10. ZETA COMMUNITIES, SAN FRANCISCO BAY AREA, CA

10.1 Executive Summary

Gate 2 - Prototype: Lancaster Townhouse, ZETA Communities, Oakland, CA

Overview

ZETA Communities is a San Francisco Bay Area startup company which has a goal of producing factory built/modular houses with net zero energy performance; they have completed a Prototype ("Lancaster live-work townhouse") in Oakland, CA. Some technologies incorporated into this prototype include high performance (triple glazed) windows, a heat pump water heater, drainwater heat recovery, and a residential-scale economizer. The house also has a proprietary control system ("zTherm"), which is intended to make use of semi-active control of the thermal mass located in the conditioned crawl space.

The house has been through several rounds of tests by BSC, and a data acquisition system has been installed to measure thermal and energy performance. NREL is slated to perform short-term testing at this house, followed by long-term (1-year) monitoring.

Key Results

The design is projected to achieve a performance level of 45% reduction relative to the Building America Benchmark without renewable energy sources, and 95% including renewables (5.4 kW roof-mounted photovoltaic array). A key challenge was meeting performance targets in a mild climate (with small heating/cooling loads) such as the Bay Area. Another challenge was that net zero performance requires the use of only electricity under the net metering laws currently in effect in California, which limited mechanical equipment options. The heat pump water heater, for instance, proved to be problematic in this installation. Some specific systems testing included examinations of subcomponents of the thermal mass control system and the drainwater heat recovery system.

Gate Status

Table 10.1: Stage Gate Status Summary

"Must Meet" Gate Criteria	Status	Summary
Source Energy Savings	Pass	With the enclosure and mechanical characteristics presented in this report, this plan achieves a performance level of 45% reduction relative to the Building America Benchmark without renewable energy sources, and 95% including renewables.
Prescriptive-Based Code Approval	Pass	The prototype was permitted as a live/work unit, R-3 occupancy. It complied with the 2007 CBC, CMC, CPC, CEC, CFC (Building, Mechanical, Plumbing, Electrical, and Fire Codes), and 2005 California Energy Code.
Quality Control Requirements	Pass	The quality assurance and quality control system used by ZETA Communities were developed in-house, to account for both factory work and site-completion work. BSC provided the Builders Challenge Quality Criteria checklist to ZETA; site inspection indicated that targets were met.

"Should Meet" Gate Criteria	Status	Summary

Neutral Cost Target	Does Not Meet	The overall performance of this prototype, given estimated the builder's estimated costs, were that it did not meet the neutral cost criteria. Given the zero net energy goal, it was not expected that the builder would be at the neutral cost point. It should be noted that the builder's goal was net zero energy use, as opposed to any specific neutral cost target. Their cost goal was primarily to produce net zero houses (including renewable energy systems) at a price point comparable to typical Bay Area construction costs.The builder is currently examining options to reduce their construction costs in further work.
Quality Control Integration	Pass	BSC worked closely with the builder and architect to develop a variety of details important to health, safety, durability, comfort, and energy efficiency. BSC also provided details for window installation and flashing, and foundation water management.
Gaps Analysis	Pass	Several items proved to be problematic in practice and implementation. There were several difficulties in the installation of the heat pump water heater. The newer options available on the market might be a solution to these issues. The economizer system proved to show a relatively low efficiency, as well as being an issue for duct leakage to the exterior. The expense of rainscreen cladding with a fiber cement panel system was another durability issue. The prefabricated mechanical core and mechanical room design proved to have some issues for air and thermal barrier continuity, which will be addressed in future designs.

Conclusions

In spite of several problematic systems and startup issues, ZETA's Lancaster live-work townhouse is substantially completed and tested; data collection is also underway. It is slated to be sold in late 2009; homeowner agreements to allow data collection and access for one year after occupancy. Some systems are of particular interest in terms of their overall energy performance; their relative effectiveness will determine whether they are included in future work. The monitoring system is designed to capture the performance of some of these systems, including the "zTherm" controller, the heat pump water heater, and the heat pump space conditioning system.

10.2 Introduction

10.2.1. Project Overview

ZETA Communities (Zero Energy Technology & Architecture) is a San Francisco Bay Area startup company operating under venture capital funding, with the goal of using factory-built modular techniques to reduce construction costs, as well as providing an energy efficient, environmentally-friendly product. The company is closely allied with several firms that share their goals, including CalStar Cement (a manufacturer of lower embodied energy cement) and Serious Materials (a manufacturer of low embodied energy gypsum board, and ultra-high performance triple, quadruple, and quintuple glazed windows).

ZETA's core mission is to produce net zero energy buildings, as noted on its website:

> *ZETA produces net zero energy multifamily housing and mixed-use structures for sustainable communities, focusing on urban infill, transit-oriented development, public land development and educational campuses.*

Their plan is to typically build infill single family houses, townhomes, and apartment buildings throughout the Bay Area. California is likely to be an excellent market for their net zero energy product, due to climate, a receptive local population, and the California Public Utilities Commission's Long Term Energy Efficiency Strategic Plan. That plan requires that "all new residential construction in California will be zero net energy by 2020." In the future, ZETA plans on re-adapting their modular plan to various climate regions, and spreading their installations over a wider geographic area.

While attempting to build an initial prototype/test house, ZETA suffered through problems hitting the homebuilding industry due to the poor economy. Several designs were proposed (and analyzed by BSC), but were not built; they included the Bayview Townhomes, the Pittsburg, CA prototype, Turk Street condominiums in San Francisco, and further projects in Marin County and at Crissy Field in San Francisco.

However, ZETA has successfully completed their Lancaster live-work prototype townhouse ("V1"), located in Oakland, CA (near the Fruitvale BART mass transit station), as shown in Figure 10.2.1. This building has gone through several rounds of commissioning testing by BSC, and is slated for short-term testing by NREL. The house is on track to receive a LEED Platinum rating, and a 240 Green Point Rating.

The builder has suffered some turnover of construction personnel during its time working with BSC; this resulted in some issues in terms of continuity of knowledge and completion of long-term items. However, other key managers and consultants are still in place, providing continuity of knowledge for the team.

Original plans called for a second unit to be built in the adjacent lot ("V2"), however, this plan has been suspended indefinitely. Instead, ZETA is concentrating its current efforts on a multifamily building located in Berkeley CA (SmartSpace™ Student Efficiency Housing), in collaboration with Berkeley developer Panoramic Interests. Preliminary analysis of this project is covered briefly under Building Science Corporation's multifamily working group participation.

Figure 10.2.1: ZETA Lancaster live-work prototype townhouse (Oakland, CA)

10.2.2. Project Information Summary Sheet

PROJECT SUMMARY	
Company	ZETA Communities
Company Profile	ZETA Communities is a provider of Zero Energy Technology & Architecture structures (residential and commercial) and communities that operate at net zero energy and carbon. The innovation is in the design and factory-based manufacturing. The cost target is mass market residential and commercial. ZETA is a development-stage company. Established in 2008.
Contact Information	Naomi Porat, CEO ZETA Communities San Francisco Office 848 Folsom Street, Suite 201 San Francisco, CA 94107 T 415.946.4084 F 415.651.9481
Division Name	n/a
Company Type	Developer (Startup)
Community Name	Lancaster Lofts
City, State	Oakland, CA
Climate Region	Marine (3C)

SPECIFICATIONS	
Number of Houses	1
Municipal Address(es)	612 Lancaster Street, Oakland, CA
House Style(s)	Multifamily/townhouse affordable
Number of Stories	2
Number of Bedrooms	2
Plan Number(s)	n/a

Floor Area	1561 ft^2 (457 ft^2 work space first floor)
Basement Area	n/a
Estimated Energy Reduction	45% over BA Benchmark without photovoltaics; 95% with PVs
Estimated Energy Savings	$992/year without photovoltaics; $93/year with PVs (Electricity @ $0.13/kWh)
Estimated Cost	$165/ ft^2 (budgeted target; $135/ ft^2 target for production); initial prototype costs likely higher than targeted
Construction Start	July 2009 (setting of units; factory construction started February 2009)
Expected Buildout	October 2009 (completion of punch list items)

10.2.3. Targets and Goals

The target goals for 2009 for Hot Dry/Mixed Dry Climates are to achieve an overall energy consumption reduction of 50% when compared to the Building America Benchmark protocol for Communities and 50% for Research Homes.

Also, some aspects of this project are of particular interest on a research level. The central air handler system and other building components are being set up to take advantage of the diurnal swings of this coastal climate to reduce heating and cooling loads through the use of “smart” control operation of air movement, and thermal mass. This system is described in more detail in section 10.3.2.4 (“zTherm” Controller).

10.3 Whole House Performance and Systems Engineering

10.3.1. Energy Analysis Summary

Table 10.2: Estimated Whole House Energy Use for ZETA Lancaster (no renewables)

ESTIMATED WHOLE HOUSE ENERGY USE		
Source (MMBtu/year)	Site (MMBtu/year)	Area + Bsmt (sq ft)
88	26	1561 + 0
	% Electric	No. of Bedrooms
	100%	2

Table 10.3: Estimated Whole House Energy Use for ZETA Lancaster (including renewables)

ESTIMATED WHOLE HOUSE ENERGY USE		
Source (MMBtu/year)	Site (MMBtu/year)	Area + Bsmt (sq ft)
8	2	1561 + 0
	% Electric	No. of Bedrooms
	100%	2

With the enclosure and mechanical characteristics presented in Table 10.6 and Table 10.7, this plan achieves a performance level of 45% reduction relative to the Building America Benchmark without renewable energy sources, and 95% including renewables.

Note that this predicted performance (not reaching net zero energy use) is largely an artifact of Benchmark operating conditions and other modeling assumptions. For instance, this prediction does not include any effect of the zTherm controller, extended thermal comfort ranges (setpoint), or energy-conscious occupant behavior. Specifically, homeowner operation has a huge effect on actual energy use; the owner of a net zero energy house is likely to be self-selecting for a low user. Given the unfavorable net metering laws in California (see the sections "Site-generated Renewable Energy"), overspecifying the PV array size would both increase first cost, and provide no financial benefit for the homeowner. Therefore, this system size was considered reasonable to assure actual net zero performance in reality.

10.3.1.1. Parametric Energy Simulations

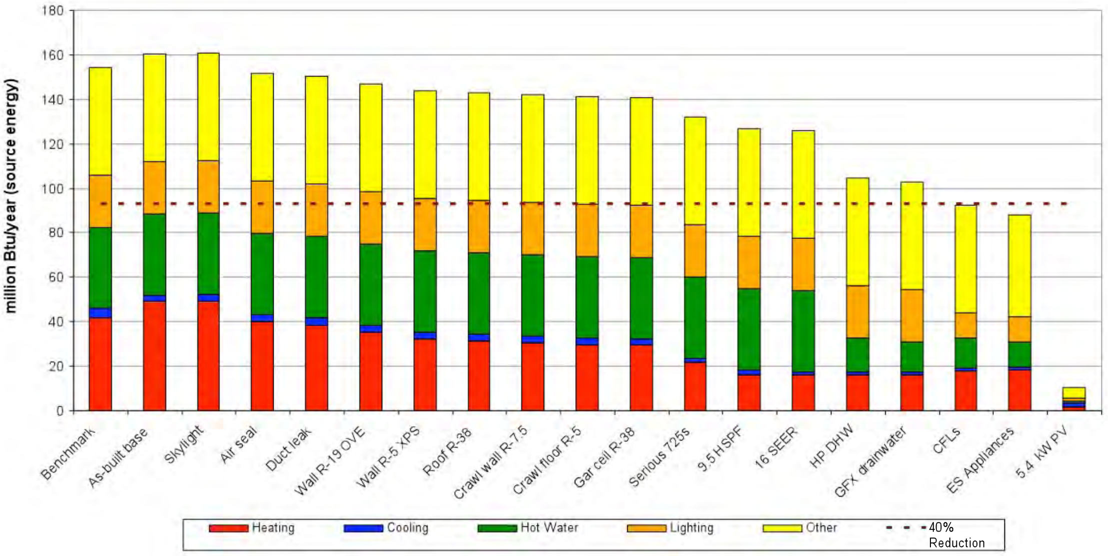


Figure 10.3.1: Parametric energy simulations for ZETA Lancaster

Note that the final parametric bar in Figure 10.3.1 shows the addition of renewable energy as a proportionate reduction of all end use loads (since this is an all-electric house).

10.3.1.2. End-Use Site and Source Energy Summaries

Table 10.4: Summary of End-Use Site-Energy

	Annual Site Energy			
	BA Benchmark		**Prototype**	
End-Use	kWh	therms	kWh	therms
Space Heating	3990	0	1806	0
Space Cooling	365		144	
DHW	3174	0	999	0
Lighting*	2054		819	
Appliances + Plug	4223	0	3866	0
OA Ventilation**	0		0	
Total Usage	13805	0	7634	0
Site Generation	0	0	6918	0
Net Energy Use	13805	0	716	0

*Lighting end-use includes both interior and exterior lighting

**In EGUSA there are currently no hooks to disaggregate OA Ventilation

it is included in Space Heating and Cooling

Table 10.5: Summary of End-Use Source-Energy and Savings

			Source Energy Savings	
	Estimated Annual Source Energy		Percent of End-Use	Percent of Total
End-Use	**BA Benchmark** 10^6 BTU/yr	**Prototype** 10^6 BTU/yr	**Prototype savings**	**Prototype savings**
Space Heating	46	21	**55%**	**16%**
Space Cooling	4	2	**60%**	**2%**
DHW	36	11	**69%**	**16%**
Lighting*	24	9	**60%**	**9%**
Appliances + Plug	48	44	**8%**	**3%**
OA Ventilation**	0	0	**0%**	**0%**
Total Usage	159	88	**45%**	**45%**
Site Generation	0	79		**50%**
Net Energy Use	159	8	**95%**	**95%**

Notes:

The "Percent of End-Use" columns show how effective the prototype building is at reducing energy use in each end-use category.

The "Percent of Total" columns show how the energy reduction in each end-use category contributes to the overall savings.

10.3.2. Discussion

10.3.2.1. Enclosure Design

Table 10.6 (below) summarizes the building enclosure assemblies used for this project.

Table 10.6: Enclosure Specifications

ENCLOSURE		**SPECIFICATIONS**
Ceiling		
	Description -	Low-slope roof with 2x12 rafter/joist framing
	Insulation -	R-32 Icynene low-density foam sprayed cavity
Walls		
	Description -	2x6 Advanced Framing with extruded polystyrene insulating sheathing
	Insulation -	Low density spray foam in most walls, cotton batt in long common walls; 2x4 R-13 to garage (long wall) + R-5 XPS
Foundation		
	Description -	Conditioned exterior insulated crawl space (part of “smart” control system)
	Insulation -	R-7.5 (1-½”) XPS at concrete foundation wall exterior; R-5 (1”) XPS under 2” rat slab floor
Windows		
	Description -	Fiberglass frame double glazed with suspended film (“triple glazed”)
	Manufacturer -	Serious Windows Series 725 High solar gain
	U-value & SHGC -	U=0.23 SHGC=0.42
Infiltration		
	Specification -	2.5 in^2 leakage area per 100 ft^2 envelope (1154 CFM 50/4.3 ACH 50)
	Performance test -	682 CFM 50 (2.5 ACH 50) for Lancaster prototype (August 2009 tests)

The San Francisco Bay Area has an exceptionally mild climate; for instance, Oakland, CA has 2880 HDD Base 65° F and 435 CDH Base 65° F; design temperatures are 37.5° F (heating 99.6%) and 81.8° F (cooling 0.4%). As a result, the heating and cooling loads are only 1/3 of the total load (for the Benchmark), thus reducing the "leverage" of enclosure improvements. This issue is shown in the parametric study (see Figure 10.3.1), and is covered in more detail in "2008-12-02 ZETA Lancaster Analysis.pdf," and "2009-07-06 ZETA Bay Area Space Conditioning.pdf."

It is unfortunate that this factor weakens the financial arguments for enclosure improvements. However, given the goal of zero net energy performance, and the expense of photovoltaic systems, the greater enclosure improvements can be financially justified relative to the incremental cost of adding additional PV modules.

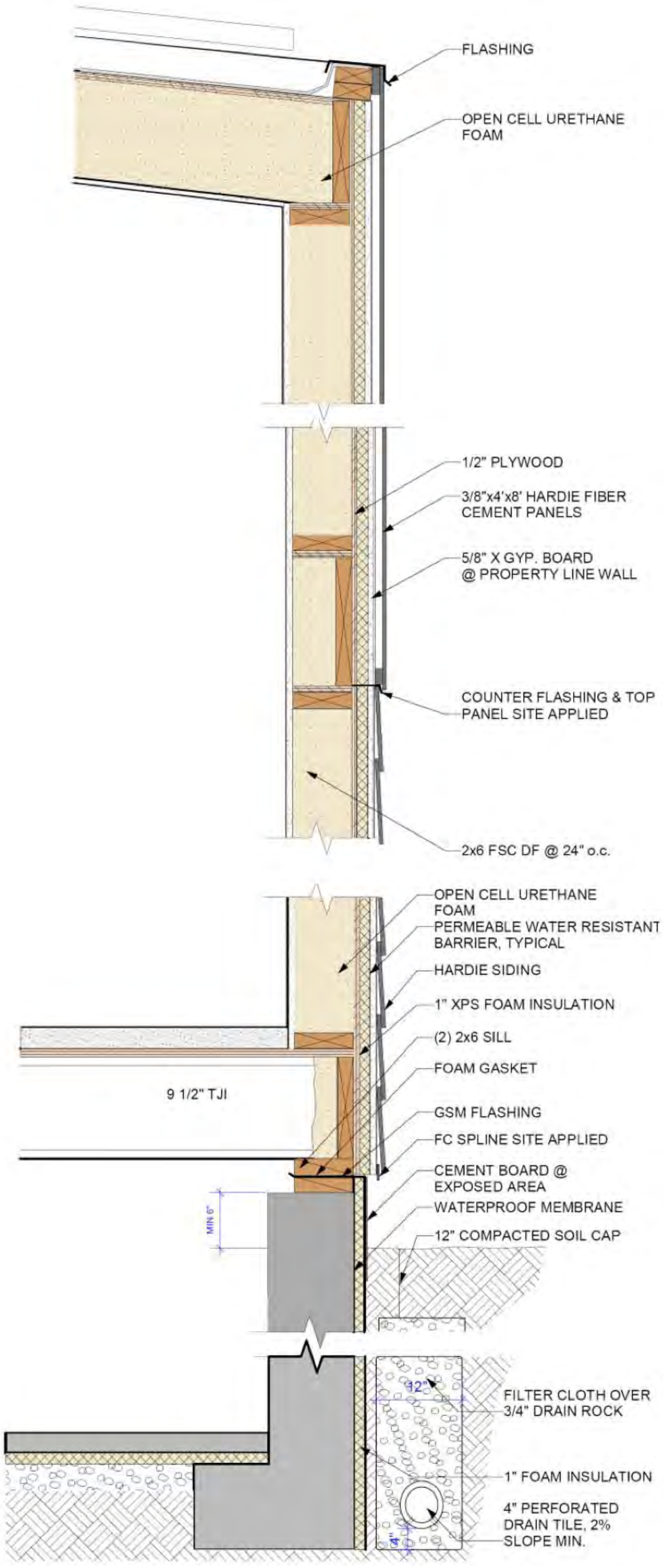


Figure 10.3.2: ZETA exterior wall section (c/o DSA Architects)

Cavity insulation: The insulation choices were decided by a rather circuitous path. Initial plans were made to use damp-spray cellulose as cavity-fill insulation, with R-5 XPS on the exterior to provide condensation control and reduce thermal bridging. However, there are apparently major moisture-induced class-action lawsuits against damp-spray cellulose installers in California. This resulted in such a strong risk-averse mentality that no nearby cellulose installers were willing to do this installation. As a result, the design team chose to use low-density (0.5 PCF) spray foam insulation throughout the building. At some portions of the building (long non-windowed sides), the builder unilaterally decided to try recycled cotton batt insulation. However, post-construction cost analysis of the spray foam showed that it is not a sustainable option for a production basis, both due to installed cost, as well as the requirement for an additional step in the production line (i.e., "flipping" the wall panel). In addition, there were several customer service issues with the specific spray foam subcontractor used at this project (see Figure 10.3.3).

