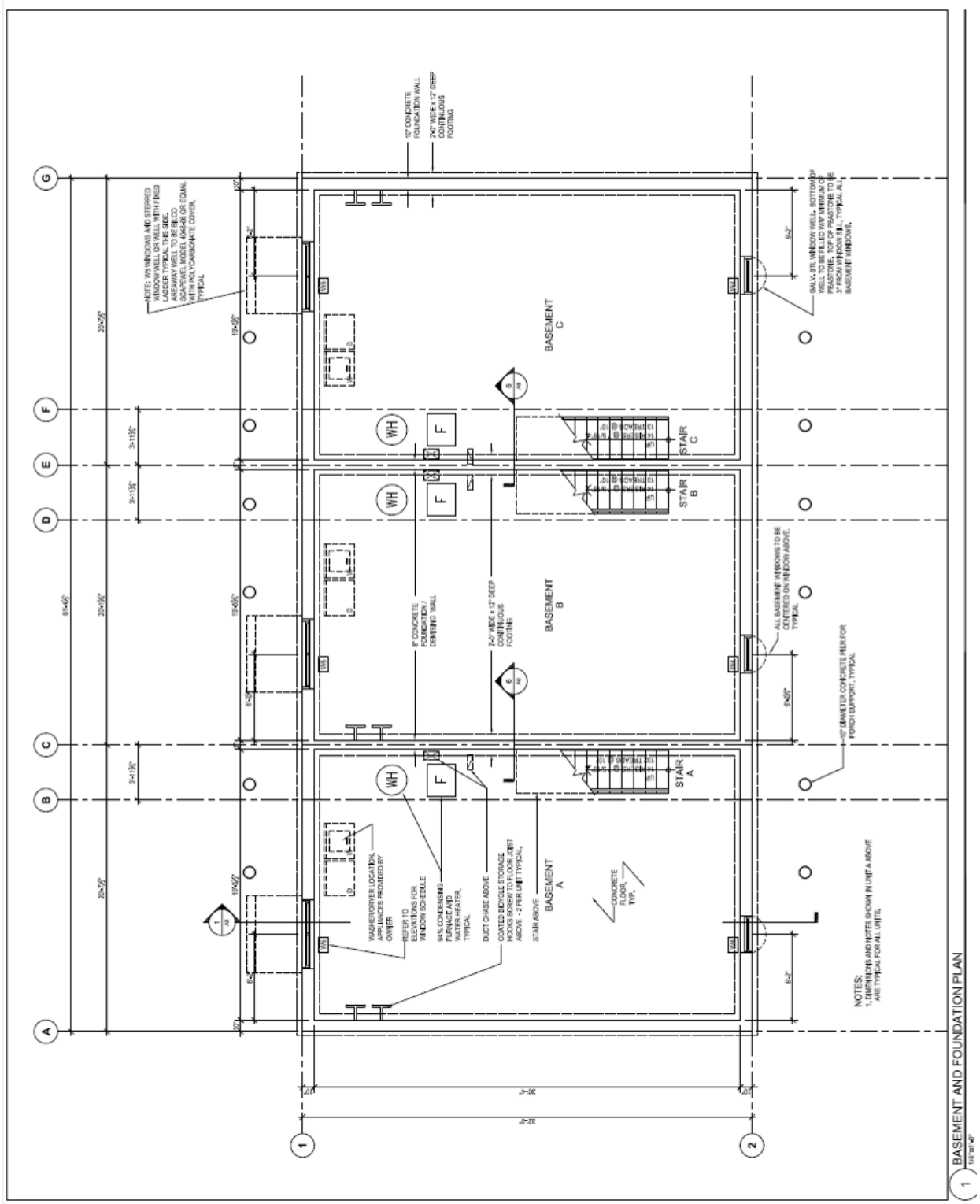

Figure 3. Triplex basement plan, C7A

(courtesy of Cambridge Seven Associates, Inc.)

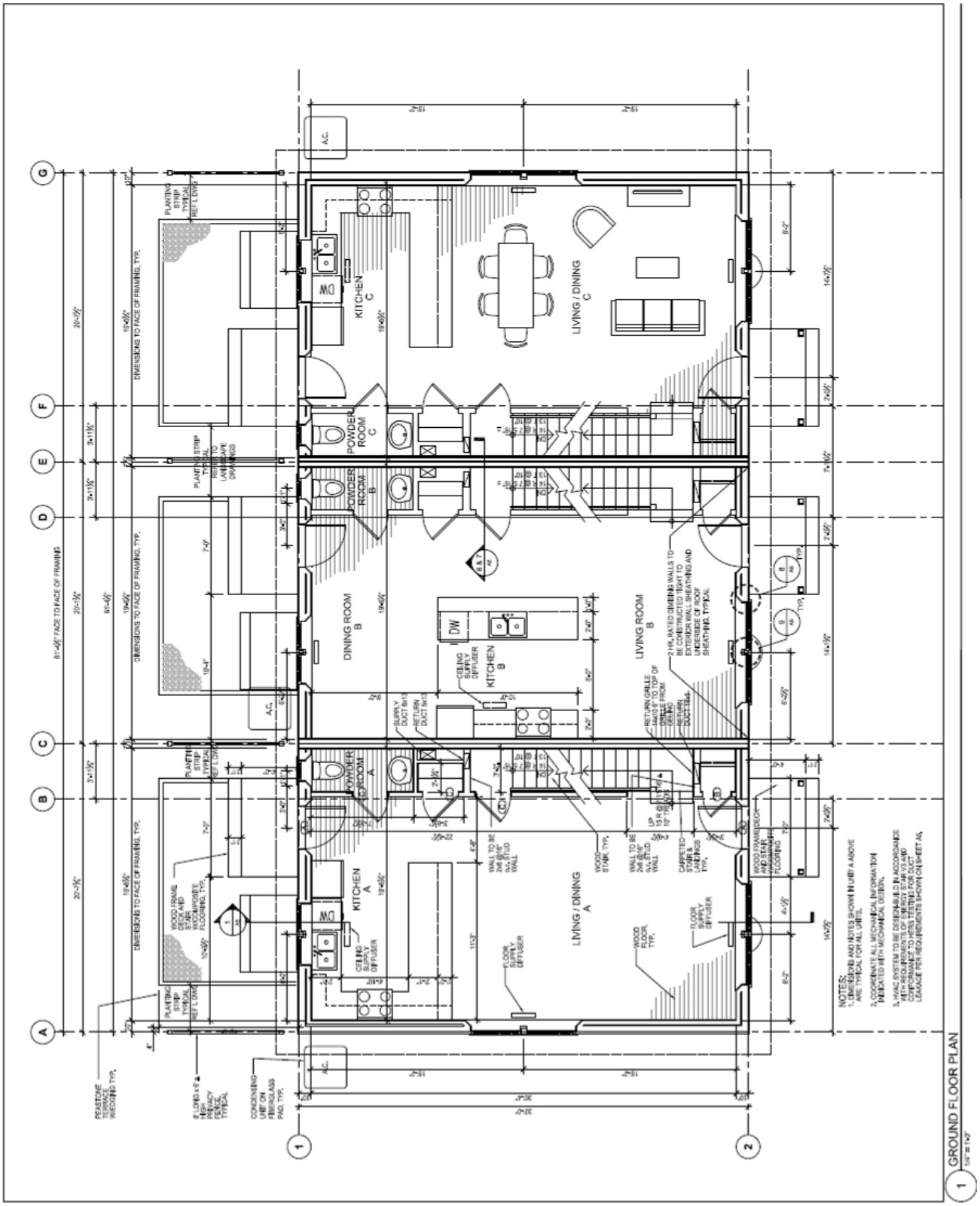

Figure 4. Triplex first floor plan, C7A

(courtesy of Cambridge Seven Associates, Inc.)

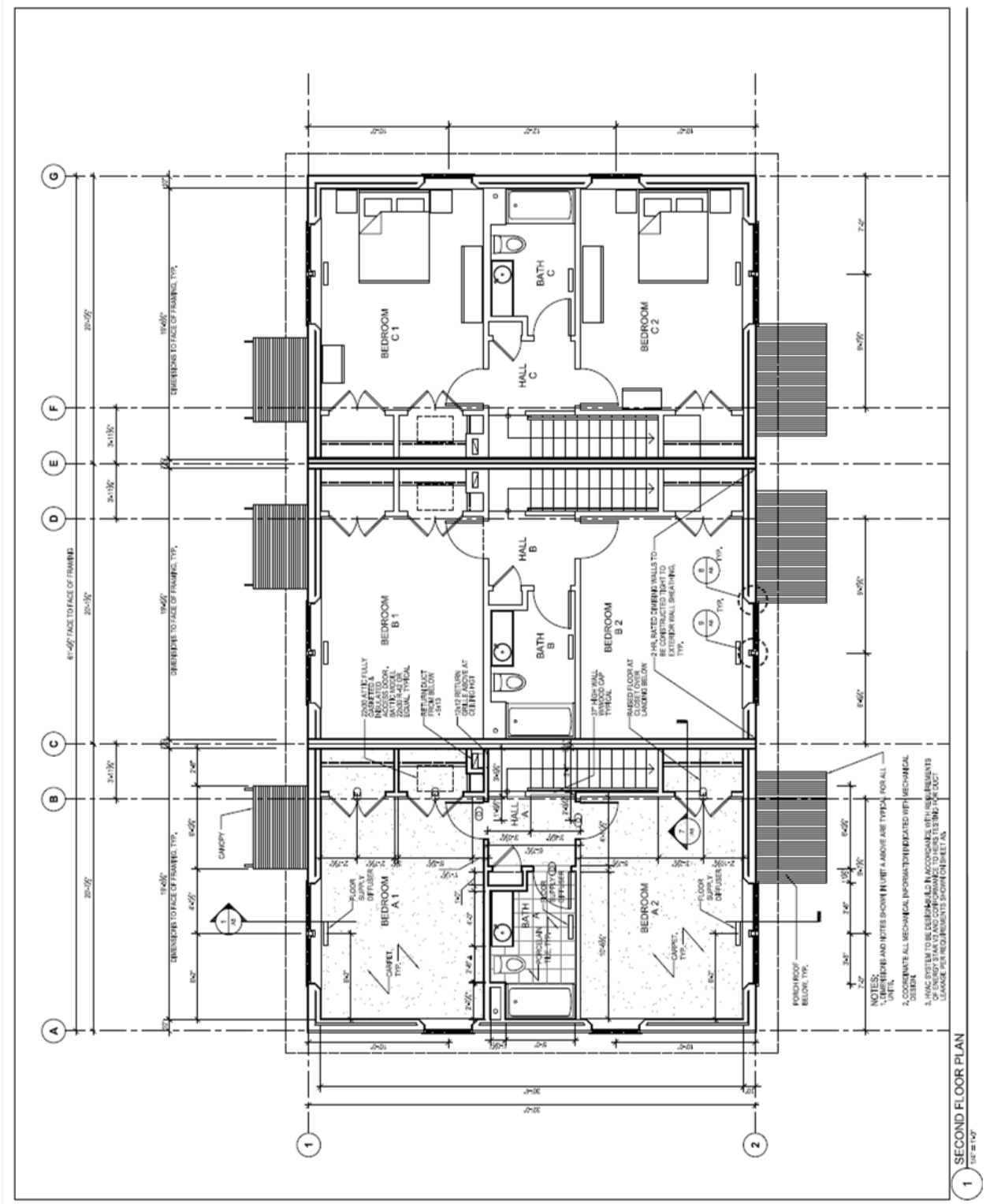

Figure 5. Triplex second floor plan, C7A

(courtesy of Cambridge Seven Associates, Inc.)