Figure 10.3.3: Spray foam installation (walls) showing excessive "shaving" of surface

Figure 10.3.4: Spray foam installation (overhang over front porch)

The insulation that will be used in future projects has yet to be decided; some options under consideration include dense-pack cellulose, spray-applied fiberglass, or batt insulation.

Foundation design: The crawl space foundation is designed to be a thermal mass reservoir, with supply ductwork that is open to the space, "bleeding" the air to the first floor. This results in coupling between the supply air and the thermal mass of the crawl space.

The foundation was actually a matter of particular contention due to its high cost. The installed cost was close to double of expected budgeted figures. However, after further study with the builder, it was determined that much of the cost was due to groundwater, constricted site conditions, and poor soils conditions, as opposed to issues exclusively attributable to the energy efficiency measures.

Figure 10.3.5: Exterior view of conditioned crawl space, showing 1.5" R-7.5 XPS

Figure 10.3.6: Interior view of conditioned crawl space ("thermal basement")

The HVAC system is controlled by a system ("zTherm") that takes inputs of exterior, interior, and crawl space (a.k.a. "thermal basement") conditions, and then runs the air handler appropriately, to minimize condenser-based space conditioning runtime.

In order to provide insulated thermal mass, the cast concrete stemwalls were insulated on the exterior with R-7.5 XPS (see Figure 10.3.6), and the slab insulated at R-5. Of course, the airtightness of the crawl space is critical, as air leakage from that space is effectively a low-pressure supply duct leak to the exterior. However, the builder carefully detailed rigid and spray foam, resulting in excellent results (see Figure 10.3.6).

Of course, given that California crawl spaces are typically low, vented spaces with bare earth floors and minimal access, the idea of cycling interior air through a "crawl space" is unappetizing to a typical consumer. This required the preparation of some educational materials for customers and investors in ZETA; the document "2009-03-04 ZETA Thermal Basement Memo V2.pdf" was created as a layperson's explanation for the moisture physics of foundations and moisture control measures being taken with this construction, in order to minimize risk of any moisture or indoor air quality complaints.

Moisture control measures are critical to the success of this assembly; specific measures included an interior drainage system and gravel field with sump pump, XPS insulation under the slab for condensation control, membrane waterproofing on exterior stemwalls, and drainage mat at the inaccessible foundation wall (zero-clearance lot line).

Windows: Ultra-high performance Serious Materials 725 series windows were selected for this project; these are fiberglass frame, triple glazed (double glazed with suspended film; U=0.23 SHGC=0.42) units. However, there was some uncertainty where they would be selected, due to their high cost—a double glazed fiberglass frame (Inline) unit was considered at one point.

Figure 10.3.7: Laser glass thickness meter, indicating double glazing + suspended film

Figure 10.3.8: Serious Materials 725 label at factory during unit assembly.

Unfortunately, energy analysis showed that in the mild Bay Area climate, these ultra high performance windows had minimal benefit, and were not a very cost-effective selection. For reference, it was in the range of a 60-70 year simple payback. Some of the specifics are discussed in "2009-06-15 ZETA Lancaster Economic Optimization.pdf"

Airtightness: The blower door testing indicated that the overall airtightness of the building was excellent (see 2009-07-03 ZETA Lancaster Testing Report.pdf and 2009-09-03 ZETA Lancaster Testing Report II.pdf), with final results at 682 CFM 50 (2.5 ACH 50), compared to the goals of 1154 CFM 50 (4.3 ACH 50). This was expected, given the spray foam construction throughout.

10.3.2.2. Mechanical System Design

Table 10.7 (below) summarizes the mechanical systems used by this project.

Table 10.7: Mechanical system specifications

MECHANICAL SYSTEMS	SPECIFICATIONS
Heating	
Description -	9.5 HSPF Air Source Heat Pump
Manufacturer & Model -	Goodman SSZ16 Series Condenser w. AEPF Series Air Handler
Cooling (outdoor unit)	
Description -	16 SEER Air Source Heat Pump
Manufacturer & Model -	Goodman SSZ16 Series Condenser
Cooling (indoor unit)	
Description -	Variable Speed/ECM Modular Blower Air Handler
Manufacturer & Model -	Goodman AEPF Series Air Handler
Domestic Hot Water	
Description -	Electric tank water heater with attached air source heat pump unit Drainwater heat recovery system (all second floor loads)

MECHANICAL SYSTEMS	SPECIFICATIONS
Manufacturer & Model -	AirGenerate AirTap A7 (2.11 EF, 7000 Btu output) Bradford-White M240T6DS 40 gallon unit GFX drainwater heat recovery system
Distribution	
Description -	Insulated sheet metal and insulated flex duct in conditioned space (conditioned crawl space and interior cavities)
Leakage -	Initial tests: 175 CFM 25 total/133 CFM 25 economizer taped (15%/11% of AHU flow; 11%/9% of floor area) Duct leakage to exterior 46 CFM 25/0 CFM 25 economizer taped (4% of AHU flow/3% of floor area) Final test: 125 CFM 25 total/85 CFM 25 supply/40 CFM 25 return 120 CFM 25 with economizer taped
Ventilation	
Description -	Heat recovery ventilator exhausting from bathrooms, supplying to second floor main space, 91 CFM high speed
Manufacturer & Model -	Suncourt Airiva HE100 100-130 CFM nominal (not HVI Certified; no ratings available)
Return Pathways	
Description -	Door undercuts at bedrooms with two returns (low on first floor; high on second floor)
Dehumidification	
Description -	None
Manufacturer & Model -	n/a
PV System	
Description -	5.4 kW grid-tied PV system; 24 panels, 225 W/panel
Manufacturer & Model -	SunPower 225 panels Sunnyboy (relabelled SunPower) inverter (SPR-5000m)
Solar Hot Water	
Description -	none
Manufacturer & Model -	n/a

Fuel Selection and Net Zero Energy: One decision that informed the entire selection process for mechanical systems was the selection of fuels to use on site. Given the builder's programmatic requirement for net zero energy performance, the specifics of California net metering came into play. Unfortunately, the current state laws are set up so that any excess renewable energy production or "net energy generation" (over the course of a year) is simply forfeited to the utility company.

One typical strategy used in previous BSC projects has been to burn fossil fuels on site to their best advantage—for instance, for domestic hot water production. The source energy of this site-burned fossil fuel is then counterbalanced by providing excess renewable energy generation (typically photovoltaics), thus netting out to zero source energy.

Therefore, given the constraints of California net metering, this option would be a serious financial loss: the only economically reasonable way to achieve net zero energy performance is with an all-electric house. This problem is discussed in more detail in "2009-10-09 ZETA Lancaster LEED ID Credit.pdf".

Space conditioning system: Given this all-electric constraint, a heat pump system was selected for heating and cooling. The mild climate of the San Francisco Bay Area lends itself to the use of an air source heat pump for heating. As outdoor temperatures fall, the efficiency of the equipment decreases, due to the increased work required to extract heat from outdoor air. In addition, when temperatures hit the mid to low 30s, the efficiency falls further, due to the requirement to add defrost energy, to melt frost that accumulates on the outdoor unit.

However, the ASHRAE design temperature (99.6% condition) for Oakland, CA is 37.5° F; therefore, the equipment operates at high efficiency levels for most of the season. This is shown in Figure 10.3.9, which plots the efficiency (COP) for several heat pumps against the outdoor temperature, including the 16 SEER/9.5 HSPF Goodman unit specified (2 and 3 ton sizes). As mentioned above, the efficiency falls with decreasing outdoor temperature. In addition, the COP value of 2.8 is plotted on the graph: this is the “threshold efficiency” level which is roughly equivalent to a furnace burning at an efficiency of 90% AFUE (assuming source energy figures presented in Deru and Torcellini 2007).

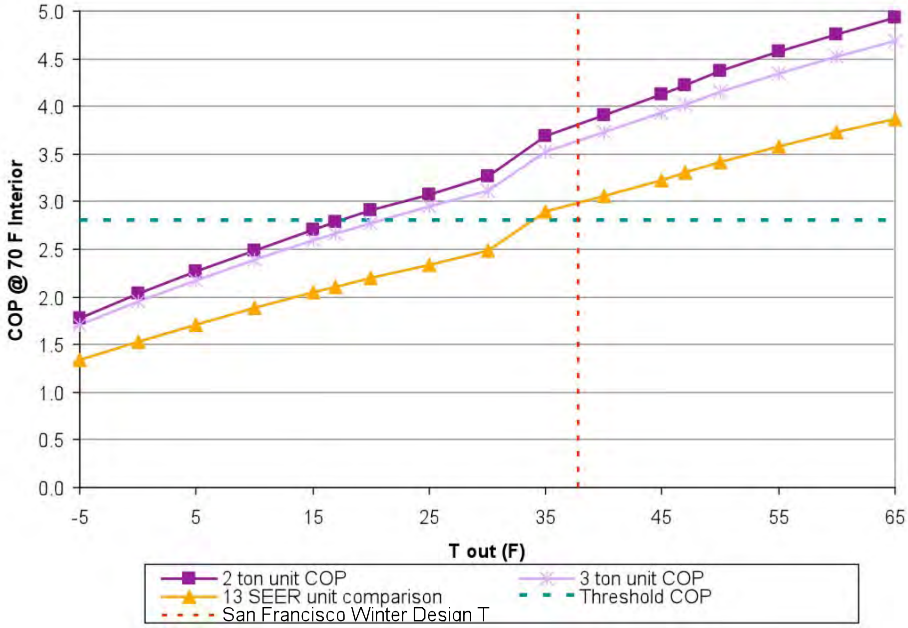


Figure 10.3.9: Goodman 16 SEER/9.5 HSPF heat pump performance, w. 13 SEER comparison

The design temperature (37.8° F) is also plotted, showing that in almost all expected conditions, the system will be operating at a higher efficiency level than burning of fossil fuels on site, as shown by the shaded grey box. A 13 SEER/7.7 HSPF Goodman unit is also plotted for comparison.

However, one significant problem occurred during the construction process: the final mechanical plans were never issued to the mechanical subcontractor. As a result (among other problems) the wrong air handler was selected and installed. The correct 2-ton outdoor condenser (16 SEER SSZ160241AB) was installed, but paired with a variable speed (ECM) air handler in the 2-½ to 5 ton size range (AEPF313716AA), resulting in high airflows and excess static pressures (2009-07-03 ZETA Lancaster Testing Report.pdf). At cooling speed, the system was operating at 1185 CFM, and 285 Pa total static pressure (1.14 IWC).

BSC first attempted to reduce speeds using DIP switch settings, but the lowest cooling speed was still resulting in excess pressures. The problem was solved by the installation of a bypass jumper, to run the air handler in "fan on" speed while in cooling mode (as discussed in "2009-08-14 ZETA Lancaster Trip Follow Up Items.pdf" and "2009-09-03 ZETA Lancaster Testing Report II.pdf." This brought the static pressure down to 120 Pa range, with airflows in the 750-800 CFM range.

The ductwork system is a mixture of insulated sheet metal and insulated flex ducts, all located within the conditioned space (except for the ductwork over the garage ceiling). Several duct leakage tests were performed (see 2009-07-03 ZETA Lancaster Testing Report.pdf and 2009-09-03 ZETA Lancaster Testing Report II.pdf); each of them resulted in incremental changes to the system, in order to address duct leakage to outside at the economizer system, and excess total (interior + exterior) duct leakage. The final tests resulted in leakage results of 125 CFM 25 total (120 CFM 25 with economizer taped). This meets the 10% of floor area total leakage requirements of Builders Challenge (156 CFM 25 target). The leakage was also broken down into supply and return leakage, at 85 CFM 25 supply/40 CFM 25 return.

The HERS tester pushed for much more stringent total leakage figure; however, given that the "open" ductwork system used in the "thermal basement" is essentially several hundred CFM of duct leakage, it was considered a lower priority for overall energy performance.

Domestic hot water heating system: The all-electric constraint mentioned above resulted in the selection of an electric domestic hot water system. The reasonable upgrade path was to use a heat pump water heater, given the limitation of electric resistance water heaters (1.0 COP/0.9 EF). The unit selected was an add-on heat pump unit, mounted above an existing water heater tank (40 gallon electric unit selected), with a relatively low price point (roughly $700 retail). A refrigerant coil heat exchanger tube is threaded into the hot water storage tank, via a specifically designed compression fitting (see Figure 10.3.11).

However, the product quality, installation, and operating efficiency proved to be disappointing, at least initially. First, the location of the heat pump unit became a matter of a design that changed during the construction process.

At first, the mechanical room (which is adjacent to the garage) was intended to be exterior to the conditioned enclosure, and the heat pump located inside this room. However, the walls between the mechanical room and conditioned space proved to be difficult, if not impossible, to air seal and insulate effectively. Problems included mechanical penetrations, a flush-mounted electrical panel (zero insulating value in wall to bathroom), insulation of the ceiling and floor, and connections to the prefabricated mechanical core. This is covered in more detail in section 10.5.6 Gaps Analysis. As a result, the mechanical room was moved within the conditioned space, and a weatherstripped door provided. However, this meant that the heat pump water heater needed to draw air from the garage, and exhaust to another location. The design chosen was to draw air from the garage, and exhaust the cooled air to the roof, through a duct in the mechanical core. Operating the heat pump in this configuration resulted in extremely constricted airflow (85 CFM vs. 180 CFM nominal), as well as condensation on the exhaust duct. At the same time, the COP of the unit was estimated, by measuring duct inlet and exhaust temperatures, as well as airflow and wattage draw (see Figure 10.3.10). A COP under 1.0 resulted from this quick check.

Figure 10.3.10: Ductwork attached to AirTap air source heat pump water heater

Figure 10.3.11: Kinked fitting on AirTap water heater

Part of the problem was that the DHW heat pump heat exchanger tube was damaged (kinked) during installation (see Figure 10.3.11), resulting in restricted refrigerant flow. It is not clear how much of the problem was due to this kinked line, as opposed to the restricted airflow.

BSC provided analysis to show that moving the heat pump water heater to the garage should have a minimal risk of excess cooling to that space (see "2009-09-03 ZETA Lancaster Testing Report II.pdf"). This was based on the presence of a continuously running exhaust fan in the garage (98 CFM, for LEED-H purposes), the presence of the PV inverter (resulting in waste heat), and measured temperatures in the west-facing garage (noticeably above exterior temperatures).

The heat pump unit was sent back to the factory for exchange with a replacement unit; the reinstalled unit was then tested during the October field visit. This newly installed unit (see Figure 10.3.12) was tested for airflow, ΔT, and power draw, indicating that performance was similar to factory specifications. In addition, the unit was installed by plumbers without incident (i.e., no damage to or kinking of the refrigerant line). Infrared photography showed a "cold spot" above the heat pump output, as would be expected; garage temperatures and ambient dewpoints will be tracked to determine any condensation risks.

Figure 10.3.12: Water heater reinstalled in garage

Figure 10.3.13: Plumbing connections

Drainwater heat recovery: A drainwater heat recovery system was installed in the mechanical core, capturing the drainwater heat from all second floor loads, which included the kitchen and master bathroom; there is also a bathroom on the first floor, which does not have heat recovery.

During the first (June 2009) field visit, it was found that the drainwater heat recovery system was plumbed incorrectly to domestic hot water system, and would not function (see "2009-07-03 ZETA Lancaster Testing Report.pdf"). It was plumbed to provide tempered water to the hot side of the water heater, not the cold supply. This problem was corrected in time for the August field work; short-term field testing was done on the system (see 10.4.3 Systems Testing).

Ventilation: The ventilation system was another item whose design evolved over the course of construction. BSC's analysis (see "2008-12-02 ZETA Lancaster Analysis.pdf") recommended the use of a central fan integrated ventilation system; simulations indicated that a heat recovery ventilator is not a cost effective upgrade in this mild climate, and would potentially result in increased energy use for ventilation due to fan wattage draw.

However, the builder unilaterally decided to install an HRV, in a fully ducted configuration: exhausts drawing from both bathrooms, supplying to the hallway, with exterior ducts through the roof. The unit was located in the second floor closet. The installed unit was a non-HVI certified unit; build quality was rather questionable. Features included a plastic "corrugated cardboard" heat exchanger core, shaded-pole duct booster style fans, and case insulation only on front and back, not sides.

Figure 10.3.14: Heat recovery ventilator installed in second floor closet

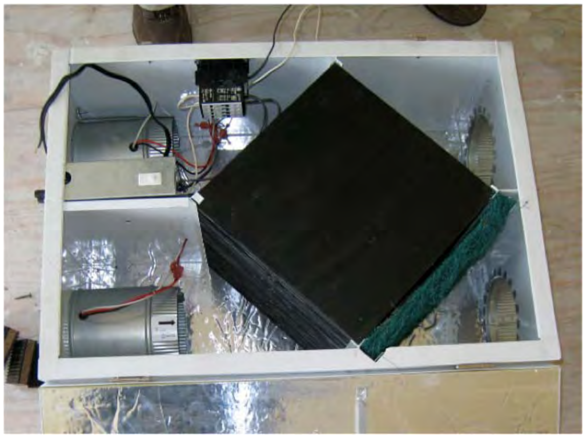


Figure 10.3.15: Interior of HRV, showing heat exchanger (plastic core) and filter

Installation problems also plagued the operation of this unit. One consultant noted that the ductwork was first set up to pull air from the bathrooms, and supply that "exhaust" air to the hallway; this was changed before our field test visit. During our field test visit, we found that the corrected ducting supplied air to the bathrooms instead of exhausting air; this fan was field-reversed to the correct orientation. However, flows were measured lower than the 50 CFM per bath required for Builders Challenge, LEED, and ASHRAE 62.2, despite the fact that the HRV is a nominal 100 to 130 CFM unit. Therefore, we recommended that the builder retrofit an inline fan (Fantech FR series), connected to the HRV controls, to boost the exhaust fan rates (see "2009-08-14 ZETA Lancaster Trip Follow Up Items.pdf"). Measurements after this retrofit (see Figure 10.3.16) indicated that the modified system met minimum requirements (86 CFM upstairs/67 CFM downstairs).

Figure 10.3.16: Fantech FR150 inline fan retrofitted on HRV exhaust side

Figure 10.3.17: Fantech Ventech fan controller (bathroom exhaust + dilution ventilation runtime)

In addition, controlling the HRV was an issue: it required a control that could both provide on-demand bathroom exhaust (for two full bathrooms) as well as timed runtime to provide dilution ventilation; a Fantech Ventech controller was used (see Figure 10.3.17).

10.3.2.3. Lighting and Miscellaneous Electrical Loads

As discussed earlier, the mild climate means that lighting, appliance, and miscellaneous end use loads form a larger fraction of the overall energy use, and therefore are that much more critical to deal with. For instance, switching to a compact fluorescent lighting package resulted in a 6% improvement over Benchmark—the second largest line item improvement. Similarly, the Energy Star appliance package resulted in a 4% improvement (albeit with a longer payback, due to the greater purchase cost).

Miscellaneous end use loads, however, were a more difficult problem to address; after other measures are taken, they are still a critically large fraction of the total (roughly 25% of the Prototype case), as shown in the parametric energy simulation results (see Figure 10.3.1). The sum of MELs, appliances, and lighting is an even higher proportion of the total: roughly 60%.

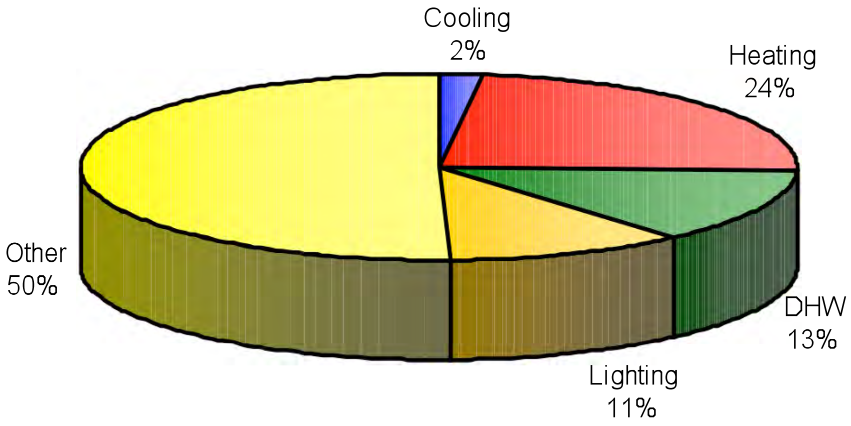


Figure 10.3.18: End use load breakdown for ZETA Lancaster (without PV array)

ZETA has explicitly addressed miscellaneous and phantom loads by providing switched outlets with centrally located switches ("zWatt Zapper," see Figure 10.3.19). One design of the whole-house controller (yet to be implemented) is to function as a real-time occupant energy feedback system. In the meantime, BSC has installed a centrally-located Energy Detective watt meter to provide feedback to occupants on the prototype operation.

All installed lighting is compact fluorescent or LED; the recessed fixtures on the first floor are all pin-based CFL fixtures (see Figure 10.3.20). Most lighting fixtures are Energy Star certified as well.

Figure 10.3.19: Plug load control with “z Watt Zapper” switched receptacles

Figure 10.3.20: Pin-based compact fluorescent light recessed fixtures (in

10.3.2.4. zTherm Controller

As mentioned above, enclosure and the mechanical system are integrated with a proprietary measurement and control system (“zTherm”) that is designed to take advantage of the diurnal swings of this coastal climate to reduce heating and cooling loads. Significant components include:

- A residential-scale economizer: 12” duct from the return plenum to the exterior, controlled by a normally-closed motorized damper; pressure relief is provided by an electrically operated skylight at the top of the central stairwell.
- A “thermal basement” storage crawl space: a crawl space with exposed concrete on the interior, with exterior insulation.
- An open duct supply system for the first floor: three supply ducts are open to the crawl space, distributed throughout the space. The supply air is then “bled” into the first floor through floor transfer grilles. The second floor has a conventional supply duct system.
- Interior and exterior temperature and relative humidity measurements

Operating modes for this system include:

- Night flushing and/or subcooling to offset daily cooling loads
- Conventional daytime economizer operation, if there are favorable interior and exterior conditions.
- During the heating season, “sequestration” of excess heat due to solar gain to crawl space/storage, for potential recovery later (see Figure 10.3.21:)
- Recovery of this heat, if needed, by operation of the central air handler (see Figure 10.3.22:)

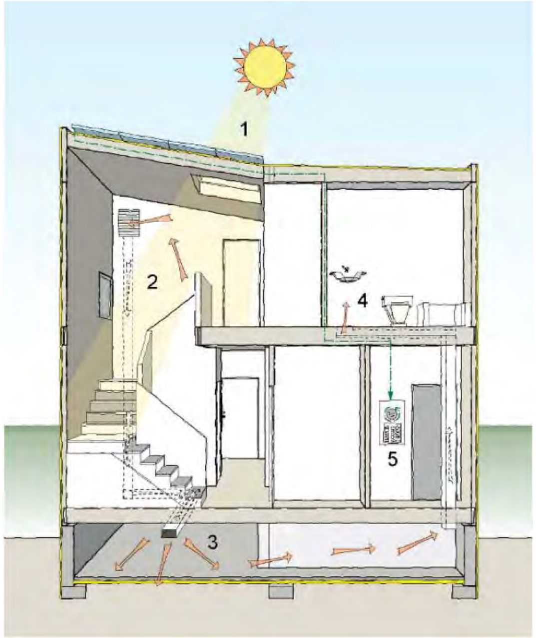


Figure 10.3.21: Daytime operation, showing storage of heat by crawl space thermal mass(c/o DSA Architects)

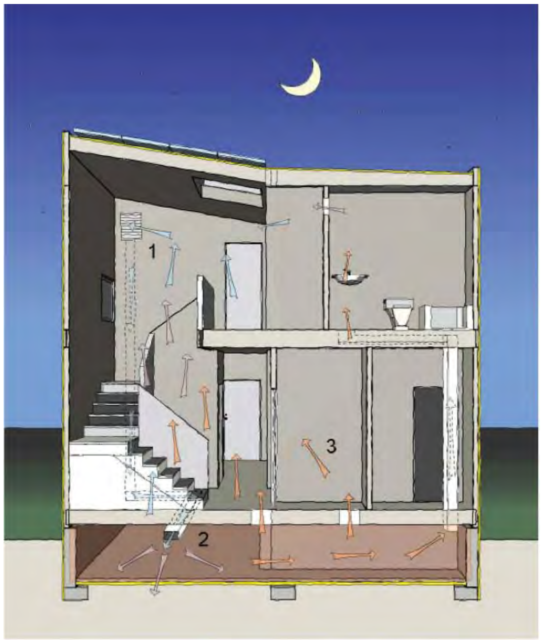


Figure 10.3.22: Nighttime operation, showing re-release of stored heat to interior from crawl space (c/o DSA Architects)

Note that the performance of this system will be highly dependent on the willingness of occupants to allow flexibility in interior setpoints; however, given the low dewpoints throughout the year, it seems that reasonable comfort conditions could be extended over a larger dry bulb range. However, this feature has not yet been implemented at the Lancaster site.

The control interfaces as shown in Figure 10.3.23 and Figure 10.3.24; they include both a two-line "thermostat" type wall controller, and a computer interface screen that simultaneously shows all relevant control parameters.

Inside Temp 77.5
Inside RH% 48.7%
Set Point 73.0
☐ Fan Cycler
☐ Control State
☐ Com Errors
☐ Com Port
☐ Relay
Outside Temp 91.1
Outside RH% 41.3%
Basement Temp 70.7
Basement RH% 63.7%
Control Status
■ Fan
☐ Compressor
☐ Changeover
■ Skylight
☐ Outside Vent
☐ Rain
Relay State 22

Figure 10.3.23: zTherm controller computer screen interface


Inside: 80.5°
Outside: 105.5°

Figure 10.3.24: zTherm wall "thermostat" prototype interface

Note that the effects of this system could not be modeled within the EnergyGauge USA simulation, and were not included in our energy analysis.

10.3.2.5. Site-generated Renewable Energy

Given the builder's net zero energy goal for this project, the use of renewables (specifically photovoltaic panels) was critical in achieving these results. A 5.4 kW grid-tied photovoltaic system (24 panels, 225 W/panel) is installed on the south-facing sloped roof, covering a slightly less than half of the roof footprint.

Figure 10.3.25: 5.4 kW PV array mounted on roof, surrounding skylight

Figure 10.3.26: Installation of solar radiation sensor during data acquisition system setup

Note that this sloped roof is at a relatively flat angle of 2:12 pitch (9 degrees), which is lower than the optimal 30 degrees determined by Christensen and Barker (2001) for this region. A quick comparison run in PVWatts showed that this lower angle resulted in a 7% penalty (roughly $70 of electricity per year, at 13¢/kWh), which is not sufficient to justify the cost of a racking system to raise the array.

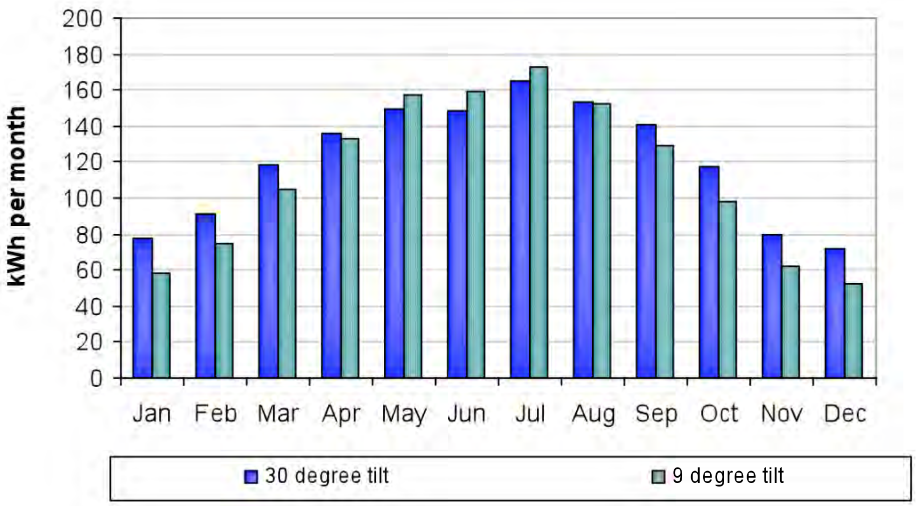


Figure 10.3.27: PVWatts comparison between optimal 30° tilt and 9° actual tilt

Sizing of this photovoltaic array was a matter that required some analysis. The builder's goal was to add sufficient panels to meet the net zero energy target. However, as discussed above, California's net metering laws are set up so that excess production is forfeited to the utility—so "overbuying" panels is essentially buys an annuity for the utility company. The builder was under the misunderstanding that the energy use of an occupied house could be precisely predicted—i.e., "If we get a slightly better fridge, could we put on one fewer PV panel?" BSC disabused them of the precision of these predictions, pointing out data on existing houses, showing a factor of three difference between identically built units (see "2009-04-09 PV Sizing Calculations.pdf"). The effect of occupancy overwhelms any attempts to accurately predict use for a given house.

Given the assumptions of operating the house at Benchmark conditions, the 5.4 kW PV array is sufficient to cover 91% of the predicted annual energy use. However, this prediction does not include any effect of the zTherm controller, extended thermal comfort ranges (setpoint), or energy-conscious occupant behavior. Given that the target audience for a net zero energy house is likely to be self-selecting for low consumers, this sizing was considered reasonable for net zero performance.

The cost of this system was greatly reduced by state and federal incentives. From a system purchase price of roughly $8/watt, the cost was offset by $2.20/watt state credits, and $1.70/watt Federal credits, resulting in a net price of roughly $4/watt. However, it is unknown if these rebates will (or can) be sustained over longer periods.

10.4 Construction Support

10.4.1. Construction Overview

Many of the events and obstacles during construction are covered under the sections 10.3.2.1 Enclosure Design and 10.3.2.2 Mechanical System Design. However, some specific milestones during construction:

- February 2009: Start of construction of modules in San Leandro, CA factory
- March 2009: Site foundation cast and insulated; water management systems installed
- May 2009: Setting of units at Oakland, CA site
- June 2009: First BSC testing visit; enclosure complete but mechanicals still being fitted out
- August 2009: Second BSC testing visit; interior finishes and mechanical systems substantially complete, with some punch list items
- October 2009: Third BSC testing visit; reinstallation of water heater; commissioning of bathroom exhaust system

Figure 10.4.1: Factory assembly of Lancaster modules in San Leandro (February 2009)

Figure 10.4.2: Module on truck being transported from factory to site (May 2009)

Figure 10.4.3: Setting of units on site, Oakland, CA

Figure 10.4.4: Site finishing work on assembled modules (June 2009)

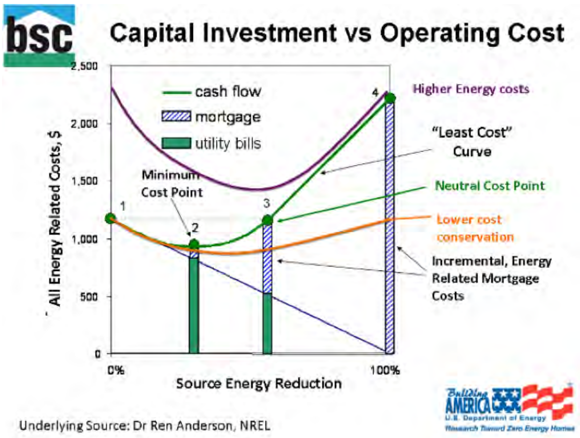
10.4.2. Educational Events and Training

In conjunction with the June 2009 field testing visit, John Straube, Ph.D., P.Eng. (a principal of Building Science Corporation) conducted a half-day training session to all ZETA personnel, covering an overview of net zero energy houses (see “2009-06-15 ZETA NZEH overview.pdf”).

The presentation included basic vital information needed in order to understand, market, and sell these net zero energy houses. It needed to include a fair amount of background, in order to make the concepts of a net zero house accessible to a non-technical audience. It included topics such as net zero energy vs. net zero greenhouse gas, off grid vs. grid tied

PVs, priorities when designing net zero energy, space conditioning equipment, IAQ and ventilation, and the future of net metering.

Figure 10.4.5: BSC principal providing half-day training to ZETA



Capital Investment vs Operating Cost

Underlying Source: Dr Ren Anderson, NREL

Figure 10.4.6: Slide from 2009-06-15 ZETA NZEH overview

10.4.3. Systems Testing

Several systems testing experiments have been conducted in the work to date, including a sub-component of the "zTherm" system (the time-temperature response of the ductwork connected to the "thermal basement"), and the drainwater heat recovery system. Both of these tests were discussed in "2009-09-03 ZETA Lancaster Testing Report II.pdf."

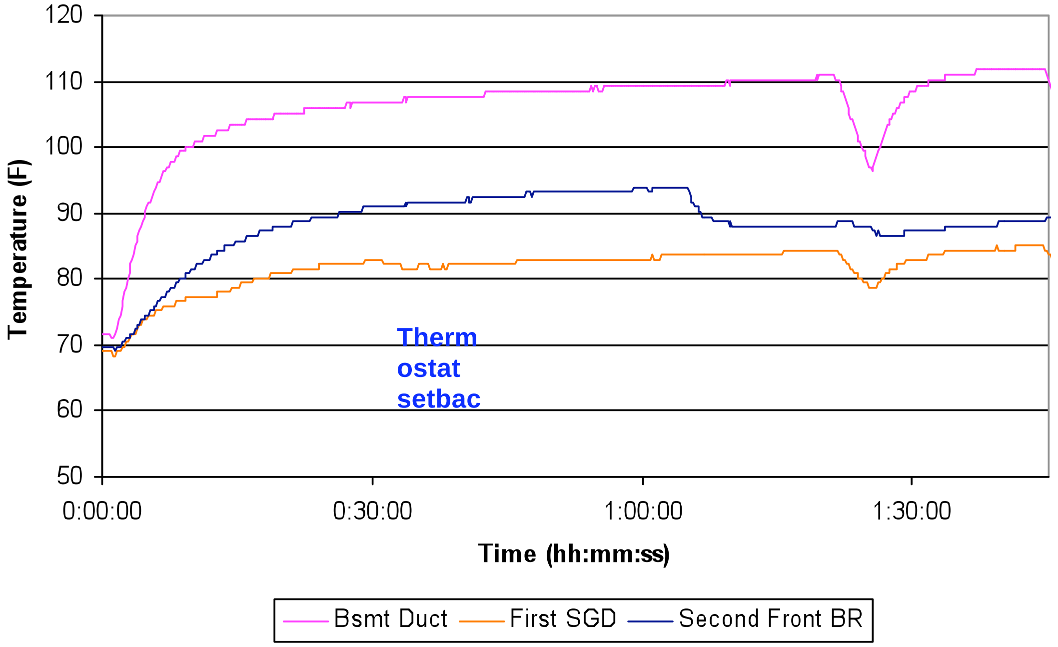
Time-Temperature Response: The "zTherm" system itself is a dynamic system that will require long term testing to demonstrate any effect on energy consumption; it is also composed of a variety of interacting components. However, some short-term testing could be conducted on one of these individual components.

One concern with the coupling of the first floor ductwork with the "thermal basement" crawl space thermal mass was its effect on delivery temperature. Therefore, we conducted an experiment to get a better feel for the behavior of the HVAC distribution system's interaction with the thermal basement. In order to do this, the system was briefly run in heating and then cooling mode, and temperatures were taken in various ducts—both in the basement (directly inside the duct, measuring system output, see Figure 10.4.8), on the first floor (showing the effect of the thermal basement, see Figure 10.4.7), and on the second floor. These temperatures would indicate how much heat or cooling is being delivered to various spaces, when combined with the previous airflow measurements.

Figure 10.4.7: Use of data loggers to collect delivered register air temperature

Figure 10.4.8: Data logger placed in open duct in basement ('Bsmt Duct')

Temperature measurements in heating mode are shown below for the basement duct (direct output of unit), first floor register (near sliding glass door), and a second floor front bedroom.



The heat pump puts out air an eventual steady state temperature of ~110° F (pink line); however, by the time the air gets to the second floor (dark blue), it is closer to 95° F; this can be ascribed to conductive losses through the ductwork. A secondary measurement with a Vaisala T/RH meter was closer to 101° F. It is unclear why the later portion (after 1:00) is closer to 88° F.

However, at the first floor, the delivery temperature is cooler—closer to 84° F. It is clear that some of the heat is getting "soaked" into the basement. This can also be seen from the main data logger temperatures: the basement air temperature rises faster than the first floor. This is expected—the system is supplying air to the basement, and "bleeding" some of it to the first floor.

Of course, it should be noted that the delivery temperatures from the first floor registers are a function of the thermal basement temperatures—i.e., the stored thermal energy in the slab and concrete walls. In this case, the thermal basement was neutral-to-cool (68° F). The performance of the system will depend heavily on whether heat can be "banked" into the thermal basement or not.