Figure 6. Triplex during construction

3.1 Building Enclosure

In the Northeast with its typically cold winters, a high performance building enclosure greatly reduces the building thermal loads, and thus the overall energy consumption. Enclosure improvements were therefore the top priority in achieving whole-house improvements at the prototype Devens triplex. Insulation R-values were significantly increased above the BA Benchmark levels; modeling optimization was used to determine the levels needed to meet the performance target. The R-value of attic insulation was 35% higher than the BA Benchmark, and the wall insulation more than doubled the R-value of the BA Benchmark.

3.1.1 Above-Grade Walls

Based on early parametric studies, the design team understood that to meet the HERS 40 target, the above-grade walls' R-values would need to approach R-40. Multiple approaches, including structurally insulated panels (SIPs) and thick exterior foam sheathing, were investigated; the developer selected the double-wall method for cost and constructability reasons. Once the basic assembly was finalized, the team investigated the insulation materials and methods. The significant air sealing advantages of closed-cell spray polyurethane foam (ccSPF) led to its inclusion in the initial assembly used in the design development drawings. Originally specified at 2-in. continuous against the inside of the sheathing, the remainder of the wall was to be filled with dense-pack cellulose, for a nominal wall R-value of 42.

Cost estimating by the developer forced this assembly to be reconsidered because the cost for a moderate market-rate product was higher than desired. CARB re-evaluated the available options and determined that by limiting the SPF to rim-joist applications and general air sealing, the target HERS Index could be met, but with more aggressive air infiltration targets (see Sections

3.1.2 and 3.1.3). The final specification for the above-grade walls thus evolved to 10 in. of dense pack cellulose (R-3.8/in.) for a nominal value of R-38, with ccSPF used only at mudsills, rim joists, and for other air sealing purposes.

Because no exterior continuous insulation is used for this assembly, an interior side vapor retarder becomes code required. To simplify the assembly, and to keep potential water vapor out of the assembly altogether, CARB specified a vapor retarder latex paint primer on the gypsum wall board, which CARB has used successfully in the past.

Figure 7. Above-grade walls with dense pack cellulose insulation

3.1.2 Below-Grade Walls

As noted in Section 3.1.1, the developer desired that the full basement foundations for these homes be usable and potentially occupiable. This dictated that the basement be treated as conditioned space and that the vertical walls define the thermal enclosure, and not the first floor framing. CARB's experience is that polyisocyanurate adhered directly to the foundation walls is the most cost-effective and practical method, and allows the insulation to remain exposed (if rated for exposure as is the specific polyiso used here), or to be covered in drywall should the future owner decide to finish the space.

The optimal R-values also needed to be considered, and again with HERS 40 as the target, the design team arrived at R-13, or 2-in. of polyisocyanurate. The material was installed full height and was adhered directly to the interior concrete wall surfaces with construction adhesive. All seams were covered with foil Underwriters Laboratories-rated duct tape.

Figure 8. Below-grade walls

3.1.3 Attic Insulation

The Devens triplexes use standard raised-heel roof trusses and vented attics for cost, constructability, durability, and energy performance reasons. The optimal ceiling insulation levels can thus be economically achieved by various types of loose fill insulation: either mineral fiber (fiberglass or mineral wool) or cellulose. As the wall assemblies were to use dense-pack cellulose, the decision was made to use loose fill cellulose at the ceiling plane as well. Energy modeling optimization suggested R-59, or 16 in. at R-3.6/in.

Figure 9. Attic insulation

3.1.4 Air Sealing

With the financial decision to eliminate the 2-in. ccSPF insulation from the above-grade walls, the design team understood the need for a more aggressive air infiltration target. Even though this was developers' first attempt at such high performance targets, CARB lowered the

infiltration specification to 2.0 ACH50 from 3.0 ACH50 to make up for the slightly lower R-value in the walls. With this, the execution of the air sealing became critical, so CARB provided the strategy and on-site training to the contractor.

The vertical framed wall air sealing was handled mostly at the exterior sheathing surface, which used a proprietary integrated water-resistive barrier oriented strand board and urethane-butyl joint tape. This product works exceptionally well on the vertical planes, leaving only the edges, terminations, and penetrations to otherwise address. The basement mudsill and the rim joist were covered with 3 in. ccSPF, and low expansion foam was used at all penetrations.

All penetrations at the attic ceiling plane were also sealed with low expansion foam. This included covering electrical boxes for surface-mounted devices such as smoke detectors with fire-stop ccSPF. Exposed frame wall top plates were similarly covered and sealed before the cellulose loose fill insulation was installed.

Final blower door testing on April 6, 2012 revealed that the home achieved 1.6 ACH50, exceeding the target of 2.0 ACH50.

The final aspect of the high performance building enclosure is the windows. Rather than the BA Benchmark-specified double-pane non-ENERGY STAR windows with U-0.35 and SHGC-0.35, the Devens triplexes have vinyl double-paned windows with U-0.24 and SHGC-0.22. Vinyl low-e windows with these impressive performance characteristics have become far more common and available at only minimal cost premiums.

3.2 Lighting and Appliances

The BA Benchmark specifies 66% incandescent bulbs, 21% CFLs, and 13% T-8 fluorescent bulbs. At the end unit in the Devens prototype, there are no incandescent bulbs, 95% CFLs, and 5% T-8 fluorescent bulbs. An ENERGY STAR refrigerator and dishwasher were installed, which was an improvement over the non-ENERGY STAR appliances in the BA Benchmark.

Figure 10. CFL and pin-based lighting installed

3.3 Heating, Ventilation, and Air-Conditioning Systems

Given the very high performance thermal enclosure intended for the Devens homes, the potential options for appropriate HVAC systems are numerous. At RDI's Wisdom Way development, similar buildings made do with 11,000-Btu unit heaters and no real distribution system (Aldrich 2012). Because these homes are market rate, the developer thought such an unconventional

approach would limit sales and insisted on a more conventional approach. The two systems shortlisted for further scrutiny were ducted air-source heat pumps and condensing gas furnaces with conventional air-conditioning outdoor units. The advantage of the air-source heat pump was that natural gas would not need to be brought to the site, which saved considerable costs. The lack of natural gas would, however, limit options for domestic hot water (DHW). The gas furnace/conventional air conditioner combination would be a less expensive first-cost option, but would require that natural gas infrastructure be brought to the site.

Figure 11. Duct during framing

3.3.1 Final Heating, Ventilation, and Air-Conditioning Specifications

Weighing and comparing the various options eventually led to the selection of a conventional but very high performing 95.6 AFUE condensing gas furnace, and a 1.5-ton 16 SEER air-conditioning system. This single-zone setup includes a programmable thermostat, and was chosen because it provides the highest energy efficiency of all the options investigated.

Figure 12. Air handler in basement

3.3.2 Distribution System

The next challenge was to integrate the ducted distribution system into the compact plan completely within conditioned space. Early design decisions had considered this and resulted in the use of open web floor trusses on both levels to accommodate the ducts. The basic premise included running the first- and second-floor ducts separately in each floor system and using floor registers for distribution in this heating-dominated climate.

Several iterations with C7A resulted in a final variation of this basic concept; the first-floor kitchen is served through a ceiling register fed from the second floor ducts. There are two return registers, one at the base of the stair near the first-floor ceiling, the other at the top of the stair near the second-floor ceiling.

Final testing of the ducted HVAC distribution system found total leakage at 25 pascals to be 85 CFM; leakage to the outside was zero.

3.3.3 Fresh Air Ventilation

CARB has had excellent results using exhaust-only ventilation strategies to meet ASHRAE Standard 62.2 ventilation requirements in similar cold-climate projects, and incorporated that strategy again here. The low-sone ENERGY STAR bath fan located in the second-floor bathroom incorporates a continuous operation mode that can be set to continuous flow, when the occupant turns off the boost feature. The bedroom count (two) and size of these dwellings dictate a continuous exhaust flow rate of approximately 43 CFM. Final testing confirmed that the design ventilation rate was met.

3.4 Domestic Hot Water

The BA Benchmark has a non-ENERGY STAR gas storage water heater with an EF of 0.59 and a 40-gal tank. The condensing gas tankless water heater installed at Devens has an EF of 0.96

(see Figure 13). This piece of equipment was chosen because of the decision to bring natural gas onto the site and to achieve a HERS Index of less than 41. After resolving to provide natural gas to the townhomes, the team focused on tankless water heaters as a relatively high efficiency solution to one of the higher end use energy loads. More standard, noncondensing tankless water heaters were investigated, but their lower efficiency values (EF .84 to EF .87) forced consideration of the condensing units, which have become more market available. The approximately 10% performance improvement over the noncondensing units helped lower the final HERS Index below 41. The water heaters were installed in the basements with the other mechanical equipment.

Figure 13. Tankless water heater

4 Targeted and Simulated Energy Savings

To align with the BA goal, 30% source energy savings were targeted. Figure 14 shows that the Devens end unit was able to achieve 30.71% savings in source energy over the BA Benchmark. This equates to a HERS Index of 39 for this dwelling. The building enclosure improved by approximately 14% over the BA Benchmark, lighting and appliances by about 4%, and HVAC by approximately 11%. Figure 14 shows the BA Benchmark with cumulative incremental changes, which combine to simulate predictive energy savings at the Devens end unit.

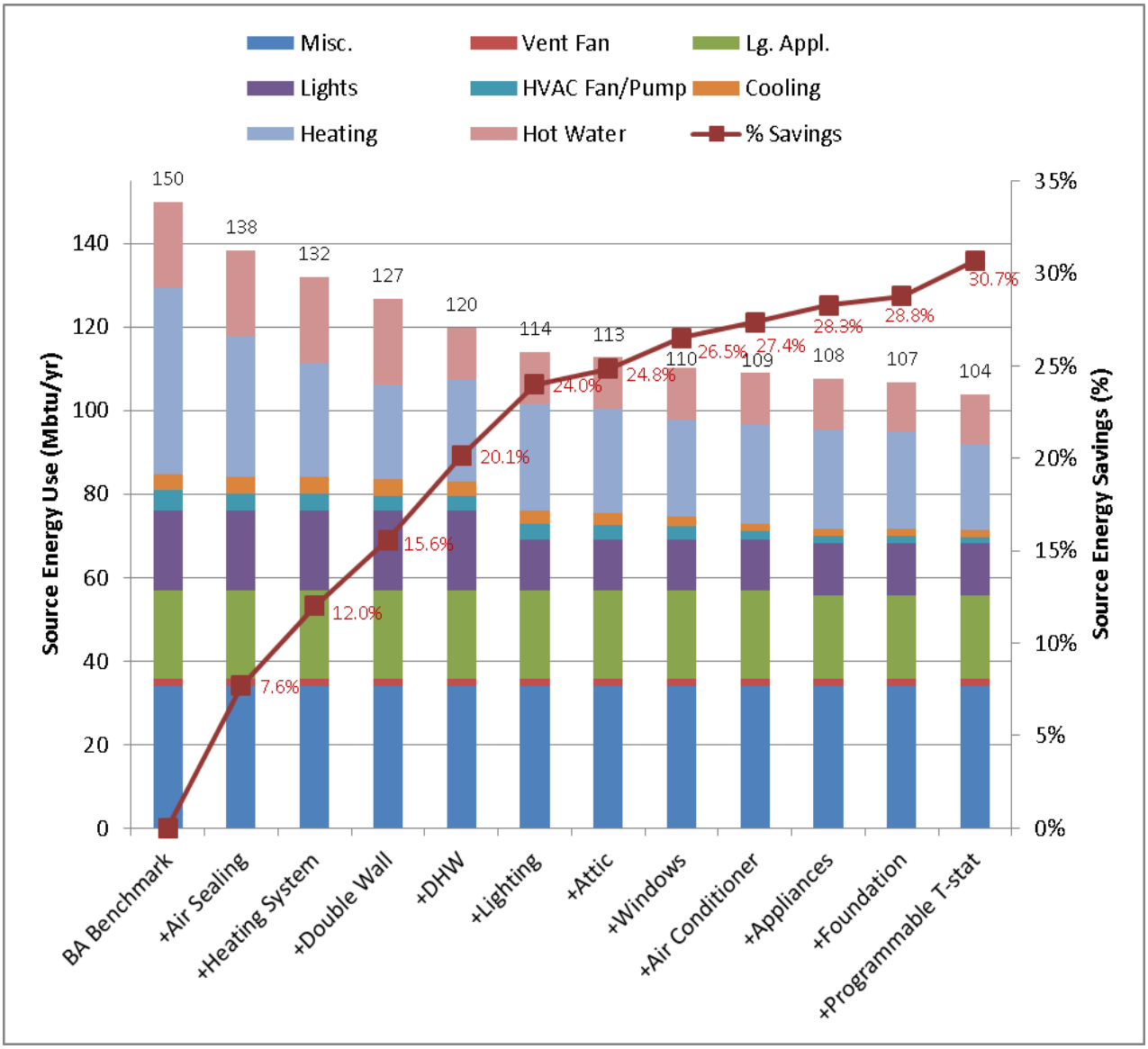

Figure 14. Achieved energy savings of Devens end unit over the BA Benchmark

To create this chart, energy savings were isolated by comparing the BA Benchmark and the measure improvement. The chart was built up by modeling the measure improvements from the most savings (air sealing) to the least energy savings (foundation) with the programmable

thermostat at the end. The programmable thermostat is placed last to better demonstrate the Devens end unit's improved capabilities.