The bottom line is that when the thermal basement is "starting from cool" (i.e., 68° F), the second floor has more heat delivered out of the registers than the first floor. For instance, a quick calculation estimates the first floor is getting ½ to 1/3 of the heat of the second floor. But the thing to remember is that the basement is being heated at the same time—and some of that will "soak" from the basement to the first floor. We will need to measure the system in operation to have more definitive results. However, if the thermal mass is often at a cold temperature during the heating season, this might cause temperature distribution/evenness problems between floors; this can be addressed by dampering off the second floor registers.

Drainwater Heat Recovery System: A set of experiments was done to determine the effectiveness of the drainwater heat recovery ("GFX") system installed. Temperature measurements were taken of the incoming fresh water ("cold mains supply"), the fresh water that was heated by the GFX ("Tempered Out"), the drain water entering the GFX ("Drainwater In"), and the drain water exiting ("Drainwater Out"). These measurement points are noted in Figure 10.4.9.

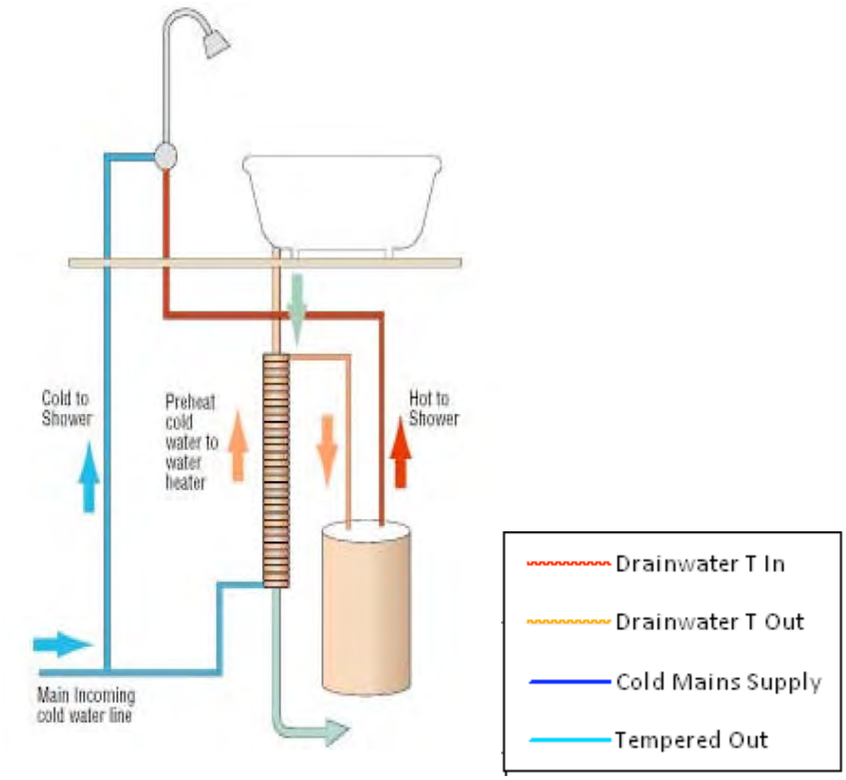


Figure 10.4.9: Schematic diagram of temperature measurements

These temperatures were measured using thermistors attached to the exterior of the copper pipes, and then covered by insulation (as shown in Figure 10.4.10 and Figure 10.4.11). These measurement points were connected to a Campbell data logger; in addition, point temperature measurements were taken of the supplied shower/sink water, and the draining water, with a handheld thermocouple.

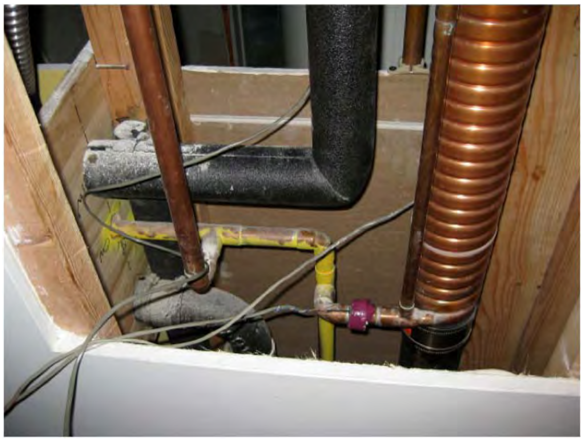


Figure 10.4.10: Drainwater heat recovery system, showing cold water input temperature sensor

Figure 10.4.11: Tempered water output sensor (left) and incoming drain water temperature (right)

Water flow rates were measured for the shower, using a stopwatch and a bucket, to determine an average flow (gallons/minute or liters/second). Tests were run for the kitchen sink (hot water only), and the shower, at 130° F and 110° F. From these temperature measurements and the flow measurement, we can calculate the energy recovery of the GFX, as well as the fraction of the shower's water heating energy that it displaces.

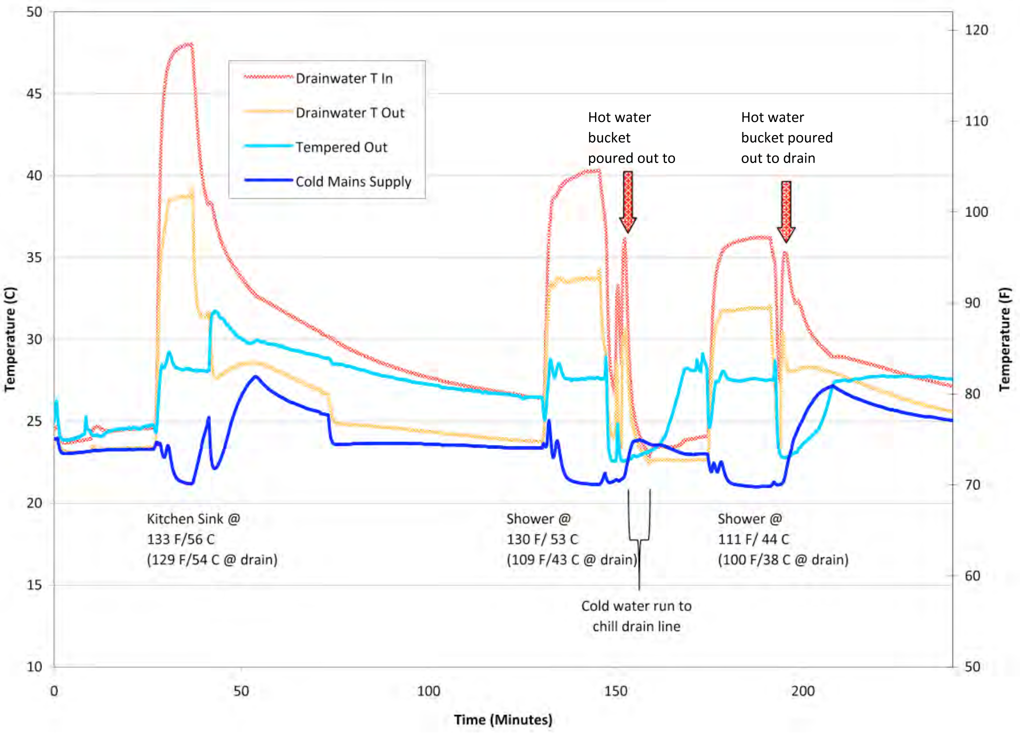


Figure 10.4.12: Temperature vs. time results for drainwater heat recovery measurements

Table 10.8: Heat recovery calculations of GFX for showering

130 F shower

104	T in
92.7	T out
1.6	GPM
8,987	Btu/hr recovered by GFX
Input required for shower @ 130	
69.8	T mains
130	Shower delivered T
47,709	Btu/hr required
19%	**saved by GFX**

111 F shower

97.2	T in
89.2	T out
1.6	GPM
6,277	Btu/hr recovered by GFX
Input required for shower @ 111	
69.8	T mains
111	Shower delivered T
32,651	Btu/hr required
19%	**saved by GFX**

These results are somewhat disappointing: earlier DOE results ("Heat Recovery from Wastewater Using a Gravity-Film Heat Exchanger," DOE/EE-0247 Revised, July 2005) had savings of roughly 40% for this plumbing configuration and temperature range. Several reasons are proposed, including drainwater temperature reduction due to evaporative shower effects, heat loss through the cast iron drain pipe, or instrumentation issues.

10.4.4. Monitoring

The Lancaster prototype was chosen for the installation of extensive monitoring equipment, in order to evaluate its net zero performance, and the effectiveness of the “zTherm” thermal mass system.

Figure 10.4.13: Data acquisition system installed at Lancaster prototype

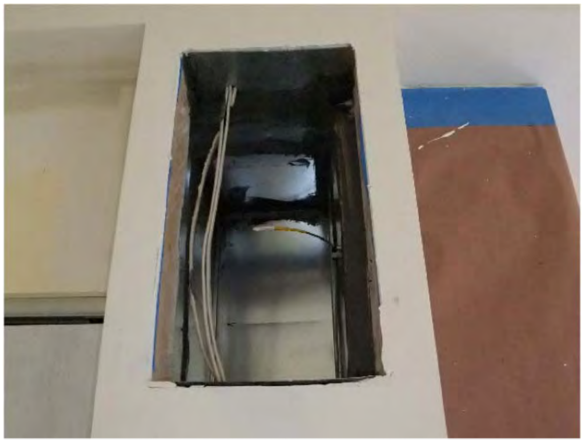


Figure 10.4.14: T/RH sensor installed in second floor return duct

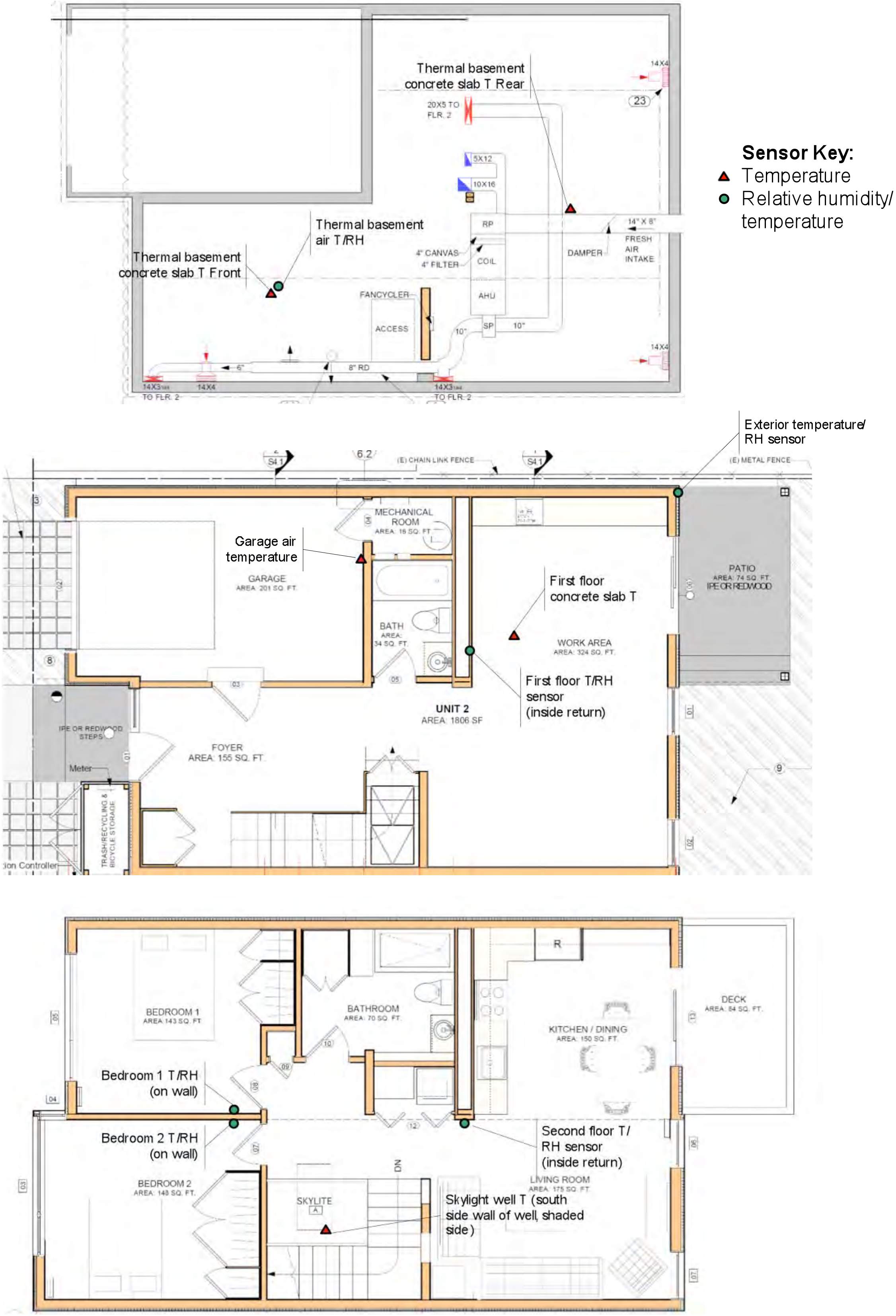


Figure 10.4.15: Sensor locations for ZETA Lancaster prototype monitoring

The installed channels were as follows:

- T/RH second floor
- T/RH front left bedroom
- T/RH front right bedroom
- T (only) skylight well (south side/shaded)
- T/RH (only) first floor
- T/RH thermal basement
- T x2 thermal basement concrete surface/mid-slab
- T first floor concrete slab (underneath slab)
- Relay on indoor HVAC unit (air handler) for runtime.
- Relay on heating system for runtime.
- Relay on cooling system for runtime.
- WattNode watt hour meter; measuring hourly consumption of outdoor (condenser) unit. Connected to pulse count channel
- T/RH exterior (north side of building) (Campbell HMP50-L Vaisala)
- Horizontal solar radiation

A draft monitoring plan is covered in "2009-07-03 ZETA Lancaster Testing Report.pdf;" the actual installed testing package is described and diagrammed in "2009-06-02 ZETA Testing and Monitoring Plan.pdf." During the August trip, the preliminary data set was downloaded and examined for consistency; these results are given in "2009-08-28 ZETA Lancaster Data Check.pdf."

In addition to the data logger-based system, monthly electrical use is being collected with a TED ("The Energy Detective") meter, for disaggregation from the utility bills. There are three measurement points: the HVAC outdoor unit, the heat pump water heater, and the electric resistance element of the hot water heater.

Furthermore, NREL will be performing short-term and long-term testing at this Prototype, starting roughly in early December. Although the house is slated to be sold in late 2009/early 2010, access for the testing crews will be incorporated into the purchase and sale documents, accommodating one year of monitoring.

10.5 Project Evaluation

The following sections evaluate the research project results based on the ability to integrate advanced systems with production building practices in prototype homes. References are made to the results from field tests and energy simulations, which are included as an appendix to this report.

10.5.1. Source Energy Savings

Requirement:	*Final production home designs must provide targeted whole house source energy efficiency savings based on BA performance analysis procedures and prior stage energy performance measurements.*
Conclusion:	***Pass***

With the enclosure and mechanical characteristics presented in Table 10.6 and Table 10.7, this plan achieves a performance level of 45% reduction relative to the Building America Benchmark without renewable energy sources, and 95% including renewables. It was interesting to note the specific breakdowns of the energy savings (as follows);

- All opaque enclosure improvements of increasing assembly R values (but not including airtightness) only added up to a 7% savings over Benchmark.
- Airtightness as a line item was a 6% improvement, and windows were another 6% gain
- The high-efficiency heat pump was a 4% improvement relative to Benchmark, including both heating and cooling savings.
- The heat pump water heater was the single largest line item improvement, at a14% upgrade. This was due both to the major improvement in efficiency (~0.9 EF to 2.1 EF), the large contribution of domestic hot water to the total load, and the large source energy consumption of the base case (electric resistance hot water heater)
- The upgrades to compact fluorescent lights and Energy Star appliances constituted 7% and 3% improvements, respectively.
- The drainwater heat recovery system was estimated at roughly a 1% incremental improvement. However, this is based on the effectiveness data presented in previous research; the field measurements suggest that the actual heat recovery in this installation may be lower (see 10.4.3 Systems Testing).

All of the upgrade strategies were skewed by the low climate-based loads in this Bay Area location, which reduced the cost-effectiveness of enclosure and space conditioning upgrades; non-space conditioning loads (domestic hot water, lighting, plug loads) were a greater proportion of the total.

10.5.2. Prescriptive-based Code Approval

Requirement:	*Must meet prescriptive or performance safety, health and building code requirements for new homes.*
Conclusion:	***Pass***

The Lancaster prototype was permitted as a live/work unit, R-3 occupancy. It complied with the 2007 CBC, CMC, CPC, CEC, CFC (Building, Mechanical, Plumbing, Electrical, and Fire Codes), and 2005 California Energy Code. The as-built plan set is attached here (see DSA Architectural Plans).

The California Energy Code (i.e., Title 24/CF-1R) results were relatively disappointing; it reflected only a 27% improvement vs. the Title 24 requirements. When these results were analyzed in detail, it was found that the performance of the electric heat pump water heater is at a penalty relative to the base case (see Table 10.9). This was particularly problematic, because Title 24 performance this low would not allow the house to qualify under a LEED innovation credit for "Exemplary performance w/r/t EA10 (Renewable Energy)."

Table 10.9: Title 24 CF-1R for Lancaster Plan "V1" Expressed as Percentages per Category

	Standard	ZETA	% of Std	% Better
Heating	15.04	6.44	43%	57%
Cooling	5.33	2.79	52%	48%
Fans	0.94	0.63	67%	33%
DHW	12.99	15.09	116%	-16%
Total	**34.3**	**24.95**	**73%**	**27%**

A request for consideration was drafted for submission to USGBC (see "2009-10-09 ZETA Lancaster LEED ID Credit.pdf"); it provides further analysis of this issue. A major component of this penalization occurs due to the use of time-dependent valuation (TDV) in the Title 24 calculations, as opposed to source energy. When a source energy-based Title 24 run was compiled, it showed a 36% improvement relative to the base case (vs. 27% with TDV), with hot water at a 12% improvement (instead of 16% penalty).

10.5.3. Quality Control Requirements

Requirement:	*Must define critical design details, construction practices, training, quality assurance, and quality control practices required to successfully implement new systems with production builders and contractors.*
Conclusion:	***Pass***

The quality assurance and quality control system used by ZETA Communities were developed in-house, to account for both factory work and site-completion work (although crews were the same for both tasks at this prototype). Given the nature of this builder (small size, startup), a rigorous written and documented quality control system was not a major priority, given that the Director of Construction was directly involved in all stages of the construction process. However, a strong degree of top-down direction was provided during the factory construction process to improve product quality and consistency; the entire enclosure and mechanical system was built as a 3-D CAD model, in order to determine cut lists, do materials takeoffs, and find interferences between services (see Figure 10.5.1 and Figure 10.5.2).

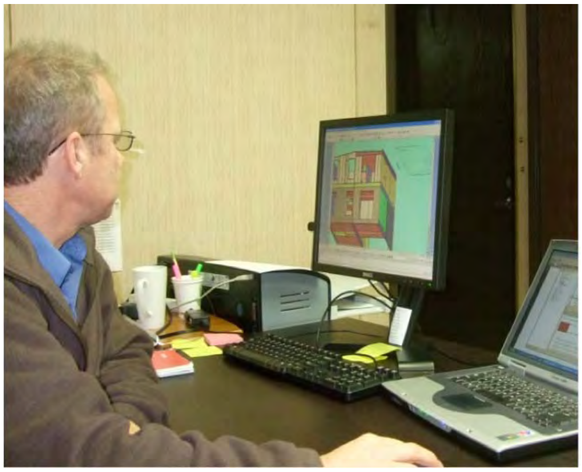


Figure 10.5.1: Complete 3D CAD model completed for factory construction

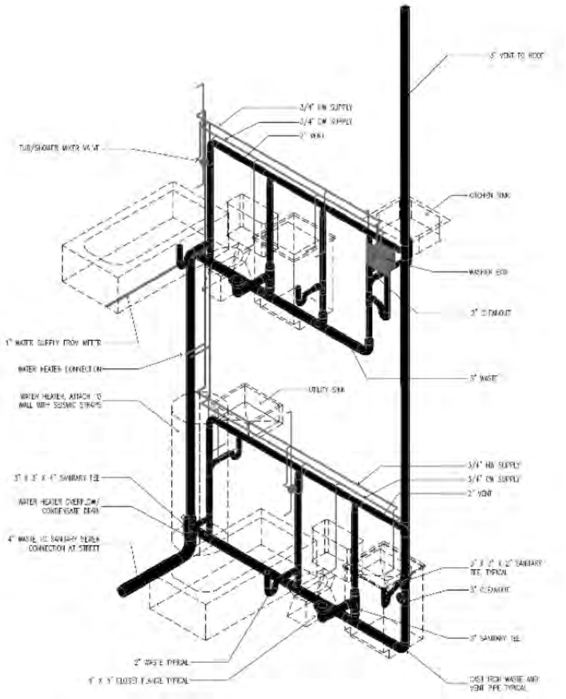


Figure 10.5.2: Mechanical/plumbing core diagram (from MEP-1.2 sheet, c/o DSA Architects)

BSC provided the Builders Challenge Quality Criteria checklist to ZETA, emphasizing it as a systematic way of identifying potentially troubling issues during their process. Site inspection indicated that targets were met. The BCQC was addressed in conjunction with other list-based programs, such as LEED-H.

10.5.4. Neutral Cost Target

Requirement:	*The incremental annual cost of energy improvements, when financed as part of a 30 year mortgage, should be less than or equal to the annual reduction in utility bill costs relative to the BA Benchmark.*
Conclusion:	***Does not qualify (“Should meet” target for Prototypes)***

As noted earlier, the heating and cooling loads for this climate are very low. As a result, this mild climate means that enclosure improvements—which would cost roughly the same amount in any climate—have a smaller associated financial payback due to energy usage reduction. This tended to reduce the financial favorability of these measures, whether calculated by simple payback or when calculated against the financing costs in a 30 year mortgage (i.e., neutral cost calculation).

The overall performance of this prototype, given estimated the builder’s estimated costs, and energy costs of $0.13/kWh, were that it did not meet the neutral cost criteria. It is interesting to note, however, that the net annual cash flow improved (became less negative) after the addition of PV panels (from -$664/year to -$143/year). This is ascribed to the very low price of the PV array ($4/watt, with subsidies and rebates), and the large fraction of plug/miscellaneous end use loads.

Table 10.10: Neutral cost analysis worksheet for ZETA Lancaster

	Annual Electric Energy (Site)		Annual Gas Energy (Site)		
	Benchmark	Prototype House	Benchmark	Prototype House	Annual Utility Bill Reduction vs Benchmark
End Use	**(kWh/yr)**	**(kWh/yr)**	**(therms/yr)**	**(therms/yr)**	**($/yr)**
Space Heating	3990	1806	0	0	$284
Space Cooling	365	144	0	0	$29
DHW	3174	999	0	0	$283
Lighting	2054	819	0	0	$161
Appliances and MELs	4223	3866	0	0	$46
Ventilation	0	0	0	0	$0
Total Usage	**13805**	**7634**	**0**	**0**	**$802**
Site Generation	0	6918	0	0	$899
Net Energy Use	**13805**	**716**	**0**	**0**	**$1,702**
Added Annual Mortgage Cost w/o Site Gen.					**$1,467**
Net Cash Flow to Consumer w/o Site Gen.					**($664)**
Added Annual Mortgage Cost with Site Gen.					**$1,844**
Net Cash Flow to Consumer with Site Gen.					**($143)**

It should be noted that the builder's goal was net zero energy use, as opposed to any specific neutral cost target. Their cost goal was primarily to produce net zero houses (including renewable energy systems) at a price point comparable to typical Bay Area construction costs.

In addition, the builder was still exploring options during the process of building this prototype. As a result, some decisions were made without a cost-effectiveness evaluation. This was addressed after the learning experience of building the prototype; a new director of construction (with a background in modular housing) was brought in, with the goal of cutting costs to meet the per square foot cost targets on a production basis. BSC provided economic analysis of the measures used in the Prototype (see "2009-06-15 ZETA Lancaster Economic Optimization.pdf"), which discussed which options should be retained or discarded. BSC's recommendations were to retain the foam sheathing (1" XPS), for thermal bridging and condensation control reasons. However, recommendations were made to eliminate the HRV (especially in light of later problems found during testing), the high-performance Serious Materials windows, and potentially the drainwater heat recovery unit. All of those items had worse cost effectiveness (quantified in terms of $\$/10^6$ Btu saved over lifetime of measure) than the photovoltaic array. In a meeting discussing this report, we covered further items, such as the elimination of spray foam as cavity insulation (see 10.3.2.1 Enclosure Design).

Overall, zero energy (or near zero energy) performance, while perhaps an admirable goal, often pushes the energy performance levels beyond cost effectiveness, depending on construction costs and energy costs. Neutral cost might not be the best metric to judge the systems choices, if NZE performance is programmatically required.

10.5.5. Quality Control Integration

Requirement:	*Health, Safety, Durability, Comfort, and Energy related QA, QC, training, and commissioning requirements should be integrated within construction documents, contracts and BA team scopes of work.*
Conclusion:	***Pass***

BSC worked closely with the builder and architect to develop a variety of details important to health, safety, durability, comfort, and energy efficiency. For instance, the marriage walls are typically difficult locations for air barrier continuity; details were incorporated into the plan set to address these locations. The resulting overall airtightness (682 CFM 50/2.5 ACH 50 vs. target 1154 CFM 50/4.3 ACH 50) demonstrated that these measures produced excellent results.

BSC also developed window installation and flashing details specific to this builder's assemblies (structural plywood sheathing, 1" XPS foam, housewrap), as well as other vital information on window pan flashings (see "2009-03-09 ZETA Window Installation.pdf"). Similarly, BSC had input on critical details for foundation waterproofing and moisture control.

10.5.6. Gaps Analysis

Requirement:	*Should include prototype house gaps analysis, lessons learned, and evaluation of major technical and market barriers to achieving the targeted performance level.*
Conclusion:	***Pass***

Several specific items proved to be problematic in practice and implementation, and warrant further discussion. They include the heat pump water heater, the economizer system, installation of the rainscreen cladding, and the mechanical room/mechanical core.

Heat pump water heater: The heat pump water heater was a critical component of overall energy performance, due to its large contribution to meeting performance targets, and the requirement of all-electric systems. An AirGenerate AirTap A7 was specified by the design team early in the process. However, as discussed in 10.3.2.2 Mechanical System Design, there were multiple problems in the installation and efficiency of this system. Specifically, the builder complained strongly about the quality and serviceability of the heat pump unit, such as the damage that occurred during the installation process (see Figure 10.3.11). On the opposing side, however, the second installation went smoothly and appeared to have reasonable performance.

Unfortunately, many options for heat pump water heaters appeared on the horizon just as the Lancaster prototype was being fitted out and completed. Some promising options include off-the-shelf single module heat pump water heaters, such as those being introduced by General Electric and Rheem. However, they are at a price point of roughly $1500, which is higher than the cost of the AirTap system (~$700 + electric storage tank + installation). In addition, another promising technology appears to be the North Road Technologies Geyser, which can be attached to an existing water heater, and is estimated at roughly $1400. The connection between the water heater and heat pump unit is water-based, as opposed to copper refrigerant lines, so is less vulnerable to installation problems. In addition, this unit allows some more flexibility in placement of the heat pump; for instance, the storage tank could be located in the conditioned space, but the heat pump in the garage, an attic, or a conditioned crawl space location. This unit would have been ideal for dealing with problems at the Lancaster prototype, leaving the DHW tank in the mechanical room, but moving the heat pump component into the garage. A crawl space location might make sense if the zTherm system sequestered heat from the house to its maximum capacity; this heat pump would be able to make use of this excess "low quality" stored heat.

Economizer system: The residential-scale economizer was considered a vital part of the "zTherm" system; part of the logic behind the system was that although there are times when an occupant would simply open windows for ventilation cooling, there are non-occupied times that would benefit from ventilation cooling as well. In addition, the accuracy of homeowner intervention in opening and closing windows can be highly variable.

However, the economizer proved to be difficult to execute in practice. First, it is an exceptionally vulnerable portion of the HVAC system: a failure of the motorized damper to form a tight seal would result in duct leakage to the exterior. This would result in unintentional flow during any air handler operation (including fan cycling/mixing). Significant problems were found both on the initial testing trip (see "2009-07-03 ZETA Lancaster Testing Report.pdf") and the second trip ("2009-09-03 ZETA Lancaster Testing Report II.pdf"), as shown in Figure 10.5.3 and Figure 10.5.4.

Figure 10.5.3: Economizer duct connected to return, showing motorized damper

Figure 10.5.4: Motorized damper, showing lack of gasket or sealing measures

A further problem was that the overall efficiency (in terms of EER, or Btu cooling/watt) was not very high. At first, this was ascribed to low flows due to an undersized economizer duct (10" installed instead of 12" shown on mechanical plans). However, after upsizing of this duct, the overall efficiency was still relatively low. For instance, at a ΔT of under 15° F (e.g., 75° F interior, 60° F exterior), the compressor-based cooling system operated at a better efficiency (in terms of EER) than the economizer, assuming that fan heat is added to the airflow, reducing cooling effect.

Part of the problem was that although the ECM air handler is moving air at a very high efficiency in fan-only mode (6.2 CFM/W), only a portion of its airflow is from the exterior. Therefore, the net fan efficiency for outside air is only roughly 1.4 CFM/W. This problem is solved in commercial economizers by a damper that modulates between all-interior and all-exterior air, forcing fan draw from the targeted location (see Figure 10.5.5 and Figure 10.5.6). Although a system like this might be added to future ZETA projects, it would add cost and complication (and potential failure points) to the system. However, it appears that the Davis Energy Group Nightbreeze uses a damper in this configuration.

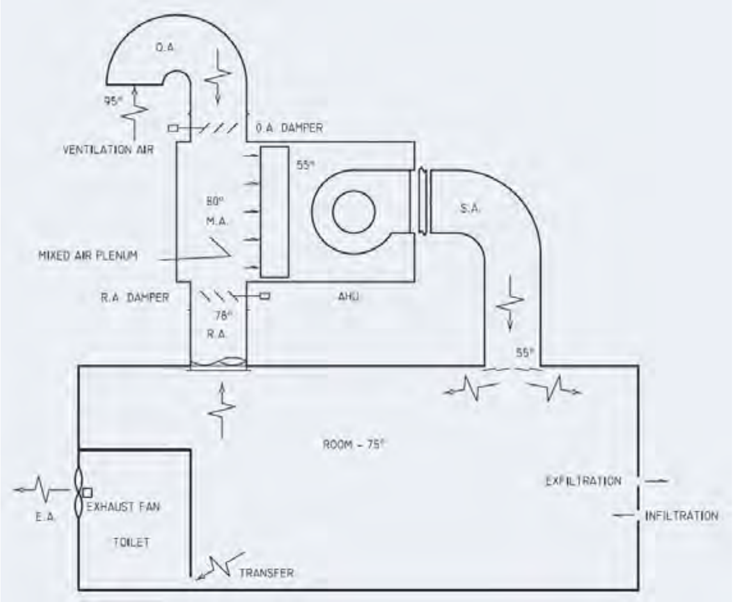


Figure 10.5.5: Commercial economizer conceptual layout with building interactions (Äsk, 2008)

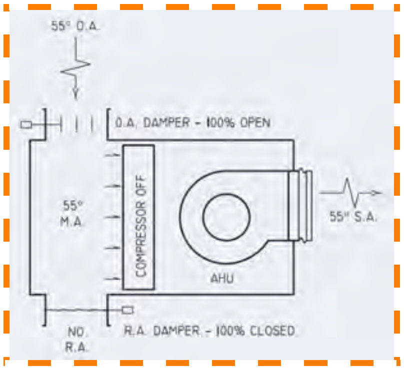


Figure 10.5.6: Economizer in all-outside air mode (Äsk, 2008)

Rainscreen cladding: A rainscreen cladding system was specified for the exterior finishes of this house; both a fiber cement panel cladding ("Hardie Artisan Matrix") and fiber cement lap siding were used. At the panel cladding, the manufacturer refuses to warrantee their product in a rainscreen installation unless it is installed on their fiber cement furring strips ("James Hardie® Furring Strips"), as shown in Figure 10.5.7. This was found to increase the costs substantially, as well as being more difficult to install (cutting and attachment). A different approach would be needed if the panel cladding were to be used in the future.

However, at the lap siding sections, the builder used an innovative detail to create a small (~¼") vented drainage cavity, using corrugated plastic "sign board" cut into strips (see Figure 10.5.8). This proved to be a reasonably effective and low-cost method of detailing a rainscreen cladding.

Figure 10.5.7: Fiber cement furring strip installation at Artisan Matrix panel cladding

Figure 10.5.8: Plastic "sign board" furring strip installation at lap siding portions

Mechanical Room and Mechanical Core: The goal of the mechanical core assembly (see Figure 10.5.2) was to have a prefabricated core that could be delivered to the site in a completed ready-to-connect state. This was done to reduce site work of costly trades such as plumbers, electricians, and HVAC subcontractor, as well as to avoid routing interferences in such a constrained space. The mechanical core was placed adjacent to the mechanical room, which was originally designed to open to the garage. The problems and changes to this system are discussed in 10.3.2.2 Mechanical System Design.

BSC pointed out issues with this mechanical design back in September 2008 (see "2008-09-01 Zeta Preliminary Energy Performance.pdf"); the three-dimensional routing of the air and thermal barrier would need to wrap around the sides of the mechanical room, including the floor and ceiling (see Figure 10.5.9). This proved to be difficult to execute in practice: not only were there many air barrier penetrations for mechanical services, but some of the walls could not be effectively insulated (e.g., flush mounted electrical panels in wall to bathroom; see red box in Figure 10.5.10, and uninsulated mechanical core wall). This is what drove the decision to bring the mechanical room inside conditioned space, which cascaded into issues with the heat pump water heater.

Me
ch

Ga

Figure 10.5.9: Garage and mechanical room, showing potential air/thermal barrier routing

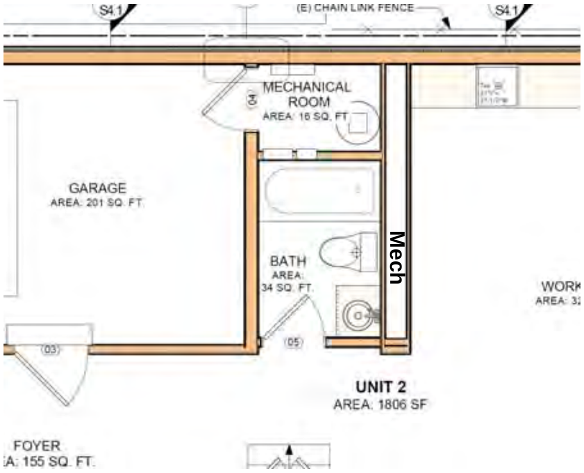


Figure 10.5.10: Mechanical room plan view, showing uninsulated walls to bathroom and mechanical core

Overall, although the concept and execution of the mechanical core were good, further design refinement is needed, in order to ensure air and thermal barrier continuity.

10.6 Conclusions/Remarks

In spite of several problematic systems and startup issues, ZETA's Lancaster live-work townhouse is substantially completed and tested; data collection is now underway. It is slated to be sold in late 2009; homeowner agreements to allow data collection and access for one year after occupancy. Some systems are of particular interest in terms of their overall energy performance; their relative effectiveness will determine whether they are included in future work. The monitoring system is designed to capture the performance of some of these systems, including the "zTherm" controller, the heat pump water heater, and the heat pump space conditioning system.