The single greatest contributor to overall energy savings was the improved air sealing. It shows a 7.71% drop in energy use compared to the BA Benchmark. Applying heating system upgrades improves the home by an additional 4.32%. When the heating system improvements are looked at independently, there is a 5.71% improvement. Using the cumulative approach demonstrated in Figure 14 the overlapping energy savings of the individual measures is eliminated.

In the Northeast, the heating load often uses the most source energy—this applied to the Devens end unit. The BA Benchmark consumes 44.74 MBtu annually for heating. Improvements to the home's air sealing, furnace, and overall enclosure insulation, and installation of a programmable thermostat reduced heating energy consumption by 53.87%. Decreasing the heating energy consumption was a critical factor in achieving the 30% targeted energy savings.

The next biggest end use was the large appliances, using 21.34 MBtu/yr in the BA Benchmark. With the refrigerator and dishwasher upgrades, large appliance improvements had only a 5.30% decrease in large appliance energy use. This improvement did not greatly contribute to the reduction in energy consumed.

The domestic hot water (DHW) system was the third largest end user, demanding 20.59 MBtu/yr according to the BA Benchmark. DHW energy use decreased by 41.48% with the improvements from a 0.59 EF gas storage water heater to an EF 0.96 condensing gas tankless water heater.

The lighting demands 18.97 MBtu/yr per the BA Benchmark and was the fourth largest energy user. The change from 66% incandescent, 21% CFL, and 13% T-8 fluorescent to 95% CFL and 5% T-8 fluorescent decreased lighting energy use by 35.37%.

Other improvements to HVAC fan/pump and cooling had much smaller end use loads but greater improvements. According the BA Benchmark, the HVAC fan/pump uses 4.89 MBtu/yr and used 66.46% less with the improvement to the air-conditioning system. The BA Benchmark cooling system uses 3.85 MBtu/yr and 60.26% less energy with the improvement. Cooling improvements increased the system efficiency, but did not substantially improve cooling because it accounts for such a small percentage of the total building energy use.

Overall, the improvements save 46.06 MBtu/yr. Three of the four greatest end uses (according to the BA Benchmark) also saved the most energy. Only miscellaneous loads and ventilation fan loads remained the same from the BA Benchmark to the final design.

5 Cost Data and Cost Effectiveness of Energy Efficiency Measures

The purpose of this prototype was to build a moderate priced, highly efficient prototype home. Improvements over the BA Benchmark cost an additional $7,804 and saved more than 46 MBtuh/yr. Costs for each improvement were estimated using market and regional costs and validated by the National Renewable Energy Laboratory Retrofit Cost Database (NREL 2010).

Cost effectiveness of these improvements is determined by simple payback. The cost is divided by the annual utility savings to see payback period in years. The utility savings are $580.66/yr, so the combined improvements have a payback period of 13.44 years. The improvements can be grouped into three categories: enclosure, mechanical, and electrical improvements (see Table 2).

The shortest payback period of all is in the electrical improvement category. In a single year, these improvements save $103.90, and it costs only $140 to upgrade the lighting. The payback period for electrical improvements is less than two years. The payback period for appliances (refrigerator and dishwasher) is negligible because the cost difference between an inefficient model and the efficient is incrementally small. Installing energy-efficient appliances is a simple way to lower energy use in new construction residential units.

The second shortest payback period was in the mechanical improvement category, which would save the resident $215.31 annually. Mechanical improvements cost $2,827 and the payback period is 13.13 years. The mechanical improvements had relatively short payback periods, including the heating system upgrade (8.62 years), DHW upgrade (13.93 years), and the air conditioning/programmable thermostat upgrade (18.28 years).

Building enclosure improvement-related annual utility savings are $261.45 and had an upfront additional cost $4,837 to upgrade, making the payback period 18.50 years. Although air sealing alone has a payback period of just 2.15 years, it is dependent the quality of installation, improved insulation type, and R-value of all enclosure insulation. There are longer payback periods for the attic insulation upgrade (27.95 years), window upgrades (28.09 years), foundation insulation upgrade (32.00 years), and the double wall (44.74 years). Although these enclosure improvements have the longest payback period, they have the most significant impact on energy savings in the Devens end unit.

Table 2. Payback of Prototype Building Specifications

Component	BA Benchmark 2010	Prototype Specification	Upgrade Costs per Measure	Energy Savings (in MBtu/yr)	Payback (years)
Foundation Assembly	Uninsulated basement slab; R-10 (2-in. extruded polystyrene at R-5/in.) at exterior **OR** R-19 (5.5 in. fiberglass batt insulation) on interior of basement cavity wall	Uninsulated basement slab; R-13 (2-in. polyisocyanurate at R-6.5/in.) at interior side of foundation wall	$288	0.77	32
Above-Grade Exterior Walls	Wood 2 × 4 stud frame, 16 in. o.c.; R-13 (3.5 in. fiberglass batt) + R-5 continuous insulation (1-in. extruded polystyrene at R-5/in.)	Wood 2 × 4 double stud frame walls, 16 in. o.c., R-38 (10 in. dense pack cellulose at R-3.8/in.)	$2880	5.31	44.74
Ceiling Assembly	R-38 fiberglass batt insulation	R-59 loose fill cellulose (16 in. at R-3.6/in.)	$469	1.27	27.95
Window Glazing	U-0.35, SHGC-0.35, double pane, non-ENERGY STAR	U-0.24, SHGC-0.22, double pane, vinyl	$900	2.51	28.09
Air Sealing	7.4 ACH50	1.6 ACH50	$300	11.56	2.15
Total Enclosure Improvements			**$4,837**	**21.42**	**18.50**
Cooling System	1.5-ton air conditioner, SEER 13	1.5-ton air conditioner, SEER 16, programmable thermostat	$1,000	4.19	18.28
Heating System	78% AFUE gas furnace	96.5% AFUE condensing gas furnace	$666	6.48	8.62
Water Heating	Non-ENERGY STAR gas storage water heater, 40-gal tank, EF 0.59	96% condensing gas tankless water heater, EF 0.96	$1,161	6.86	13.93
Total Mechanical Improvements			**$2,827**	**17.53**	**13.13**
Appliances	Non-ENERGY STAR appliances	ENERGY STAR	n/a	1.34	n/a
Lighting	66% incandescent, 21% CFL, 13% T-8 fluorescent	0% incandescent, 95% CFL, 5% T-8 fluorescent	$140	5.77	1.65
Total Electric Improvements			**$140**	**7.11**	**1.35**
Total Improvements			**$7,804 additional cost**	**46.06 MBtu/yr saved**	**13.44 year payback**

The optimization curve in Figure 15 shows the curve's relationship with the BA Benchmark, the final Devens end unit, and the final Devens end unit without the programmable thermostat. The BA Benchmark point shows the home saves little source energy and the energy-related costs are very high.

The final Devens end unit point reinforces how much it saves in source energy and in energy-related costs compared to the BA Benchmark. Without a programmable thermostat, the home saves less energy and energy-related costs are higher than the actual design.

The final design point is very close to the optimization curve, indicating the final design package is close to ideal in terms of annual energy related cost savings and source energy savings.

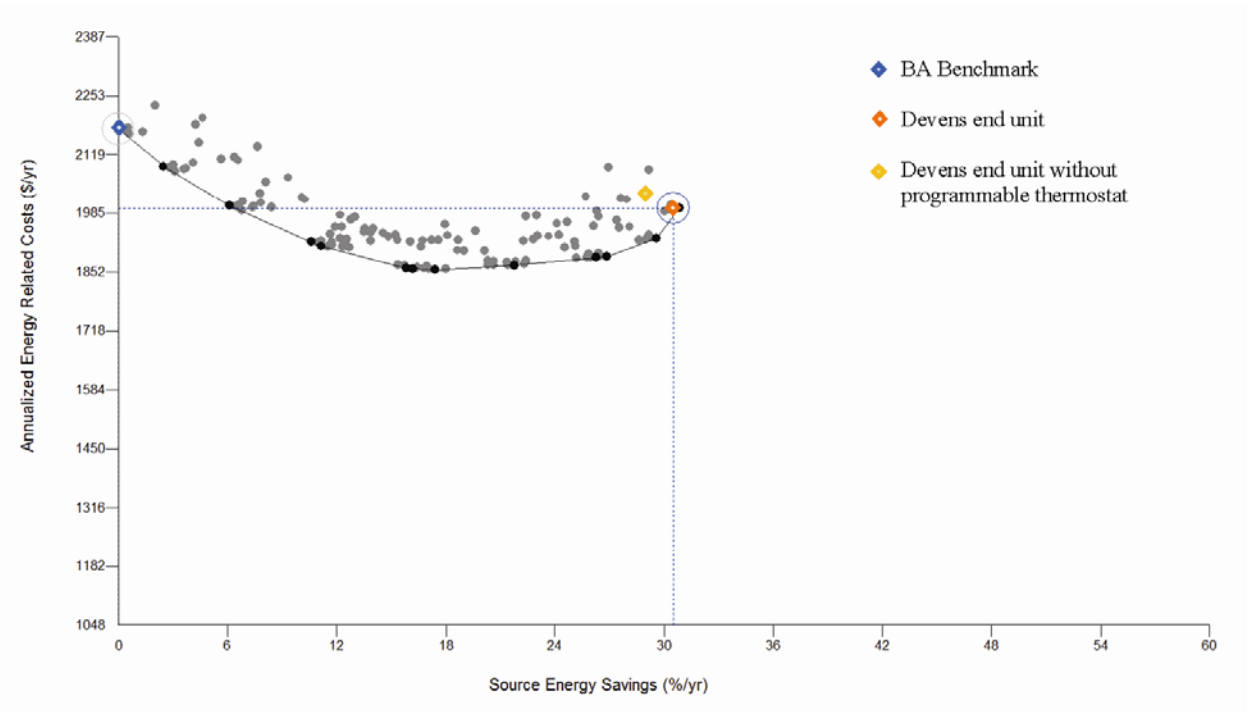

Figure 15. Comparison of modeling iterations and optimization curve

6 Research Question Conclusions

With the basic goal of meeting or exceeding the BA Benchmark by 30% with cost in mind, the team was interested in answering this overarching research question:

Question: What solution packages can be readily implemented in cold climate homes to achieve at least 30% energy savings compared to the BA Benchmark?

Conclusion: This solution package successfully surpassed the target of 30% source energy savings, using only market-present technologies to achieve the targeted source energy savings. This can be attributed to early planning and design decisions, and proper installation. The uniform upgrade in enclosure construction contributed to more than 14% improvement over the BA Benchmark.

This prototype represents a viable solution package. Its standout feature is its replicability. The improvements, such as a double stud wall, are simply efficient construction methods that do not require special equipment, skills, or training, just extra attention during installation.

Question: Is that solution package commercially viable? Where are opportunities to reduce costs in this solutions package?

Conclusion: This solution package is commercially viable. For $7,804, this unit's improvements had a payback period of less than 14 years. This triplex building is the first prototype in a series of four similar buildings. The developer has indicated remaining with the exact energy efficiency improvement package for future triplexes as this prototype building, based on its success.

Question: What are the specific gaps to achieving the solution package at a production scale (cost, risk adversity, implementation complexity, etc.)?

Conclusion: Air sealing stands as a huge barrier to effectively deploying this solution package. The team's thoroughness in installation led to better than anticipated infiltration results. This improvement is determined by the quality of installation and by material choice, and was confirmed with blower door testing. This construction team has determined a good air sealing strategy at will be replicable in the future triplexes. Specifically advocated by CARB and adopted at Metric Development is the use of the exterior sheathing plane as the primary vertical air barrier. The structural sheathing and proprietary joint-tape system used effectively seals the planer elements leaving only the edges, terminations, and material transitions to be sealed. The CARB team provided walk-through inspections and subcontractor training to point out the critical remaining areas to be sealed, and methods and material options available. Most nonsheathing air sealing was accomplished with low expansion ccSPF.

Question: Based on the results of this test home, what other alternative energy efficiency solution packages should be considered?

Conclusion: To reduce source energy use and associated costs, the developer might consider switching from an electric to a gas clothes dryer. The developer might also consider decreasing window area; however, this will impact user comfort.

It would be interesting to see the impact of a solar PV panel installation. Miscellaneous electric loads remained unchanged from the BA Benchmark to the final design. This could substantially decrease each unit's electric load, especially because this building has a south-facing roof.

Question: What are the market interest and consumer reactions, developer and builder reactions and feedback loops, and stakeholder enthusiasm for replicating the package?

Conclusion: This triplex building was the first of four slated for construction on this site. The developer's HERS goal keeps all parties invested in creating a robust prototype by planning, adjusting, and replicating. It will be interesting to see what the developer retains and discards based on lessons from the prototype triplex.

Initial marketing results were very encouraging. The first (middle unit) triplex dwelling went to buyer contract approximately 30 days following completion. Closing on that home occurred the end of September. Based on early interest and foot traffic the developer has commenced construction on the final two triplexes.

Question: How effectively does each EEM meet its specific cost and performance targets? How effective is each when integrated into a whole-house package?

Conclusion: Individual EEMs provide interesting results. In the Devens end unit, the enclosure improvements cost the most, but also saved the most energy in the biggest end use category. Lighting and appliances were the most cost effective in terms of payback period and provided the simplest changes, but also yielded limited energy savings. Mechanical improvements struck a fine balance between the moderate price and substantial energy savings, with a payback period of $7,804 and energy savings of 46.06 MBtu/yr, for a payback period of 13.44 years. This package of improvements proved to be cost effective with a short payback period and relatively overall low cost for considerable energy savings.

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Aldrich, R.; Zuluaga, M. (2006). "The Challenges of Basement Insulation." *Home Energy* January/February 2006, pp. 30–34. Accessed May 2013. www.carb-swa.com/articles/in%20the%20news/HomeEnergy_The%20Challenges%20of%20Basement%20Insulation.pdf.

Hendron, R.; Engebrecht, C. (2010). *Building America House Simulation Protocols*. Golden, CO: National Renewable Energy Laboratory. TP-5500-49246. www.nrel.gov/docs/fy11osti/49246.pdf.

NREL. (2010). National Residential Efficiency Measures Database v2.0.0. Accessed August 10, 2012. www.nrel.gov/ap/retrofits/about.cfm.

Appendix A: Plan Set

(courtesy of Cambridge Seven Associates, Inc.)

ISSUED FOR PERMIT

26 October 2011

DRAWING LIST

Cover Sheet, Project and Code Information
A0 Basement / Foundation Floor Plan
A1 Ground Floor Plan
A2 Second Floor Plan
A3 Building Elevations
A4 Interior Elevations
A5 Building Sections
A6 Section Details
S1 Framing Plans
E1 Electric Layout Plans

BUILDING CODE

All work shall comply with Massachusetts 780 CMR 6th Edition Massachusetts Residential Code (International Residential Code + MA Amendments)

General:

Project is conform to all dimension requirements for Residential.

R202 Townhouse - A single Family Dwelling Unit Constructed in a Group of Three or More Attached Units in Which Each Unit Extends From Foundation to Roof and With a Yard or Public Way on at Least Two Sides.

R301.2(2) Seismic Design Category - B

R301.2(4) Basic Wind Speed - 90MPH

R301.2(5) Ground Snow Loads - 50 PSF

R301.5 Minimum Uniformly Distributed Live Loads

R301.6 Minimum Roof Live Loads

R302 Fire Resistant Construction

R302.2 Townhouses - Separation Equal to Requirements for Exterior Walls.

Exception: A Common 1-Hour Rated Wall is Permitted if Walls Do Not Contain Plumbing or Mechanical Equipment, Ducts or Vents in the Cavity of the Wall. Wall to be Rated For Exposure From Both Sides and Shall Extend to and be Tight to Exterior Walls and Underside of Roof Sheathing. Electrical Installation Shall be Installed in Accordance With Chapters 34 Through 43. Penetrations for Electrical Shall be in Accordance with Section R302.4.

Table R302.1 Exterior Walls:

EXTERIOR WALL ELEMENT	MINIMUM FIRE-RESISTANCE RATING	MINIMUM SEPARATION DISTANCE
Walls(Walls)Fire Resistance Rated)	1-Hour | Tested	Less Than 5 Feet.
Walls(Not Fire Resistance Rated)	0-Hour	≥ 5 Feet

R302.2.4 Structural Independence:

Exception 5 - Townhouses Separated By Common 1-Hour Fire Resistance Rated Wall as Provided in Section R302.2.

R302.10 Flame Spread Index and Smoke Developed Index for Insulation: Shall be in Accordance With R302.10.1 Through R302.10.5.

R302.10.3 - Cellulose Loose Fill Insulation Shall Comply With CPSC 16CFR Parts 1209 and 1404. Packages Shall be Clearly Labeled in Accordance With CPSC 16CFR Parts 1209 and 1404.

R302.10.4 - Exposed Attic Insulation: Shall Have Critical radiant Flux Not Less Than 0.12 Watts Per Square Centimeter.

R303.6 Stairway Illumination Shall Comply With 527 CMR 10.00 Fire Prevention, General Provisions.

Interior Stairs - Not Less Than 1 Foot-Candle Measured at Center of Treads and Landings

Exterior Stairs - Artificial Light Source at Top Landing.

R310 Emergency Escape and Rescue Openings:

Basements, Habitable Attics, And Every Sleeping Room Shall Have at Least One Operable Emergency Escape and Rescue Opening.

Exception: Basements Used Only to House Mechanical Equipment and Not Exceeding Total Floor Area of 200 Square Feet.

R310.1.1 - Double Hung Windows Shall Have Minimum Net Clear Area Opening of 3.5 Square Feet.

R310.1.2 - Dimensions: The Minimum Net Clear Opening Dimensions Shall Be 20 Inches by 24 Inches in Either Direction.

R310.2 - Window Wells - Minimum Horizontal Area Shall Be 9 Square Feet, Minimum Horizontal Projection and Width of 36 Inches.

R310.2.1 - Ladders and Steps - Vertical Depth Exceeding 44 Inches Shall be Equipped with Permanently Affixed Ladders or Steps.

R313 Automatic Fire Sprinkler Systems

R313.1 - Automatic Residential Fire Sprinkler Systems For Townhouses Shall be Designed and Installed in Accordance With NFPA 13, 13R, or 13D As Applicable.

2. A Townhouse Building With an Aggregate Area Less Than 12,000 Square Feet Shall Be Permitted in Use

R314 Smoke Alarms Shall be Installed as Required by IRC and Massachusetts Amendments

R315 Carbon Monoxide Alarms Shall be Installed as Required by IRC and Massachusetts Amendments

Fair Housing Act: Applies to this project

GENERAL NOTES:

1. ALL DIMENSIONS LOCATED ON THE DRAWINGS ARE TO BE FIELD VERIFIED PRIOR TO AND DURING CONSTRUCTION. SHOULD DISCREPANCIES OCCUR, NOTIFY THE ARCHITECT FOR CLARIFICATION.
2. ALL MATERIALS, MEANS, AND METHODS AND RESULTING CONSTRUCTION SHALL COMPLY WITH STATE AND LOCAL CODES. CONTRACTOR IS TO FURNISH AND INSTALL AND INSTALL ALL LABOR, EQUIPMENT, MATERIALS, SUPPLIES, AND SERVICES REQUIRED, NECESSARY, OR INCIDENTAL FOR A COMPLETE PROJECT.
3. THE CONTRACTOR SHALL COMPLY WITH ALL APPLICABLE FEDERAL, STATE, AND LOCAL LAWS, RULE, AND REGULATIONS AND SAFETY CODES IN THE CONSTRUCTION OF THIS PROJECT.
4. ARCHITECT HAS NO KNOWLEDGE OF EXISTING ASBESTOS OR OTHER HAZARDOUS MATERIALS LOCATED ON THIS SITE. IF HAZARDOUS MATERIALS ARE ENCOUNTERED THE CONTRACTOR SHALL NOTIFY THE OWNER IMMEDIATELY.
5. MINOR DETAILS NOT USUALLY SHOWN OR SPECIFIED BUT NECESSARY FRO A COMPLETE, PROPER, AND ACCEPTABLE CONSTRUCTION, INSTALLATION, OR OPERATION OF ANY PART OF THE WORK SHALL BE INCLUDED IN THE WORK AS IF IT WERE SPECIFIED OR INDICATED ON THE DRAWINGS.
6. CONTRACTOR SHALL BE RESPONSIBLE FOR THE PROTECTION OF ALL NEW CONSTRUCTION AND MATERIALS WITHIN THE AREAS DESCRIBED IN THE LIMIT OF WORK OF THESE DRAWINGS. THE CONTRACTOR SHALL KEEP AREAS CLEAR OF DEBRIS AND UNAUTHORIZED PERSONS.
7. REMOVALS TO BE PROPERLY DISPOSED OF AND CAREFULLY COORDINATED AND SEQUENCED WITH NEW WORK. FULLY MAINTAIN INTEGRITY OF EXISTING STRUCTURE(S). FINAL DETAILS TO BE APPROVED THROUGH THE SHOP DRAWING PROCESS.
8. THE CONTRACTOR IS TO PROVIDE A DESIGN-BUILD APPROACH FOR ALL MECHANICAL , HVAC, PLUMBING, ELECTRICAL, AND FIRE-PROTECTION COMPONENTS OF THIS PROJECT. LAYOUTS FOR LIGHTING, SPRINKLER HEADS, AND DUCTWORK DISTRIBUTION SHALL BE FULLY COORDINATED TO AVOID CONFLICTS. LAYOUTS TO BE REVIEWED WITH THE ARCHITECT.
9. ALL PIPE AND DUCT PENETRATIONS THROUGH WALLS, SLABS, AND CEILINGS SHALL BE FIRE-STOPPED MAINTAINING FIRE RATINGS REQUIRED BY THE MASSACHUSETTS STATE BUILDING CODE, 2009 INTERNATIONAL BUILDING CODE WITH MASSACHUSETTS AMENDMENTS, NFPA LIFE SAFETY CODE, AND LOCAL JURISDICTION.
10. ALL WATER, SEWER, AND ELECTRICAL WORK SHALL BE PERFORMED ACCORDING TO THE REQUIREMENTS AND THE STANDARD SPECIFICATIONS OF DEVENS.
11. UTILITY LOCATIONS TO BE ESTABLISHED BY THE CONTRACTOR. ALL UTILITY CONNECTIONS ARE SUBJECT TO THE APPROVAL OF, AND GRANTING PERMIT OF DEVENS AND UTILITY COMPANIES. THE CONTRACTOR SHALL COORDINATE ALL UTILITY CONNECTIONS.
12. THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE REMOVAL FROM THE SITE ALL DEBRIS AND RUBBISH FOUND. THE CONTRACTOR SHALL LEAVE THE SITE IN SAFE, CLEAN, AND LEVEL CONDITION UPON COMPLETION OF CONSTRUCTION PRIOR TO LANDSCAPE CONSTRUCTION.
13. FOR ALL DIMENSIONAL AND CONSTRUCTION DETAIL QUESTIONS CONSULT WITH THE ARCHITECT. FOR ALL MECHANICAL AND INSULATION QUESTIONS CONSULT WITH STEVEN WINTER ASSOCIATES (SWA).