10.7 Appendices

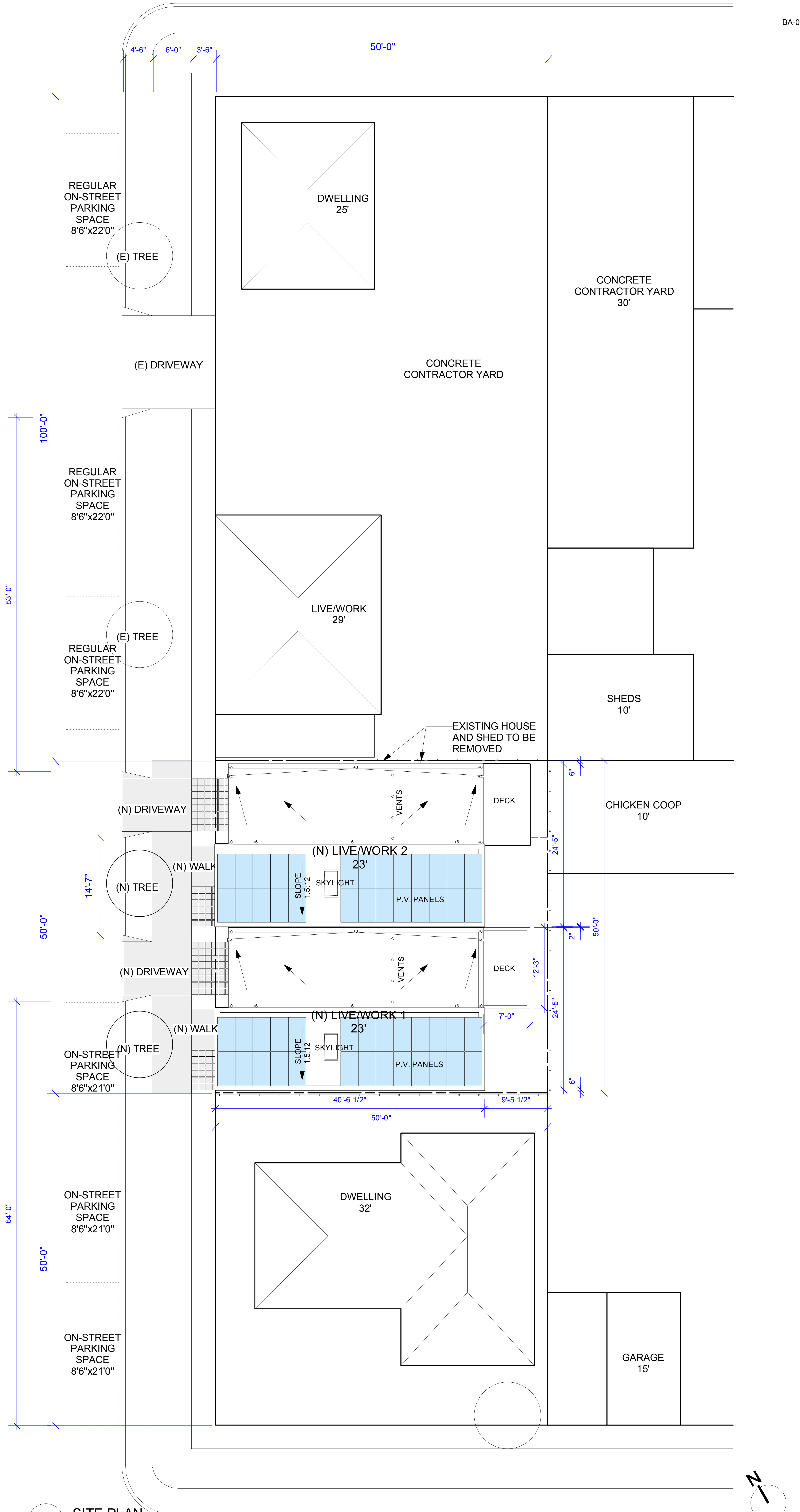
10.7.1. Drawings and Specifications

10.7.2. Energy Modeling

10.7.3. Mechanical System Design

10.7.4. Site Visit Reports, Monitoring

Appendix D.10.7.1
Drawing and Specifications

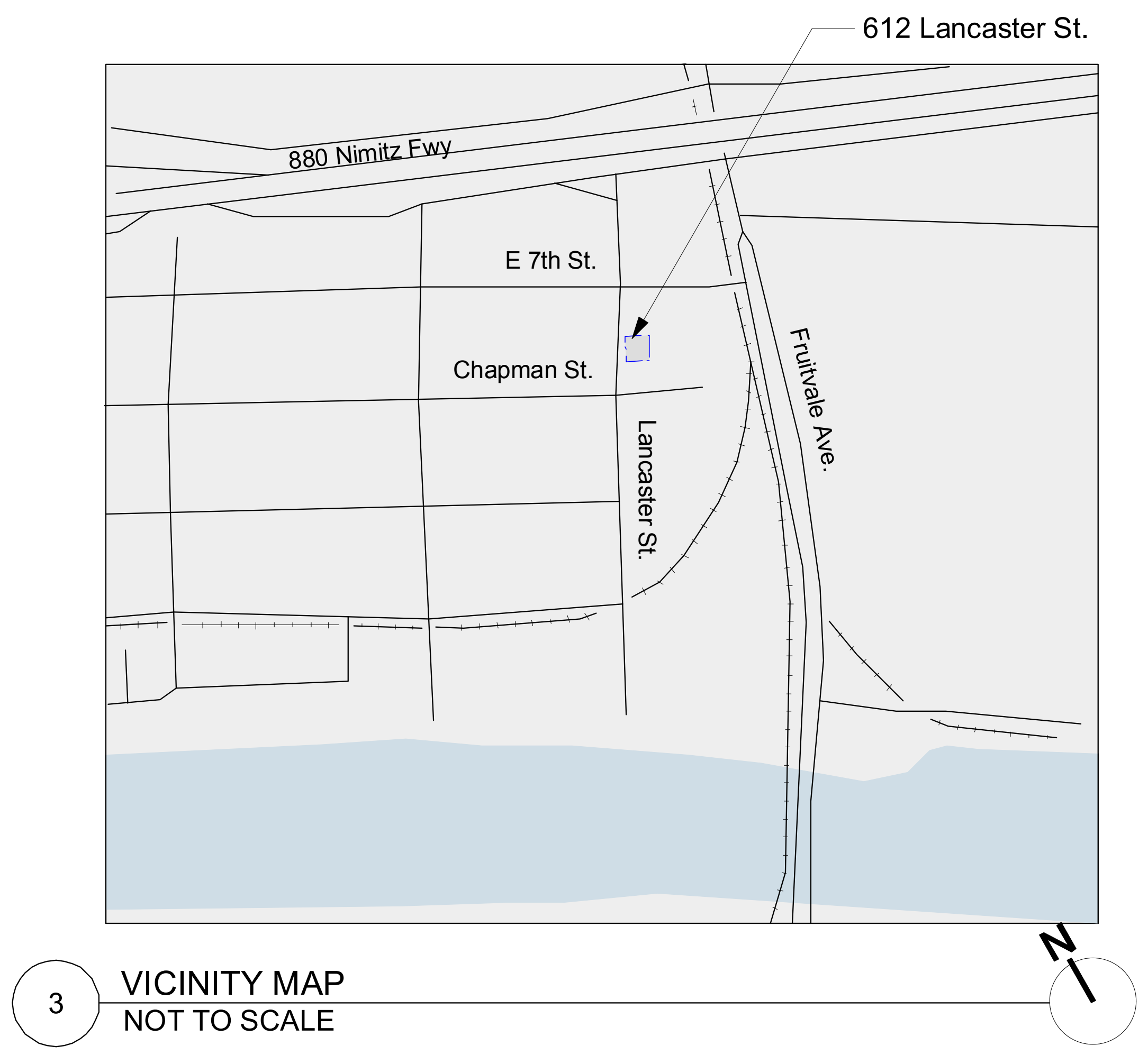


1 SITE PLAN
SCALE: 3/32" = 1'-0"

ABBREVIATIONS

&	And
∠	Angle
@	At
℄	Centerline
∅	Diameter or Round
#	Pound or Number
A.B.	Anchor Bolt
ACT	Acoustical Ceiling Tile
ACOUS.	Acoustic
A.D.A.	Americans With Disabilities Act
A.F.F.	Above Finish Floor
ALT.	Alternate
ALUM.	Aluminum
APPROX.	Approximate
ARCH.	Architect(ural)
BD.	Board
BLDG.	Building
BLKG.	Blocking
BM.	Beam
BOT.	Bottom
B.P.	Backing Plate
CAB.	Cabinet
C.J.	Control Joint
CLG.	Ceiling
CLR.	Clear
F.A.	Fire Alarm
F.B.O.	Furnished By Owner
F.D.	Floor Drain
F.E.	Fire Extinguisher
F.F.	Finish Floor
F.I.	Film Illuminator
FIN.	Finish
FLR.	Floor
FLUOR.	Fluorescent
F.O.B.	Face of Bale
F.O.C.	Face of Concrete
F.O.F.	Face of Finish
FT.	Foot or Feet
GA.	Gauge
GALV.	Galvanized
G.B.	Grab Bar
GND.	Ground
GR.	Grade
G.S.M.	Galvanized Sheet Metal
GYP.BD.	Gypsum Board
HC.	Handicapped
HDWD.	Hardwood
HORIZ.	Horizontal
HR.	Hour
HT.	Height
INSUL.	Insulation
LAV.	Lavatory
MAX.	Maximum
RESIL.	Resilient
R.O.	Rough Opening
R.W.L.	Rain Water Leader
S.A.D.	See Architectural Drawings
S.C.D.	Seat Cover Dispenser
SCHED.	Schedule
S.D.	Soap Dispenser
S.E.D.	See Electrical Drawings
S.F.	Square Feet
SIM.	Similar
S.L.D.	See Landscape Drawings
S.M.	Sheet Metal
S.M.D.	See Mechanical Drawings
S.M.S.	Sheet Metal Screw
S.N.D.	Sanitary Napkin Dispenser
S.N.R.	Sanitary Napkin Receptacle
SPEC.	Specifications
SQ.	Square
S.S.D.	See Structural Drawing
S.STL.	Stainless Steel
STA	Station
STD.	Standard
STL.	Steel
STOR.	Storage
STRL.	Structural
S.T.S.	Self Tapping Screw
SYM.	Symmetrical
T.M.E.	To Match Existing
CNTR.	Counter
COL.	Column
CONC.	Concrete
CONN.	Connnection
CONST.	Construction
CONT.	Continuous
CPU	Central Processing Unit
CTR.	Center
D.B.	Design Build
DBL.	Double
DET.	Detail
DIA.	Diameter
DIM.	Dimension
DISP.	Dispenser
DN.	Down
DWG.	Drawing
DWR.	Drawer
(E)	Existing
EA.	Each
EL.	Elevation
ELEC.	Electrical
ELEV.	Elevator
E.M.L.	Expanded Metal Lath
E.P.	Electrical Panelboard
EQ.	Equal
EXT.	Exterior
M.C.	Medicine Cabinet
MECH.	Mechanical
MFR.	Manufacturer
MIN.	Minimum
MIR.	Mirror
MISC.	Miscellaneous
(N)	New
N.I.C.	Not In Contract
NO.	Number
NOM.	Nominal
N.T.S.	Not To Scale
O.C.	On Center
OF.D.	Overflow Drain
O.F.C.I.	Owner Furnished, Contractor Installed
PL.	Plate
P. LAM.	Plastic Laminate
P.D.F.	Powder Driven Fastener
PLG.	Plumbing
PLYWD.	Plywood
PRHT.	Partial Height
P.T.D.	Paper Towel Dispenser
PTN.	Partition
P.T.R.	Paper Towel Receptacle
P.V.C.	Polyvinyl Chloride
QTY	Quantity
R.C.P.	Reflected Ceiling Plan
REQD.	Required
T.O.	Top Of
T.P.H.	Toilet Paper Holder
TYP.	Typical
U.O.N.	Unless Otherwise Noted
UTIL.	Utility
V.C.T.	Vinyl Composition Tile
VERT.	Vertical
V.I.F.	Verify In Field
W/	With
WHLCHR.	Wheelchair
WD.	Wood
W/O	Without
W.P.M.	Water Proof Membrane
W.W.M.	Welded Wire Mesh

NOTE: NOT ALL ABBREVIATIONS ARE USED.



3 VICINITY MAP
NOT TO SCALE

SHEET INDEX

ARCHITECTURAL SHEETS

A1.1	COVER SHEET AND PLOT PLAN
A1.2	PLOT PLAN
A2.1	FLOOR PLANS
A3.1	EXTERIOR ELEVATIONS
A4.1	SECTIONS
A5.1	INTERIOR ELEVATIONS
A6.1	DETAILS
A6.2	DETAILS
A7.1	NOTES & SCHEDULES

MEP SHEETS

MEP1.1	FOUNDATION, FLOOR & ROOF PLANS
MEP1.2	MEP SCHEDULES, PLUMBING DIAGRAM
MEP2.1	T24 - UNIT 1
MEP2.2	T24 - UNIT 2

SURVEY SHEETS

PLOT PLAN

STRUCTURAL SHEETS

S1.1	DRAWING INDEX & ABBREVIATIONS
S1.2	GENERAL NOTES
S2.0	FOUNDATION PLAN
S2.1	1ST FLOOR FRAMING PLAN
S2.2	2ND FLOOR FRAMING PLAN
S2.3	ROOF FRAMING PLAN
S3.1	WEST BUILDING ELEVATION
S3.2	EAST BUILDING ELEVATION
S3.3	LINE B ELEVATION
S3.4	LINE C ELEVATION
S3.5	NOT USED
S3.6	LINE F ELEVATION
S3.7	LINE G ELEVATION
S3.8	TYPICAL WALL SECTION
S3.9	WALL SECTIONS
S4.1	TYPICAL CONCRETE DETAILS
S4.2	CONCRETE DETAILS
S4.3	CONCRETE FDN DETAILS
S6.1	WOOD TYPICAL DETAILS
S6.2	WOOD TYPICAL DETAILS
S6.3	WOOD SHEAR WALL DETAILS
S6.4	WOOD DETAILS
S6.5	WOOD DETAILS

1

PROJECT INFORMATION

PROJECT LOCATION
612 LANCASTER STREET
OAKLAND, CA 94601

PROJECT OWNER
MALPAS AND MALPAS
612 LANCASTER ST.
OAKLAND, CA 94601

BUILDING INFORMATION

CONSTRUCTION TYPE	V
OCCUPANCY	R-3
USE	2 LIVE/WORK UNITS

ZONING INFORMATION

A.P.N.	025-066101200
PARCEL SIZE	2500 sf
GENERAL PLAN	HBX-3
ZONING	M-40
UNITS	2
HEIGHT LIMIT	55'
PARKING SPACES	2
FRONT SETBACK	None
REAR SETBACK	None
SIDE SETBACK	None
F.A.R.	2.5

GENERAL NOTES

1.1 SCOPE OF WORK:
REPLACEMENT OF EXISTING 310 SF SINGLE FAMILY RESIDENCE AND SHED WITH (2) NEW 1500 SF LIVE/WORK UNITS.

1.2 MODULAR CONSTRUCTION
THE UNITS ARE ASSUMED PREFAB CONSTRUCTION. THE STATE IS TO PERMIT & INSPECT WORK IN THE SAN LEANDRO FACTORY. CITY IS ASSUMED TO PERMIT & INSPECT ALL WORK DONE ON SITE, INCLUDING FOUNDATION, MODULE INTERCONNECTIONS, & SOME FINISHES & EQUIPMENT INSTALLED ON SITE.

1.3 CODE COMPLIANCE:
THE PREMISES AND NEW CONSTRUCTION SHALL BE IN COMPLIANCE WITH THE 2007 CBC, CMC, CPC, CEC, CFC; 2005 CALIFORNIA ENERGY CODE.

1.4 ALL DIMENSIONS ARE TO FACE OF UNFINISHED WALL UNLESS OTHERWISE NOTED. WRITTEN DIMENSIONS ARE TO GOVERN. DO NOT SCALE THE DRAWINGS. CONSULT ARCHITECT REGARDING ANY AMBIGUITIES OR UNCLEAR SITUATIONS WHICH MAY OCCUR.

1.5 ALL MANUFACTURED MATERIALS AND EQUIPMENT TO BE INSTALLED ACCORDING TO MANUFACTURER'S SPECIFICATIONS.

1.6 ALL DIMENSIONS AND CONDITIONS TO BE VERIFIED ON SITE.

2 SITE WORK

2.4 UTILITY SERVICES
A. UTILITIES:
1. ELECTRICAL: EXISTING ABOVE GROUND SERVICE AT ROADWAY
2. WATER: EXISTING
3. SEWER: EXISTING
3. TELEPHONE: EXISTING ABOVE GROUND SERVICE

2.5 SITE DRAINAGE
A. FOUNDATION TO HAVE A PERIMETER 4" PERFORATED PIPE WITHIN A MIRADRAIN VERTICAL MEMBRANE; CONNECTED TO 3" SUB SLAB PIPE CONNECTED TO SUMP IN BASEMENT SLAB.
B. LIMIT DISRUPTION OF NATURAL WATER FLOWS BY REDUCING STORM WATER RUNOFF, INCREASING ON-SITE INFILTRATION.
C. ROOF DRAINAGE PIPED THROUGH CURB.

2.6 PAVING
A. PAVERS AT GARAGES & ADJANCENT TO FRONT ENTRANCES.
B. CONCRETE WALK TO FRONT ENTRANCES.

FOR ADDITIONAL GENERAL NOTES, SEE SHEET A7.1

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BUILDING SCIENCE CORP.
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1035 FOLGER AVE
BERKELEY, CA 94710
510.845.2997

Seal & Signature:

Revisions:	Date:
1 State Submittal	1.20.09

Lancaster Lofts

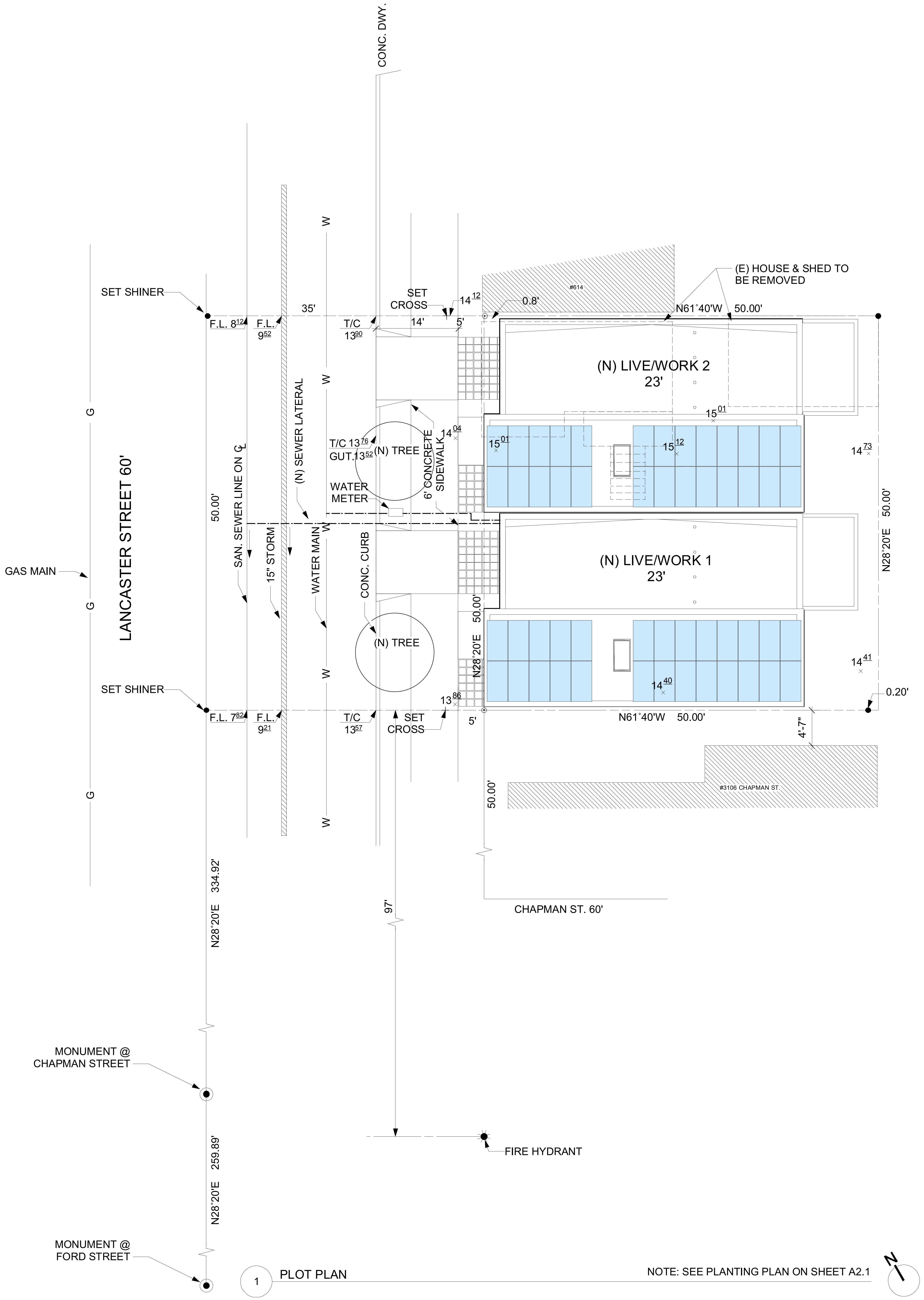
Owner & Developer:
Malpas

Sheet contents:

COVER SHEET

Drawn by: NJB, MC Checked: DS
Scale: Date: 01.20.09
ZETA Project No.: 0811

A1.1



1 PLOT PLAN

NOTE: SEE PLANTING PLAN ON SHEET A2.1

DESIGNER'S STATEMENT

THIS PLOT PLAN CORRECTLY REPRESENTS A PLOT PLAN MADE BY ME OR UNDER MY DIRECTION

I HEREBY STATE THAT TO THE BEST OF MY KNOWLEDGE ALL PROVISIONS OF THE APPLICABLE STATE LAWS AND LOCAL ORDINANCES HAVE BEEN COMPLIED WITH.