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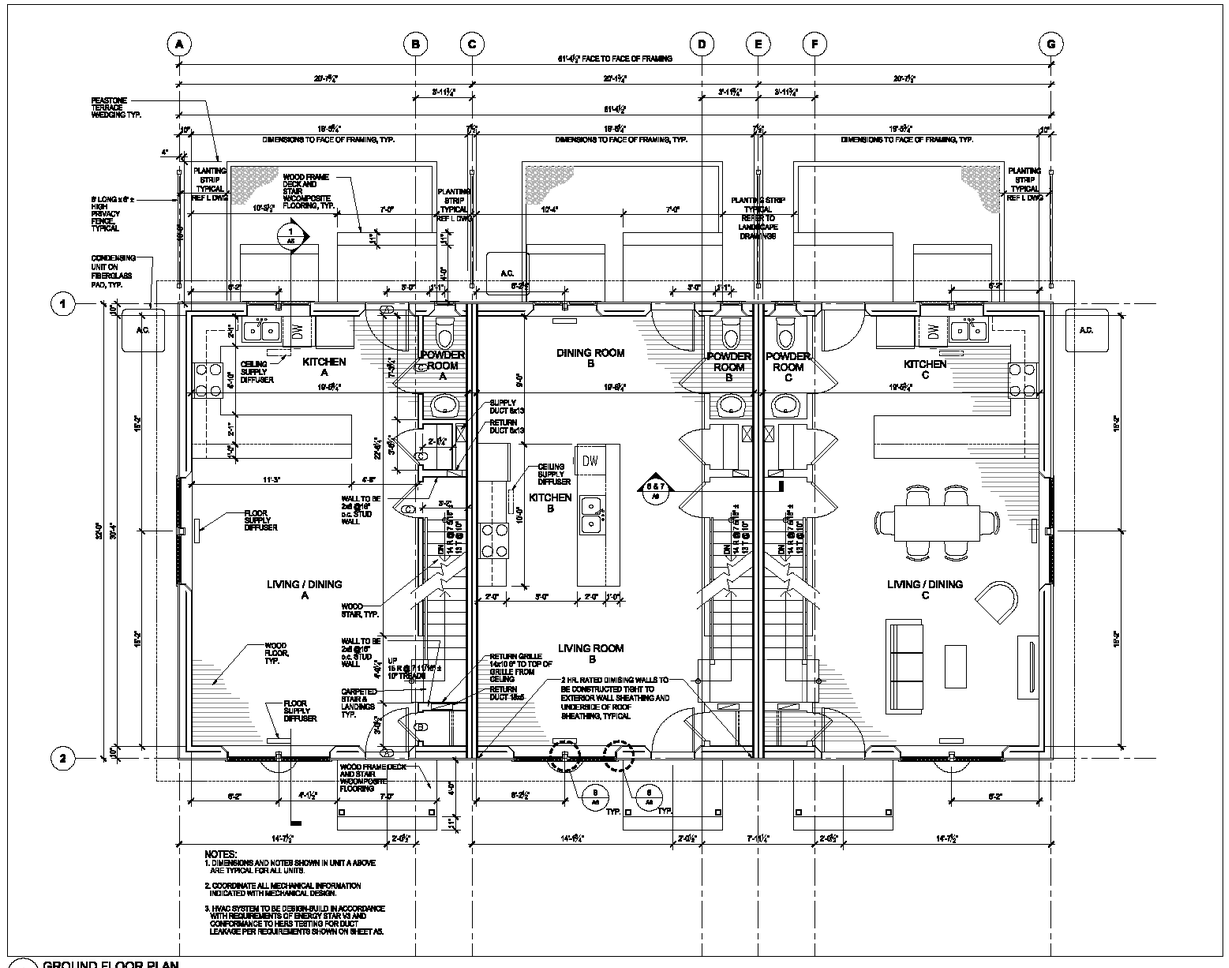
Unified Permit Documents

Devens Sustainable Housing

Revised: October 26, 2011

Owner	Devens Net Zero LLC Boston, MA
Contractor	Metric Corporation Boston, MA
Architect	CAMBRIDGE SEVEN ASSOCIATES, INC. Cambridge, MA
Structural Engineer	Hawksworth Bibb Winchester, MA
Sustainable Design Consultant	Steven Winter Associates, Inc. Norwalk, CT
Civil Engineer	FSL Associates Boston, MA



NOTES:
1. DIMENSIONS AND NOTES SHOWN IN UNIT A ABOVE ARE TYPICAL FOR ALL UNITS.
2. COORDINATE ALL MECHANICAL INFORMATION INDICATED WITH MECHANICAL DESIGN.
3. HVAC SYSTEM TO BE DESIGN-BUILD IN ACCORDANCE WITH REQUIREMENTS OF ENERGY STAR V3 AND CONFORMANCE TO HERS TESTING FOR DUCT LEAKAGE PER REQUIREMENTS SHOWN ON SHEET A5.

1 GROUND FLOOR PLAN
1/4" = 1'-0"

DEVENS NET ZERO, LLC
DEVENS, MASSACHUSETTS

GENERAL NOTES:
1. BUILDING TO BE FULLY PROTECTED BY AUTOMATIC SPRINKLER SYSTEM, BASEMENT, FIRST FLOOR, SECOND FLOOR, AND ATTIC. INSTALL PIPES IN MANNER TO PROTECT PIPING FROM FREEZING. SPRINKLER SYSTEM IN ATTIC SHALL BE DRY TYPE SYSTEM.

ISSUED FOR PERMIT
OCTOBER 26, 2011

Number	Revision	Date
1	MISC. REVISIONS	03.04.2011

Cambridge Seven Associates, Inc.
Architects and Planners
1050 Massachusetts Ave.
Cambridge, MA 02138
617 492-7998 Fax 492-7007

Job # 1019
Project Devens Sustainable Housing
Drawn by HR Checked GJ
Date October 20, 2010
Scale AS NOTED
Drawing Title
Ground Floor Plan

A1

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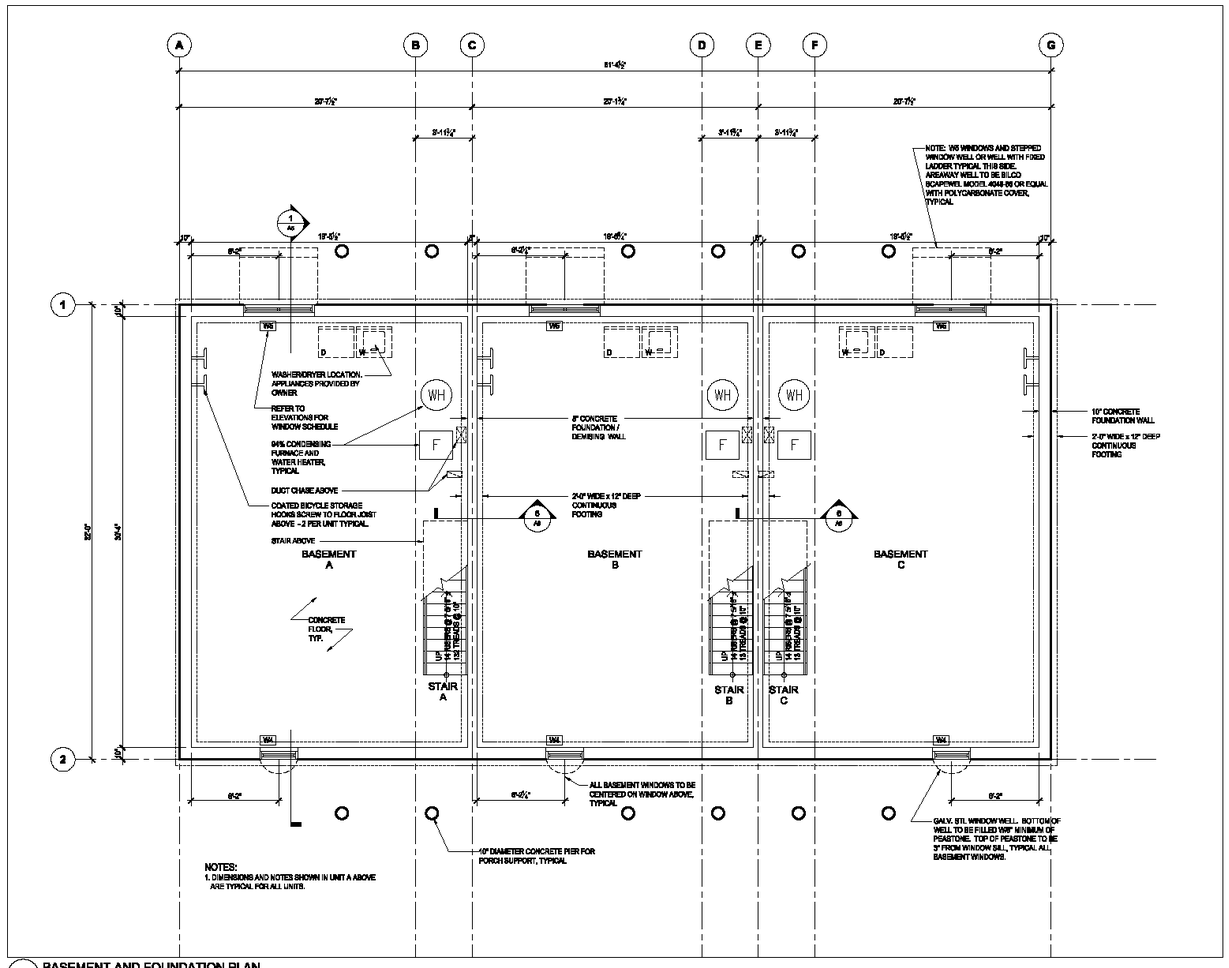