I HEREBY FURTHER STATE THAT ALL PROPOSED GRADES, ELEVATIONS, AND CONTOURS DELINEATED UPON THIS PLOT PLAN ARE BASED UPON A SURVEY BY AHMAD MOGHADDAS (RCE # 27185) DATED 1.15.09 THAT WAS INDICATED THEREON BY THE SURVEYOR AS BEING BASED UPON THE CITY OF OAKLAND DATUM.

______________________ DATE:____________________

TITLE: ______________________

LICENSE NUMBER:__________________ EXPIRES:__________________

ZETA Communities

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Seal & Signature:

Revisions:	Date:
1 State Submittal	1.20.09

Lancaster Lofts

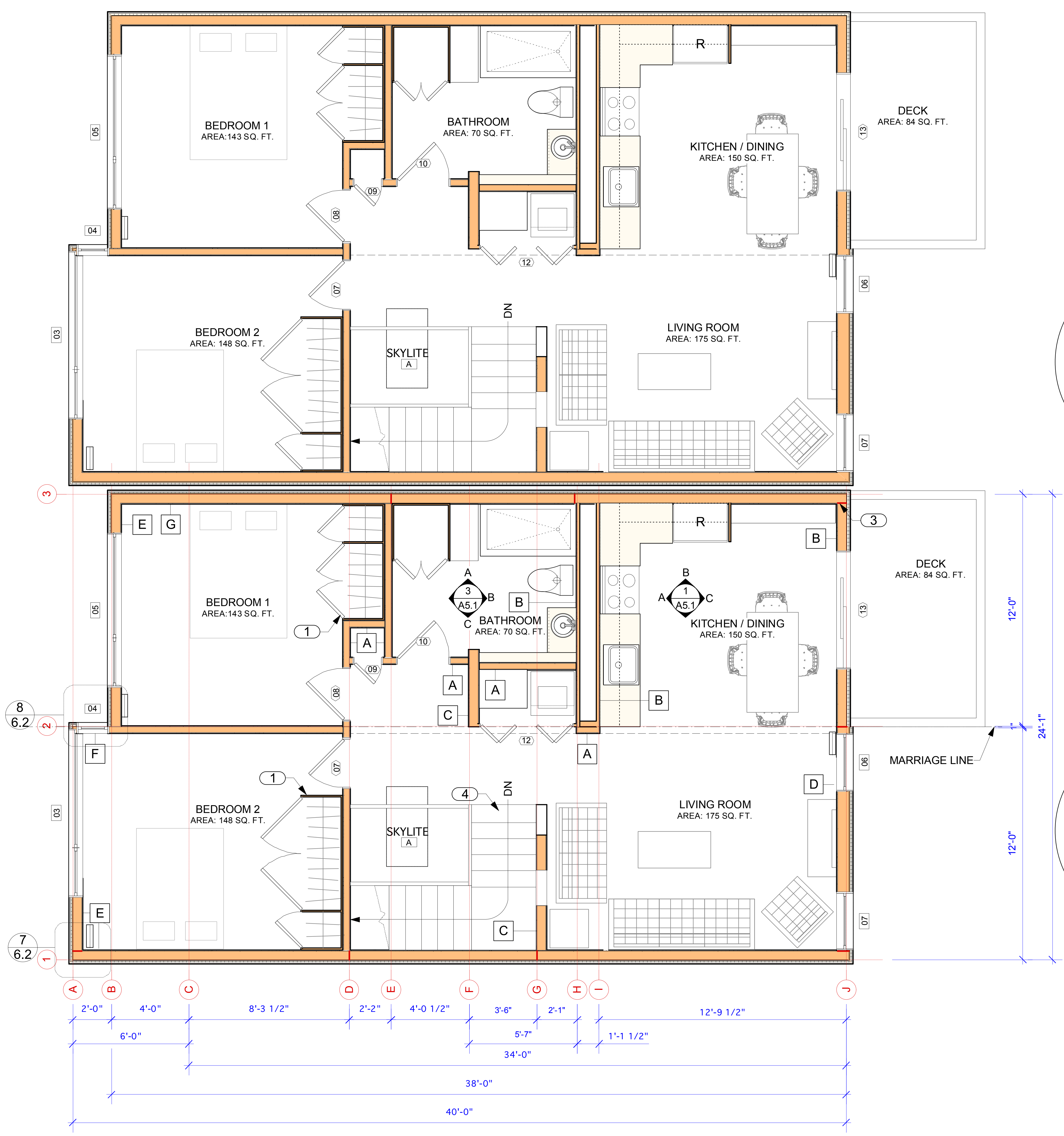
Owner & Developer:
Malpas

Sheet contents:

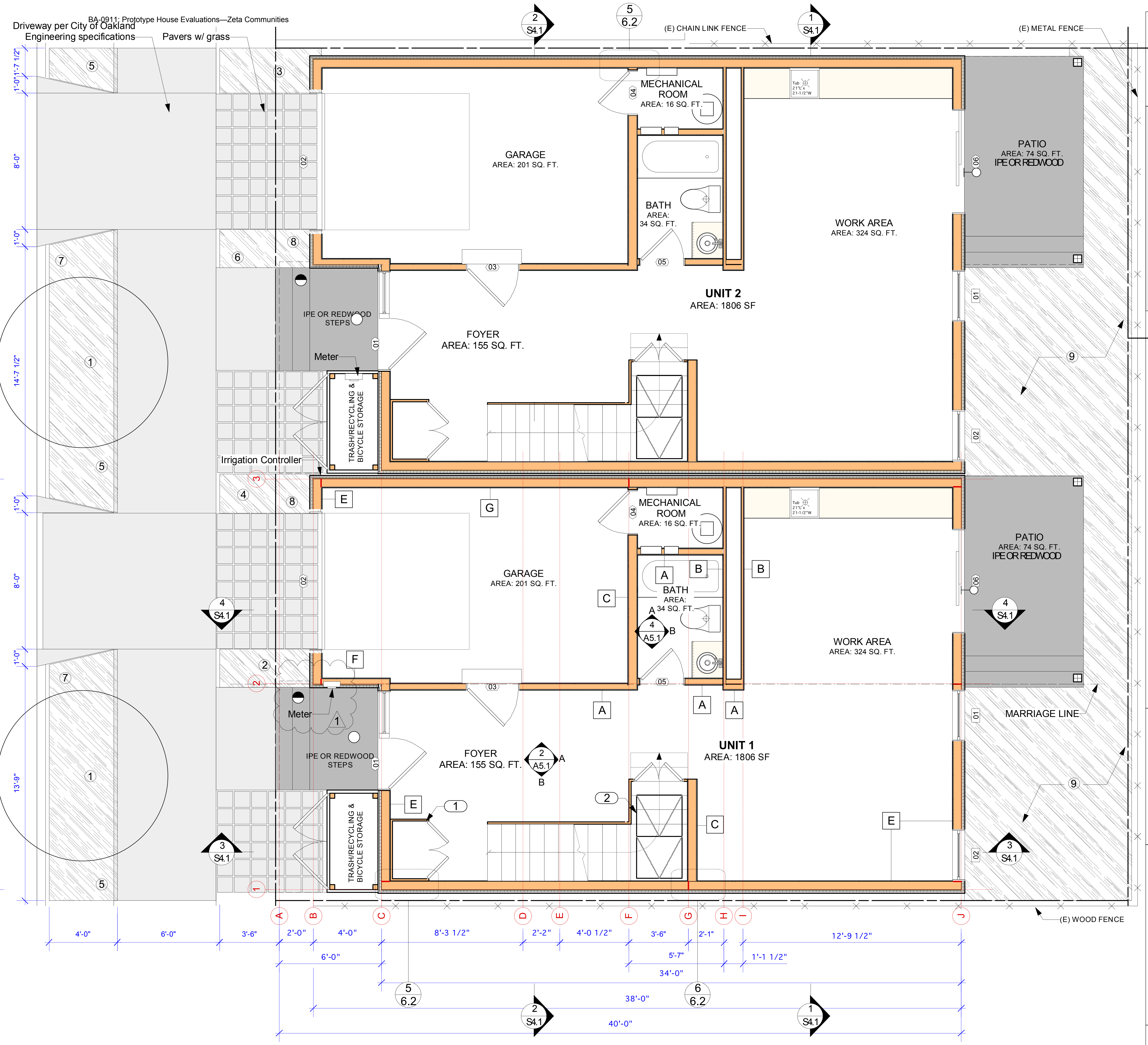
PLOT PLAN

Drawn by: NJB, MC Checked: DS
Scale: 1/8"=1'0" Date: 01.20.09
ZETA Project No.: 0811

A1.2



3 UPPER FLOOR PLAN



2 MAIN FLOOR PLAN

KEY NOTES

1. CLOSET MADE FROM 3/4" PLYWOOD.
2. ACCESS HATCH TO CONDITIONED HALF BASEMENT.
3. INDICATES CONSTRUCTION WALL BREAKS
4. STAIRS 17R @ 7.3" RISER & 10.2" TREAD

DRAWING ABBREVIATIONS

+9'-3" ATYPICAL CEILING HEIGHT

A WALL/PARTITION TYPE TAG, SEE DETAILS SHEET A6.2

4 DOOR IDENTIFICATION (SEE SCHEDULE, A6.1)

4 WINDOW IDENTIFICATION (SEE SCHEDULE, A6.1)

DIMENSIONING

℄

CENTERLINE OF ELEMENT

FACE OF STUD (F.O.S.) TYP.

FACE OF FINISH (F.O.F.)

DETAIL IDENTIFICATION

1 / A1.0

DRAWING NUMBER

SHEET NUMBER, IN SAME DISCIPLINE (`-' INDICATES THE SAME SHEET)

1 KEY NOTES

FIRST FLOOR +0'-0" ELEVATION DATUM

INTERIOR ELEVATION IDENTIFICATION

A, B, C, D — 2 / A2.1

LETTER SHOWS SEQUENCE

ARROW SHOWS ELEVATION

DRAWING NUMBER

SHEET NUMBER (IN SAME DISCIPLINE)

SECTION IDENTIFICATION

3 / A3.1

ARROW SHOWS DIRECTION

DRAWING NUMBER

SHEET NUMBER (IN SAME DISCIPLINE)

PLANT SCHEDULE

SYMBOL	TREES		
1	T62 CN	Red Maple	25gal
	NATIVE CLIMBING PLANTS		
2	V24	Wisteria	2gal
3	V4	*Clematis Armadii* - Evergreen Clematis	2gal
4	V19	*Rosa Banksiae* - Lady Banks Rose	1gal

	NATIVE SHRUBS AND GROUND COVER	
5	SS13CN *Mahonia Aquifolium* - Oregon Grape	1gal
6	SS18 *Westringia Rosmarinformis* - Rosemary Bush	1gal
7	GC8 CN *Ceanothus Gloriosus* - Ceanothus	1gal
8	GC6 *Baccharis Pilularis* - Dwarf Coyote Bush	1gal
9	Various Native Grasses	

NOTE: All Landscape Plant Numbers are from EBMUD "Water Conserving Plants and Landscapes for the Bay Area" 1990

Irrigation to be provided in 2 zones

AREA TABULATIONS:

CONDITIONED	1561 SF
GARAGE/UTILITY	245 SF
TOTAL UNIT AREA:	1806 SF
TOTAL AREA FOR UNITS:	3,612 SF

LIGHT SCHEDULE:

EXT. WALL MOUNTED FLURESCENT (MOTION SENSOR)

EXT. RECESSED FLUORESCENT (MOTION SENSOR) ○

EXT. RECESSED FLUORESCENT DIRECTIONAL (MOTION SENSOR) ◓

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510.845.2997

Seal & Signature:

Revisions:	Date:
1 State Submittal	1.20.09

Lancaster Lofts

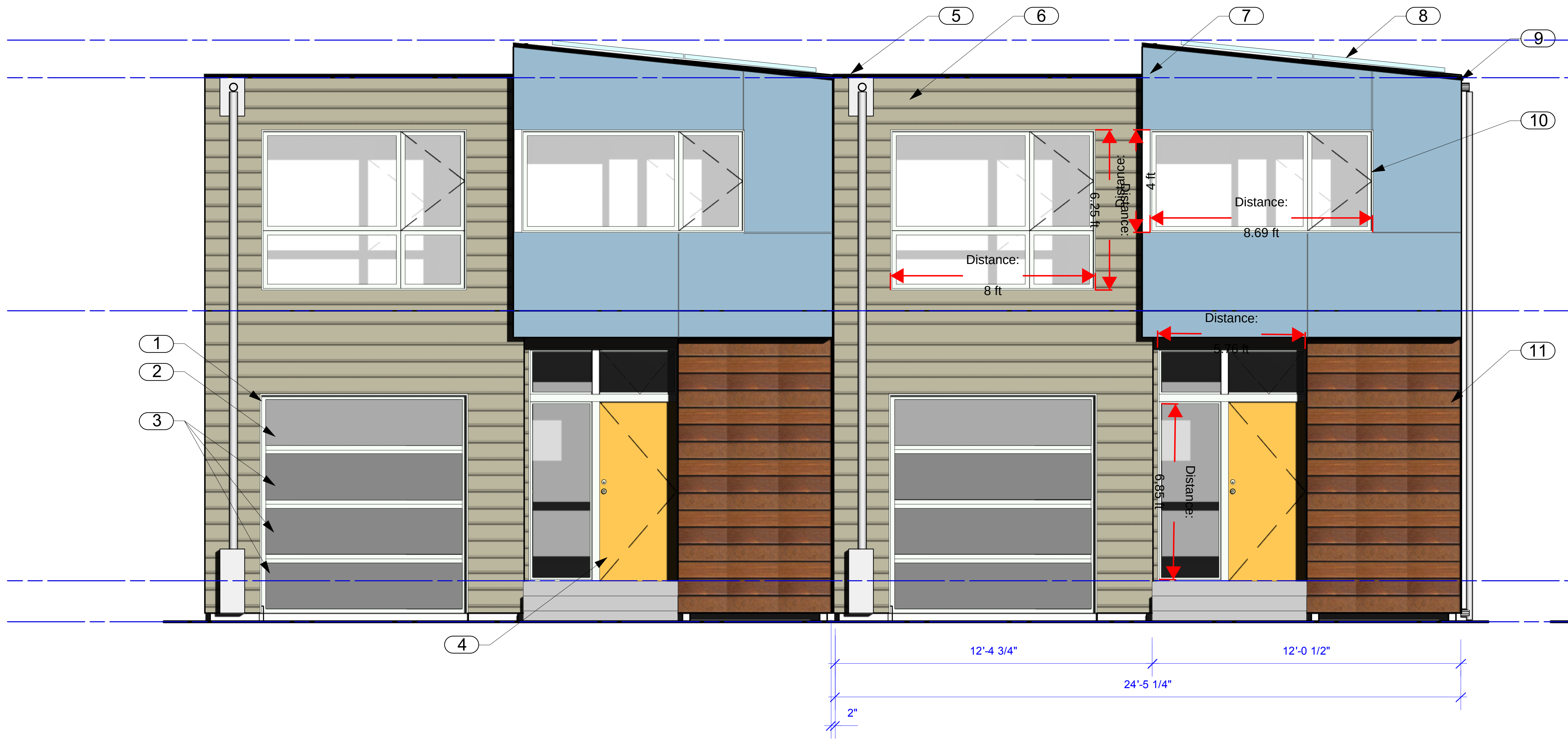
Owner & Developer:
Malpas

Sheet contents:

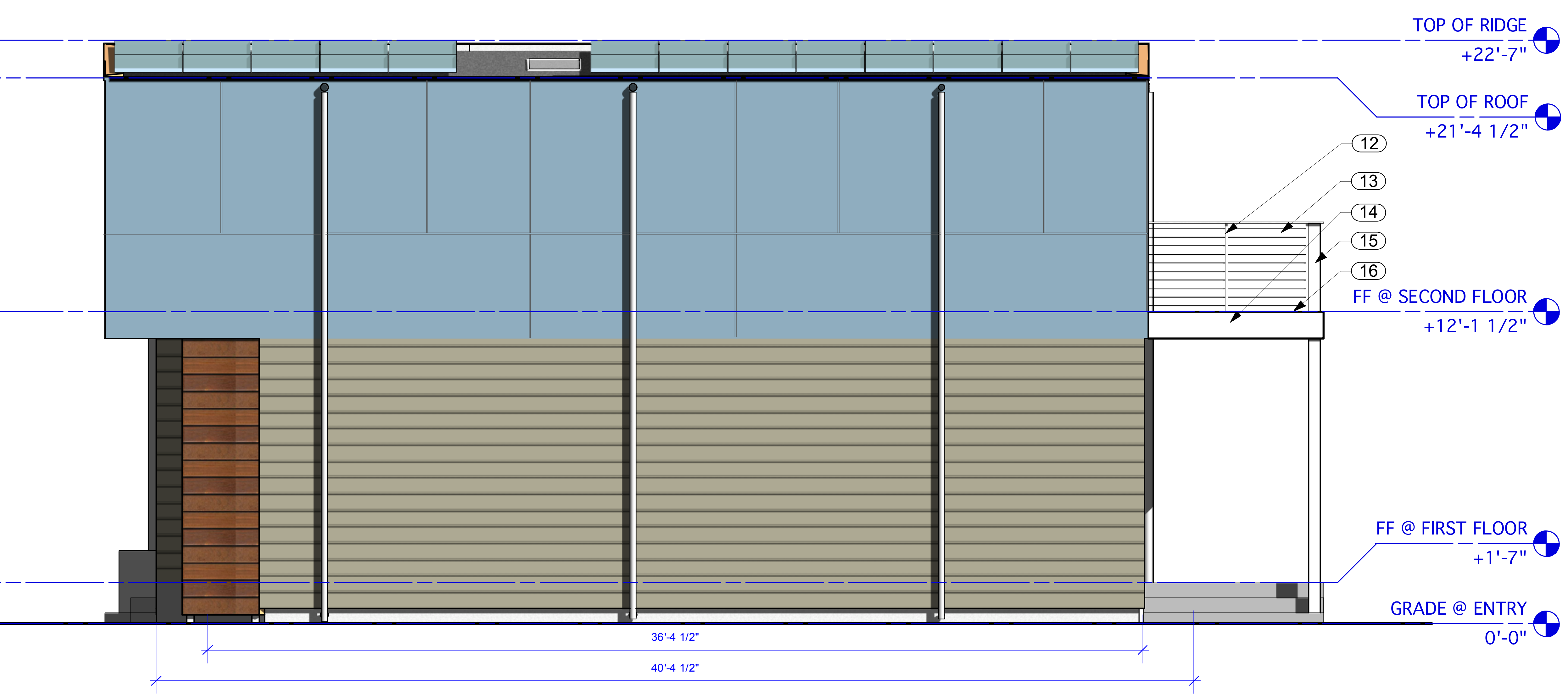
FLOOR PLANS

Drawn by: NJB, MC Checked: DS
Scale: 1/4"=1'0" Date: 01.20.09
ZETA Project No.: 0811