1 BASEMENT AND FOUNDATION PLAN
1/4"=1'-0"

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Drawn by	NR — Checked GJ
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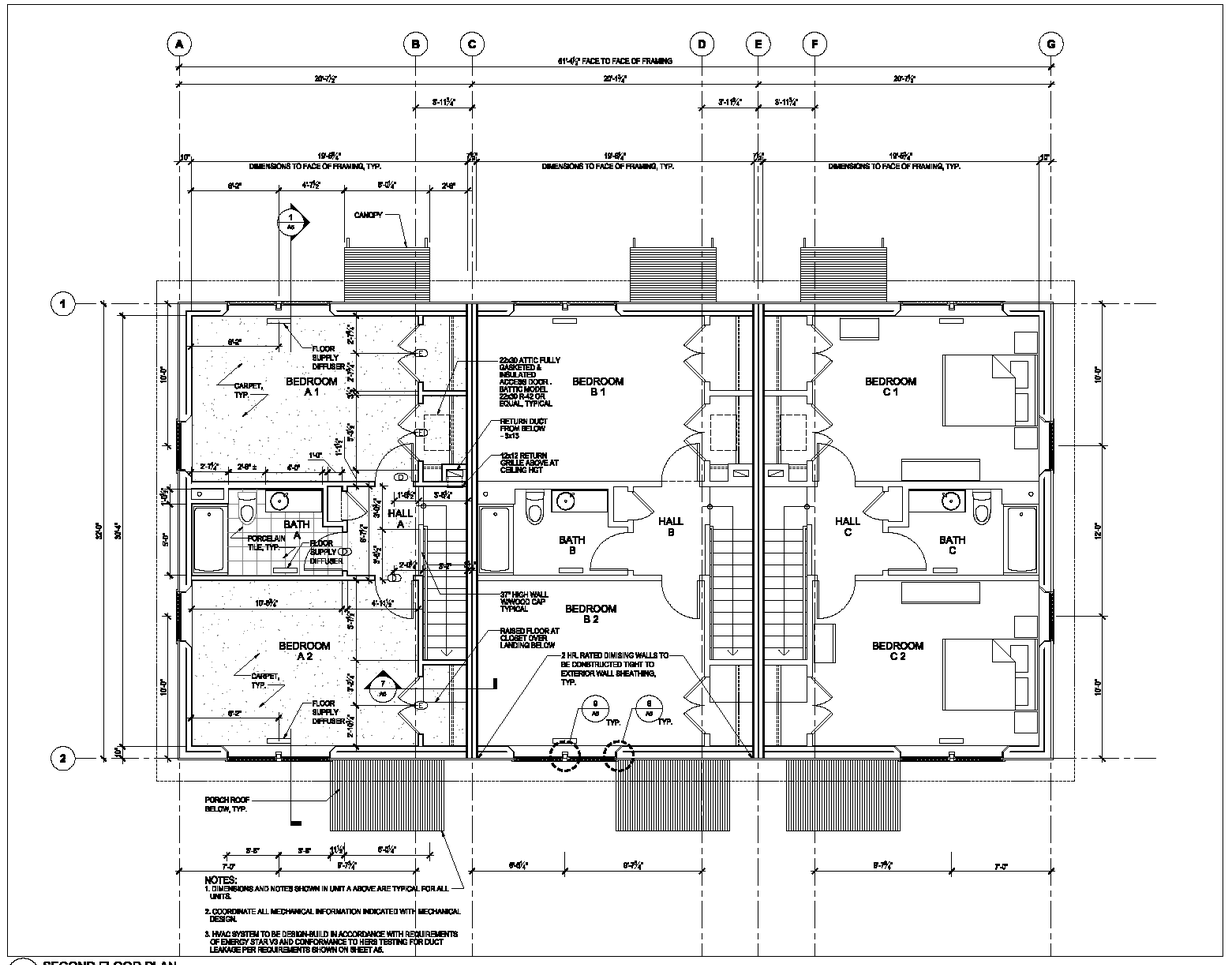
Drawing Title
BASEMENT AND FOUNDATION PLAN

A0



1 SECOND FLOOR PLAN
1/4" = 1'-0"

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GENERAL NOTES:

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1	MISC. REVISIONS	03.04.2011

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Project	Devens Sustainable Housing
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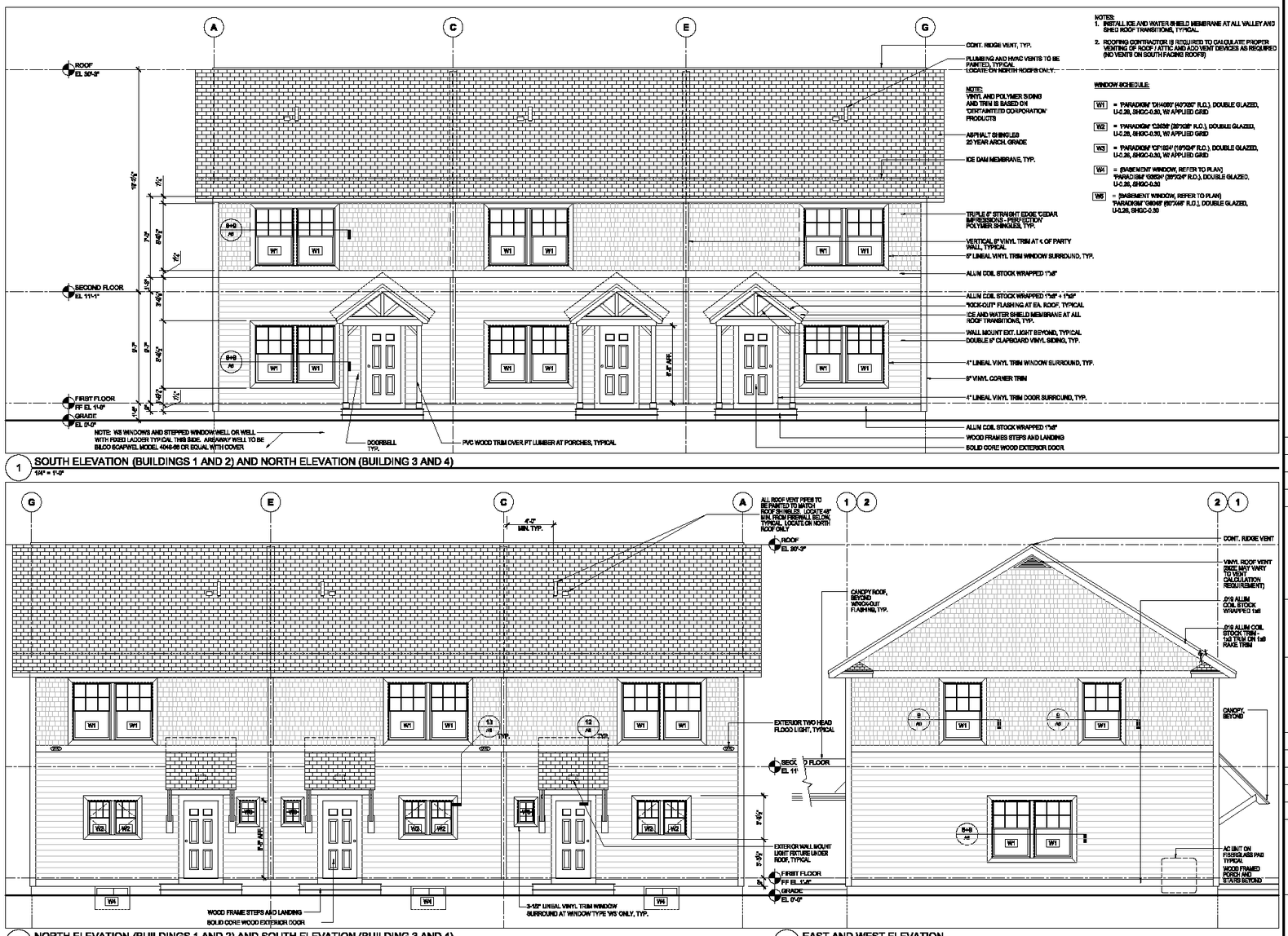
Date	October 20, 2010
Scale	AS NOTED

Drawing Title
Second Floor Plan

A2



1 SOUTH ELEVATION (BUILDINGS 1 AND 2) AND NORTH ELEVATION (BUILDING 3 AND 4)
1/4" = 1'-0"

2 NORTH ELEVATION (BUILDINGS 1 AND 2) AND SOUTH ELEVATION (BUILDING 3 AND 4)
1/4" = 1'-0"

3 EAST AND WEST ELEVATION
1/4" = 1'-0"

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2	UNIFIED PERMIT - REVISIONS	04.20.2011
1	UNIFIED PERMIT	03.04.2011

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Date October 20, 2010
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Drawing Title
Building Elevations

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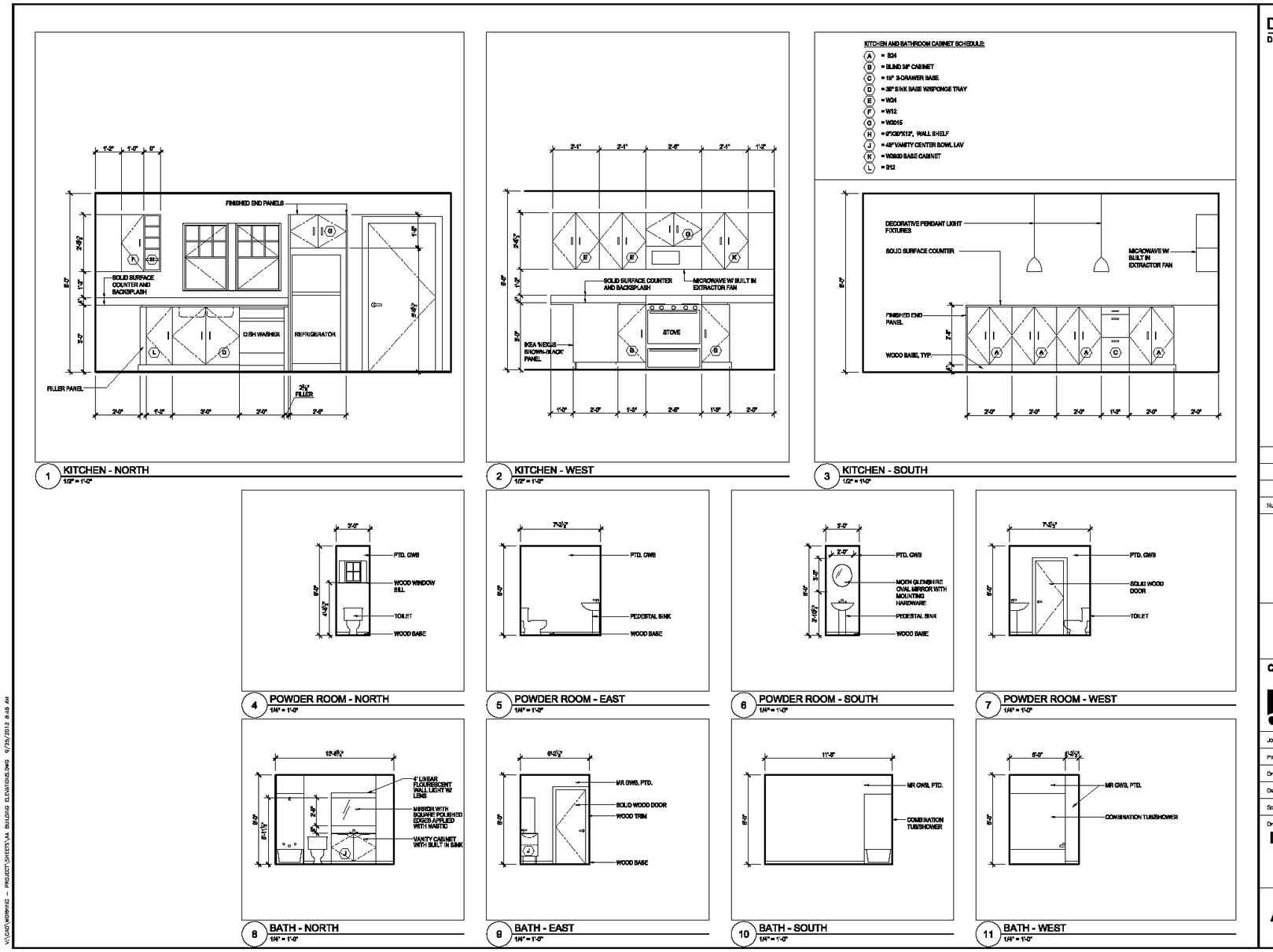

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Scale AS NOTED
Drawing Title
Interior Elevations

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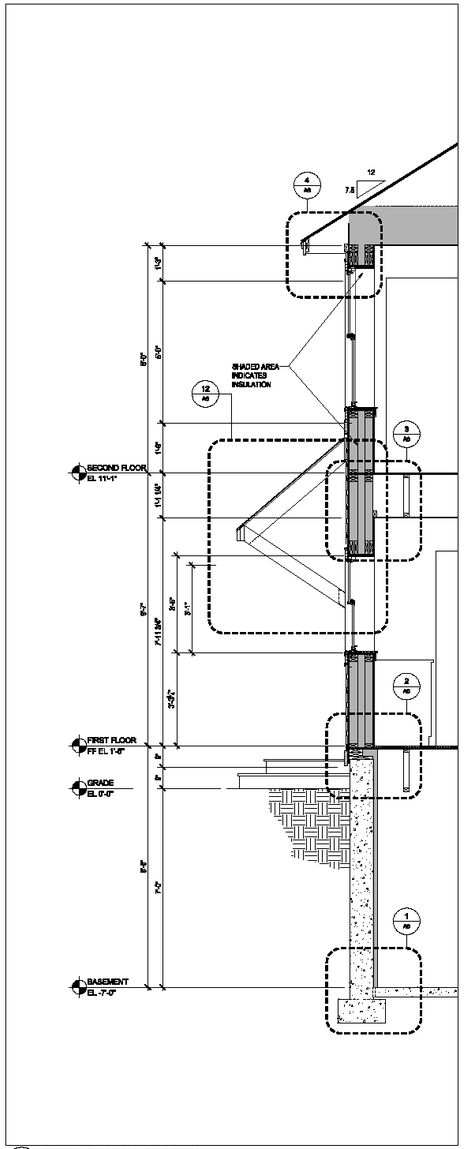
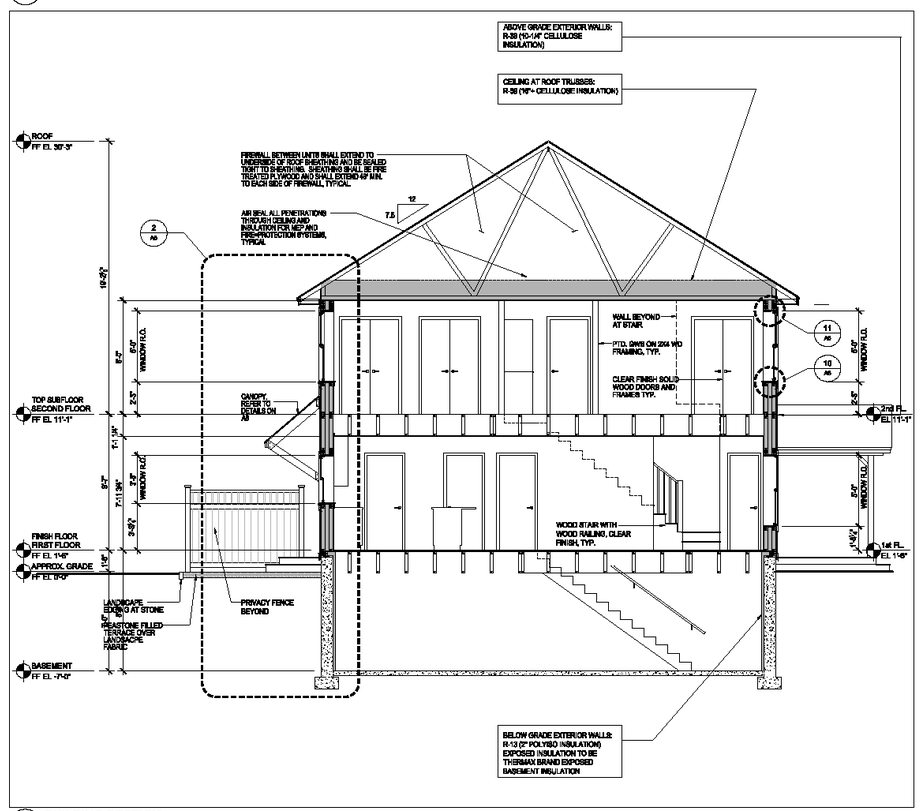


2 EXTERIOR WALL SECTION
1/2" = 1'-0"

END UNIT	HERS Index 39
Ceiling Insulation (660 SF)	R-59 (16" + cellulose)
Above Grade Exterior Walls (1314 SF)	R-38 (10 1/4" cellulose)
Below Grade Exterior Walls (584 SF)	R-13 (2" polyiso), 'conditioned' basement
Floor (880 SF)	Uninsulated slab and frame floor
Windows (double glazed all faces)	U-0.26, SHGC-0.30 (N-35SF, S-46SF, W-65SF)
Infiltration	0.15 ACH/wt
Ventilation	Exhaust only 42 CFM, 24 hr/day, 5.6 Watts Panasonic WhisperGreen, FV 08VKS2
Heating (floor registers)	94% AFUE condensing gas furnace
Cooling (floor registers)	16 SEER, 1.5 ton AC, prog t'stat
Hot Water	95% instant condensing gas
Ductwork (no leakage to 'outside')	Within conditioned space (needs ducts within 2nd floor or foamed/buried in attic floor)
Lighting	100% CFL (95% pin-type)
Fridge	ENERGY STAR, <483 kWh/yr
Dishwasher	ENERGY STAR, EF>0.70
Renewables	none

3 BUILDING HERS INDEX 40 SPECIFICATION
N.A.



1 BUILDING SECTION
1/4" = 1'-0"

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DEVENS, MASSACHUSETTS

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Job # 1019
Project Devens Sustainable Housing
Drawn by HR Checked GJ
Date October 20, 2010
Scale AS NOTED
Drawing Title
Building Sections

A5

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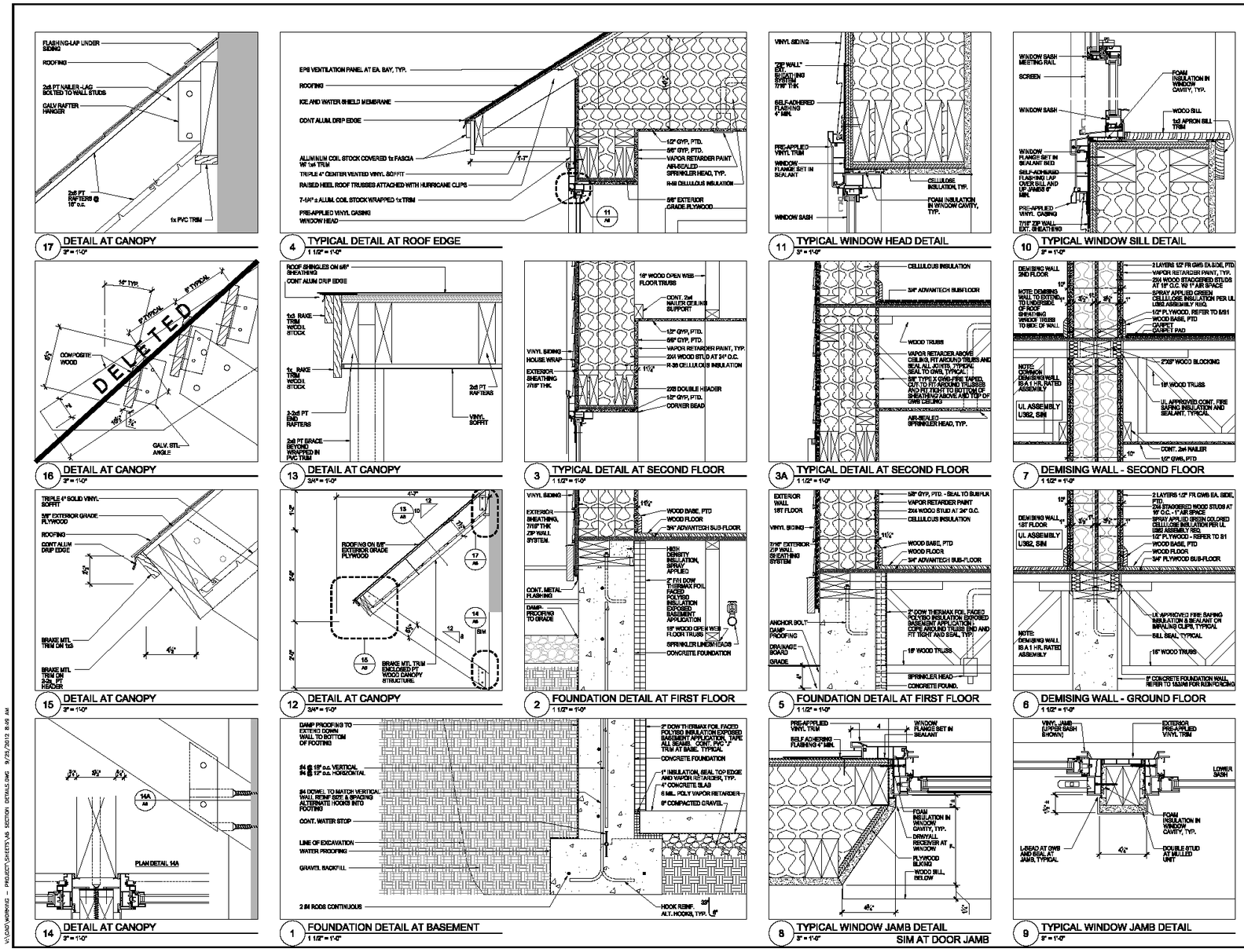


DEVENS NET ZERO, LLC

DEVENS, MASSACHUSETTS

ISSUED FOR PERMIT

OCTOBER 26, 2011

Number	Revision	Date

Cambridge Seven Associates, Inc.

Architects and Planners

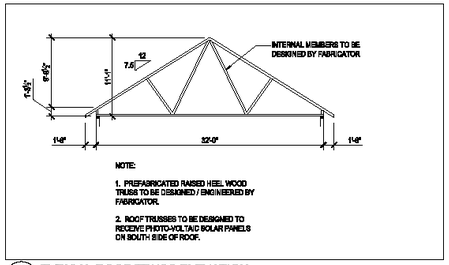
1050 Massachusetts Ave.
Cambridge, MA 02138
617 492-7996 Fax 492-7007

Job #	1019
Project	Devens Sustainable Housing
Drawn by	JL, NR — Checked GJ
Date	October 20, 2010
Scale	AS NOTED

Drawing Title

Section Details

A6

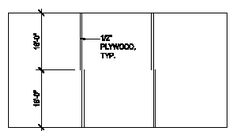


NOTE:

1. PREFABRICATED RAISED HEEL WOOD TRUSS TO BE DESIGNED / ENGINEERED BY FABRICATOR.

2. ROOF TRUSSES TO BE DESIGNED TO RECEIVE PHOTO-VOLTAIC SOLAR PANELS ON SOUTH SIDE OF ROOF.

4 TYPICAL ROOF TRUSS ELEVATION
1/8" = 1'-0"



NOTE:

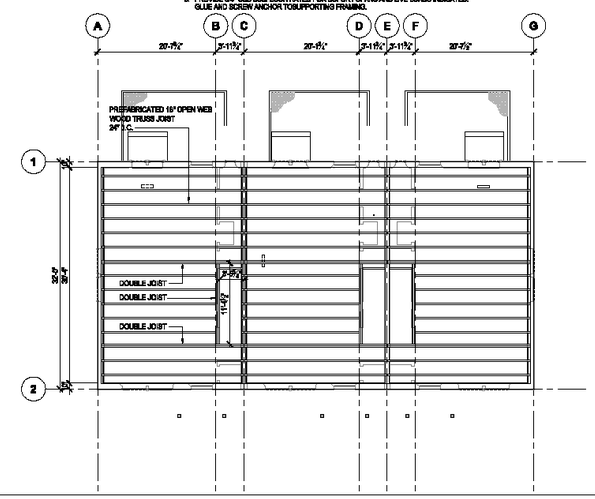
1. 1/2" PLYWOOD FOR LATERAL STABILITY IN DEMISING WALLS TO BE FASTENED WITH 8P NAILS 4" OC.

2. MINIMUM OF 14.5 LF (16 LF SHOWN) OF HORIZONTAL PLYWOOD SHEATHING REQUIRED AT EACH DEMISING WALL FROM FOUNDATION WALL TO ROOF SHEATHING. NAIL 16' OF PLYWOOD TO FRAMING AS SHOWN.

3. BLOCK ALL EDGES OF PLYWOOD SHEATHING.

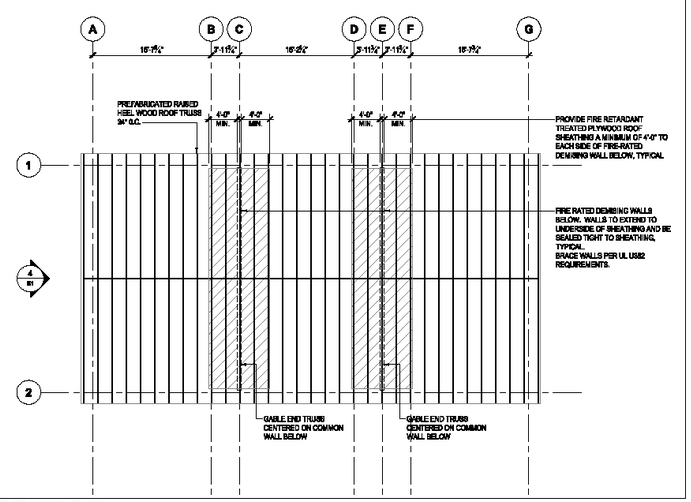
5 SHEAR WALL / DEMISING WALL PLAN DIAGRAM
N.A.

NOTE:
1. PREFABRICATED 16" OPEN WEB WOOD TRUSS JOISTS TO BE DESIGNED FOR A 40 LBS LIVE LOAD AND AND 1/480 DEFLECTION.
2. PROVIDE BRIDGING PER JOIST MFG. AND BUILDING CODE REQUIREMENTS.
3. PROVIDE 3/4" OSB SUBFLOOR RATED FOR SUPORT SPANS AND LIVE LOADS INDICATED. GLUE AND SCREW ANCHOR TOSUPPORTING FRAMING.



1 GROUND FLOOR FRAMING PLAN
1/8" = 1'-0"

NOTE:
1. PROVIDE BRACING PER TRUSS MFG. AND BUILDING CODE REQUIREMENTS.
2. PROVIDE FRAMING OPENING FOR ATTIC ACCESS IN BOTTOM CHORDS OF TRUSS. REFER TO LEVEL 2 PLAN FOR LOCATIONS.



3 ROOF FRAMING PLAN
1/8" = 1'-0"

NOTE:
1. PREFABRICATED 16" OPEN WEB WOOD TRUSS JOISTS TO BE DESIGNED FOR A 40 LBS LIVE LOAD AND AND 1/480 DEFLECTION.
2. PROVIDE BRIDGING PER JOIST MFG. AND BUILDING CODE REQUIREMENTS.
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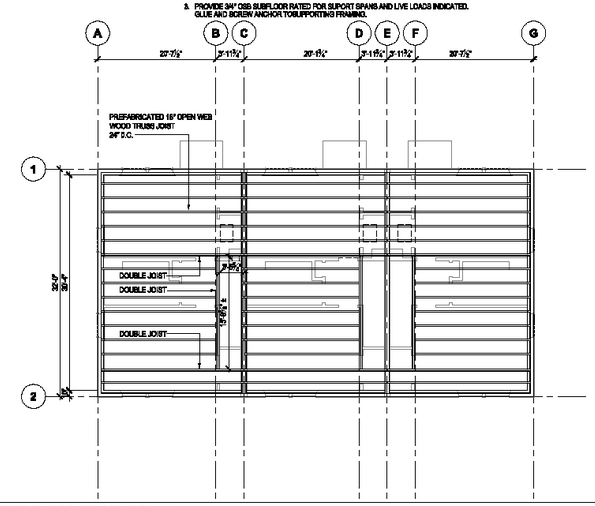

2 SECOND FLOOR FRAMING PLAN
1/8" = 1'-0"

DEVENS NET ZERO, LLC

DEVENS, MASSACHUSETTS

GENRAL NOTES:

1. PROVIDE ROOF TRUSS AND FLOOR TRUSS DESIGN COMPUTATIONS AND SHOP DRAWINGS PREPARED AND STAMPED BY A PROFESSIONAL STRUCTURAL ENGINEER REGISTERED IN THE STATE OF MASSACHUSETTS.

STRUCTURAL NOTES:

STRUCTURE SHALL BE BE CONNECTED AS FOLLOWS:

1. TRUSS TO TOP PLATE - SIMPSON H7Z TIE AT EACH TRUSS, TYPICAL.
2. SECOND FLOOR WALL TO FLOOR SYSTEM TO FIRST FLOOR WALL - SIMPSON MSTC40 STRAP TIE, 24" O.C. TYPICAL.
3. FIRST FLOOR FOUNDATION CONNECTION - SIMPSON STHD10RJ AT EACH CORNER, ENDS OF SHEAR WALLS, TWO (2) LOCATIONS AT GABLE ENDS, AND AT MIDSPAN BETWEEN DEMISING WALLS AT DOUBLE STUD LOCATIONS.

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Drawing Title
Framing Plan

S1

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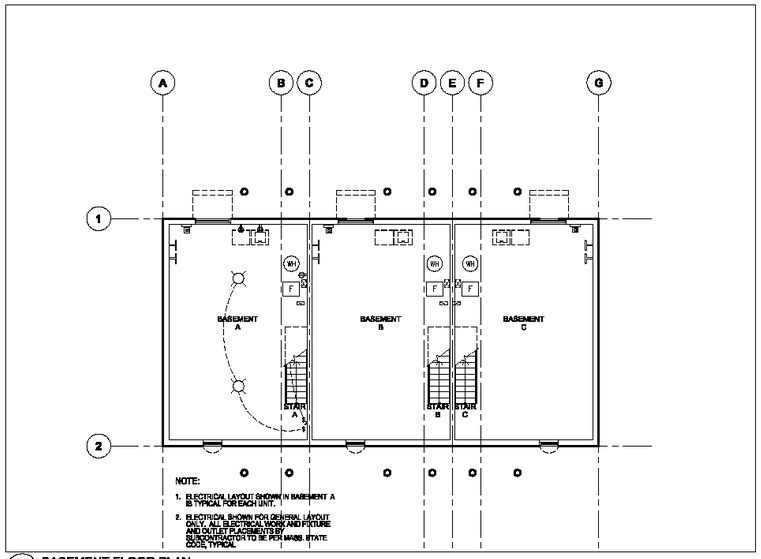
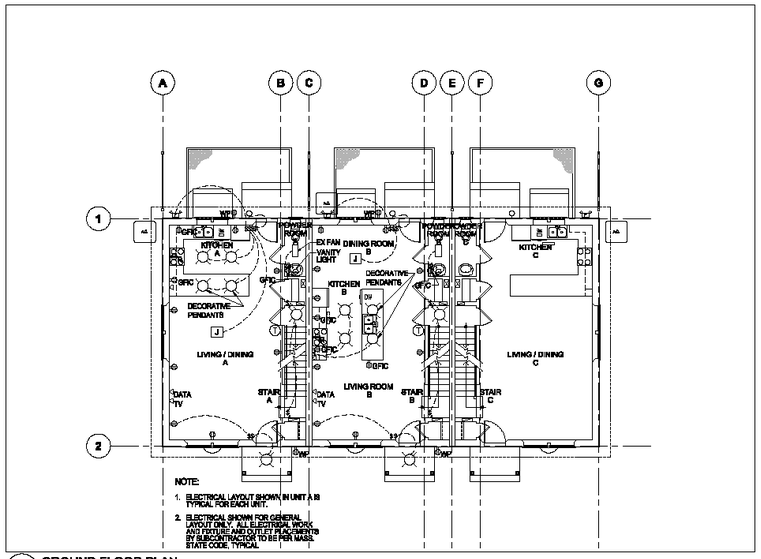


1 BASEMENT FLOOR PLAN
1/8" = 1'-0"



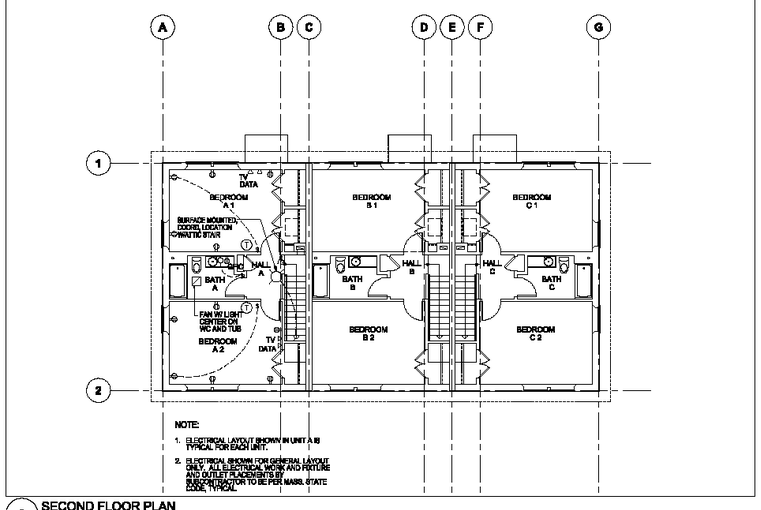
2 GROUND FLOOR PLAN
1/8" = 1'-0"

NOTE:

CEILING LIGHTS SHOWN ARE 6" RECESSED DOWNLIGHTS WITH COMPACT FLUORESCENT EXCEPT AT KITCHEN COUNTERS (DECORATIVE PENDANTS).

SPRINKLER HEADS ARE RECESSED AND TO BE AIR TIGHT. INSTALLATION TO AVOID AIR MIGRATION TO ROOF CAVITY. CENTER SPRINKLER HEADS IN CEILINGS AS REQUIRED. SPRINKLER HEADS TO BE RESIDENTIAL CONCEALED TYPE HEADS, TYPICAL

CEILING FANS IN RESTROOM AND POWDER ROOM IS PANASONIC "WHISPER GREEN". RESTROOM FAN IS ON CONTINUOUSLY TO PROVIDE BUILDING EXHAUST.



3 SECOND FLOOR PLAN
1/8" = 1'-0"

V:\CAD\WORKING – PROJECT SHEETS\E1 ELECTRICAL PLAN.DWG 1/25/2012 8:48 AM

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Electrical Layout Plan

E1

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