A2.1



1 WEST ELEVATION



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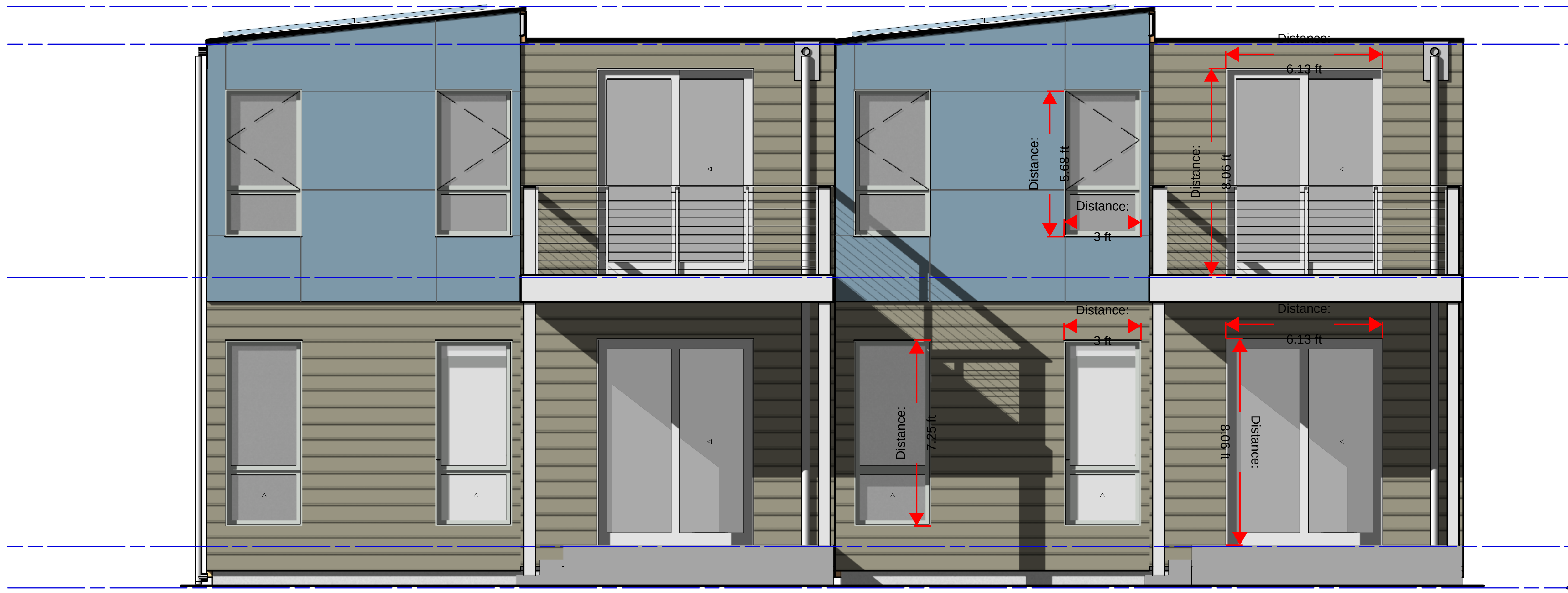

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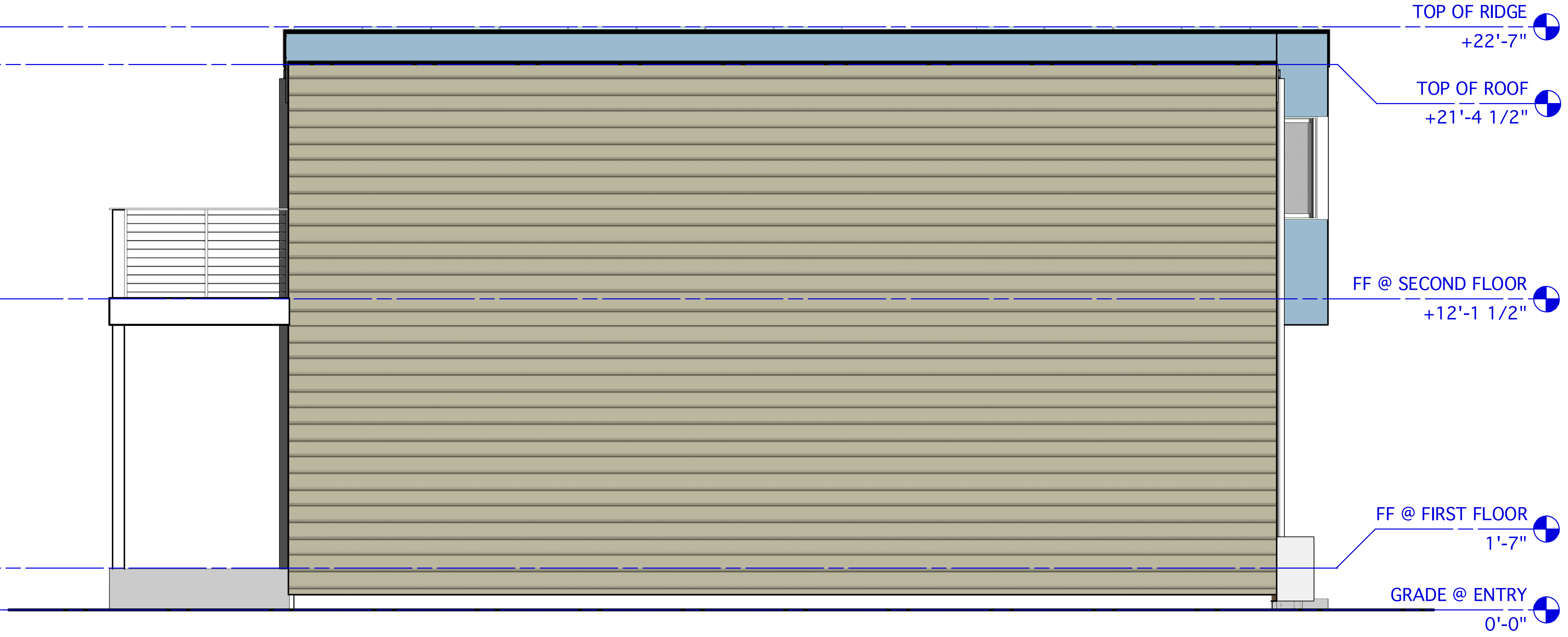

4 NORTH ELEVATION

KEY NOTES

1. ALUMINUM FRAME GARAGE DOOR
2. CLEAR GLASS
3. FROSTED GLASS
4. PTD WOOD DOOR (YELLOW ICI # 543)
5. WHITE "MODIFIED" B.U.R.
6. PTD FIBER-CEMENT LAP SIDING (TANGREY ICI #700)
7. PTD FIBER-CEMENT PANELS (BLUE ICI # 140)
8. PHOTOVOLTAIC PANELS
9. 2" CEMENT PANEL TRIM (BLACK)
10. FIBERGLASS WINDOWS (WHITE)
11. IPE SIDING (CLEAR SEAL)
12. 1 1/4" VERTICAL SUPPORTS @ 3'-0" O.C.
13. 42" HIGH GALVANIZED CABLE RAILING. 1/8" CABLE @ 4" O.C. MAX.
14. 2X10 JOISTS HUNG FROM 6X10 GIRDER SPANNING POSTS
15. CONTINUOUS 6X6 POSTS
16. IPE OR REDWOOD DECKING

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1 State Submittal	1.20.09

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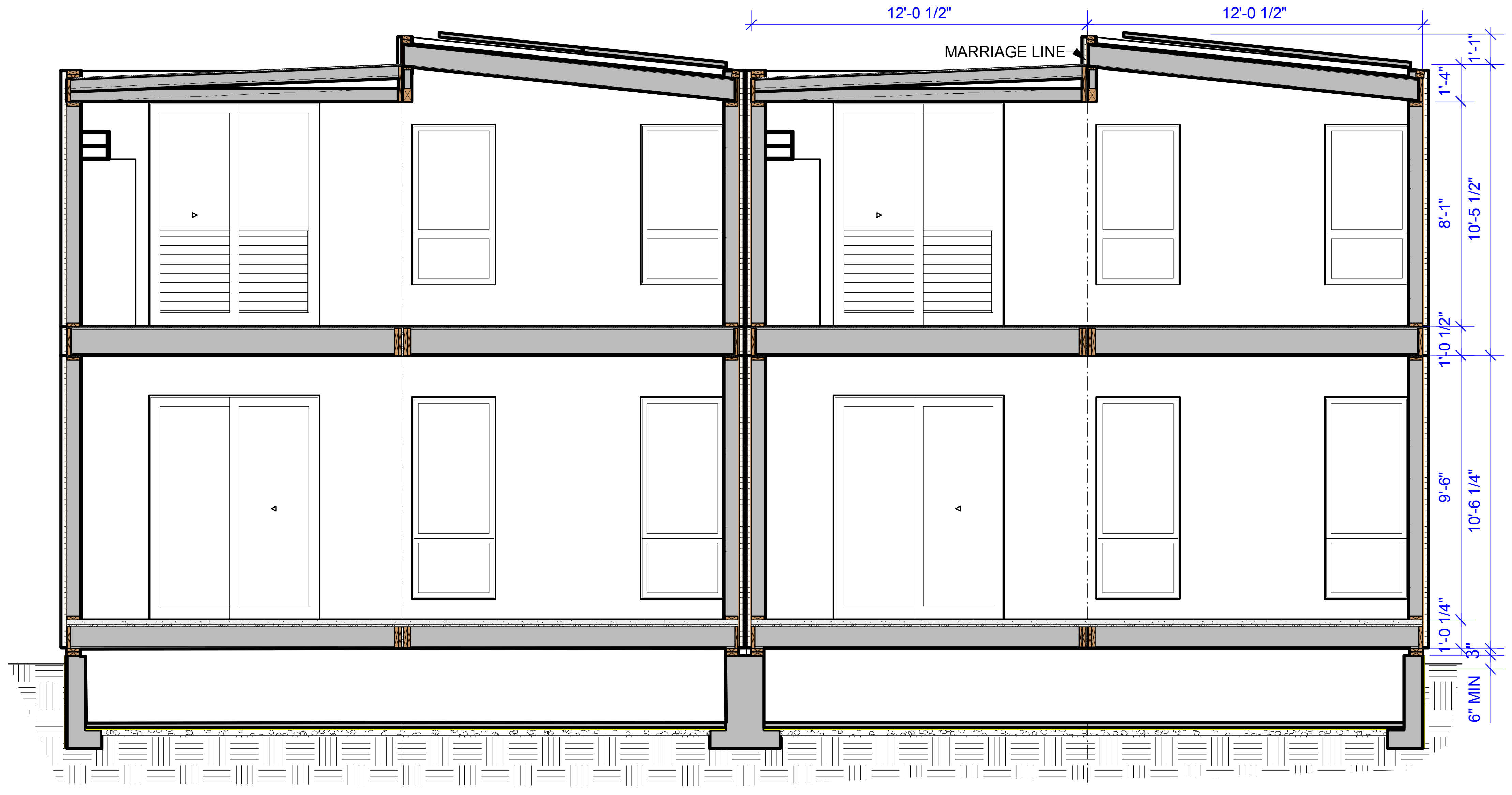
Sheet contents:
ELEVATIONS
PLAN 1A

Drawn by: NJB, MC Checked: DS
Scale: 1/4"=1'0" Date: 01.20.09
ZETA Project No.: 0811

A3.1



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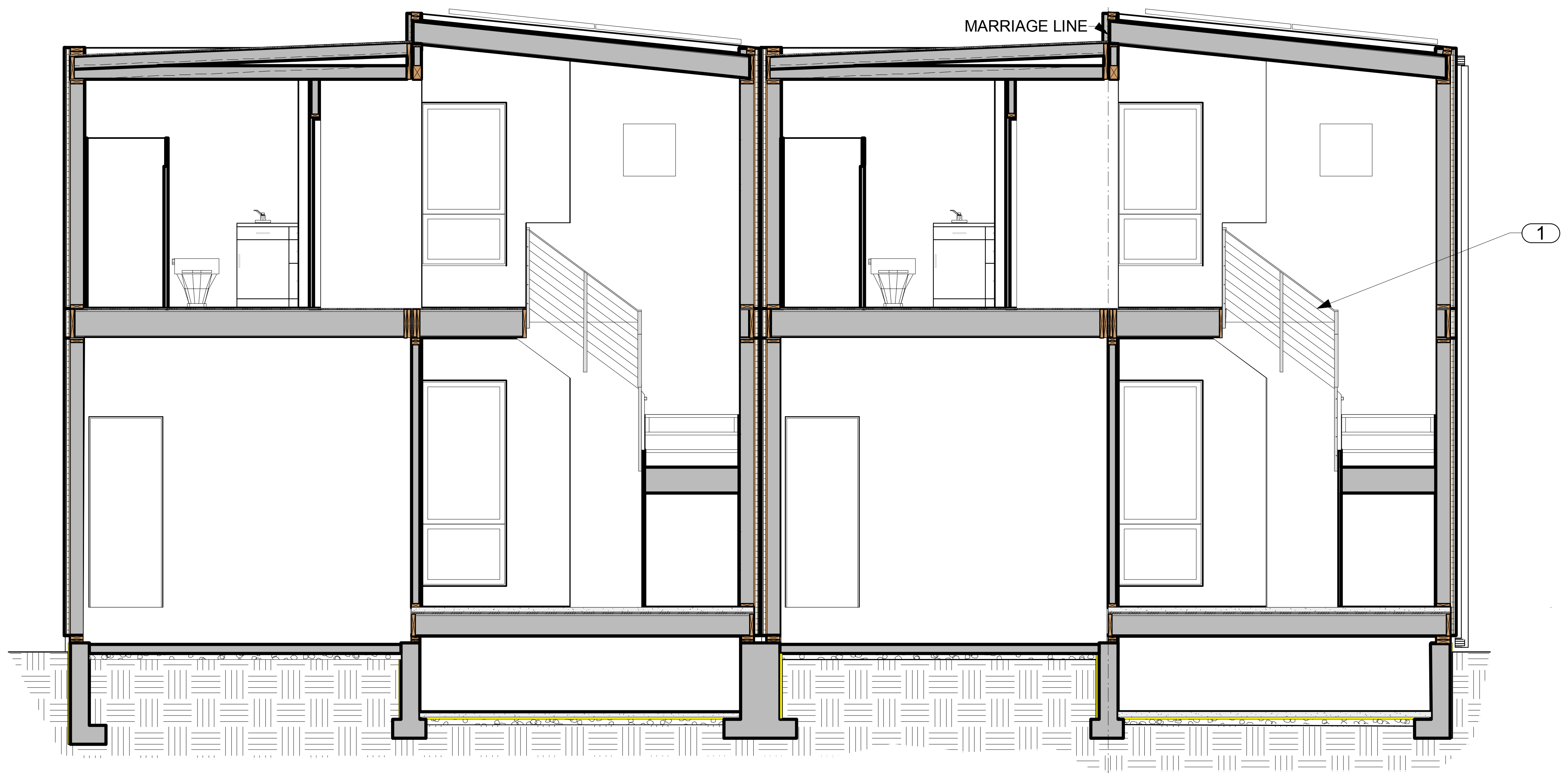

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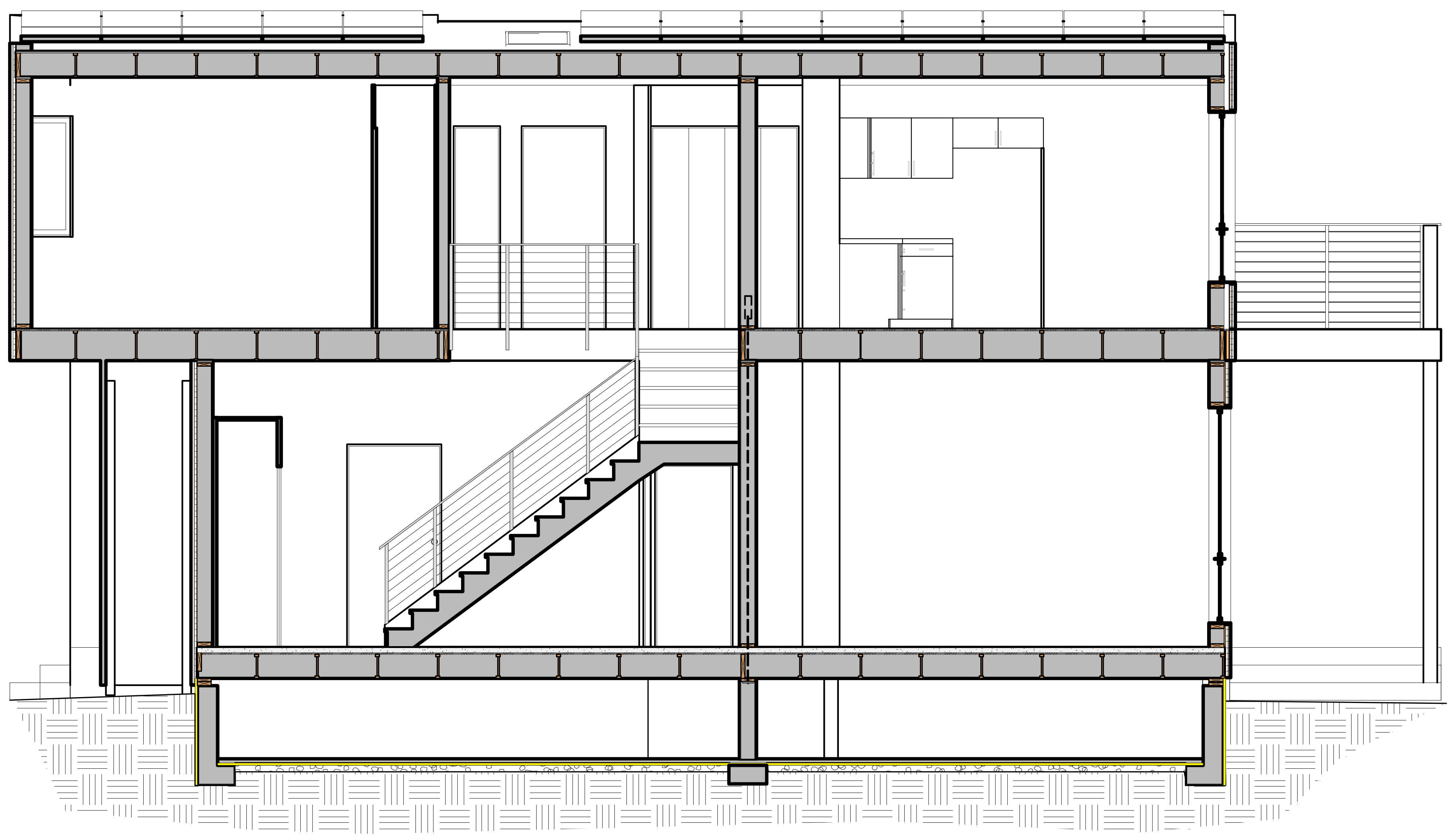

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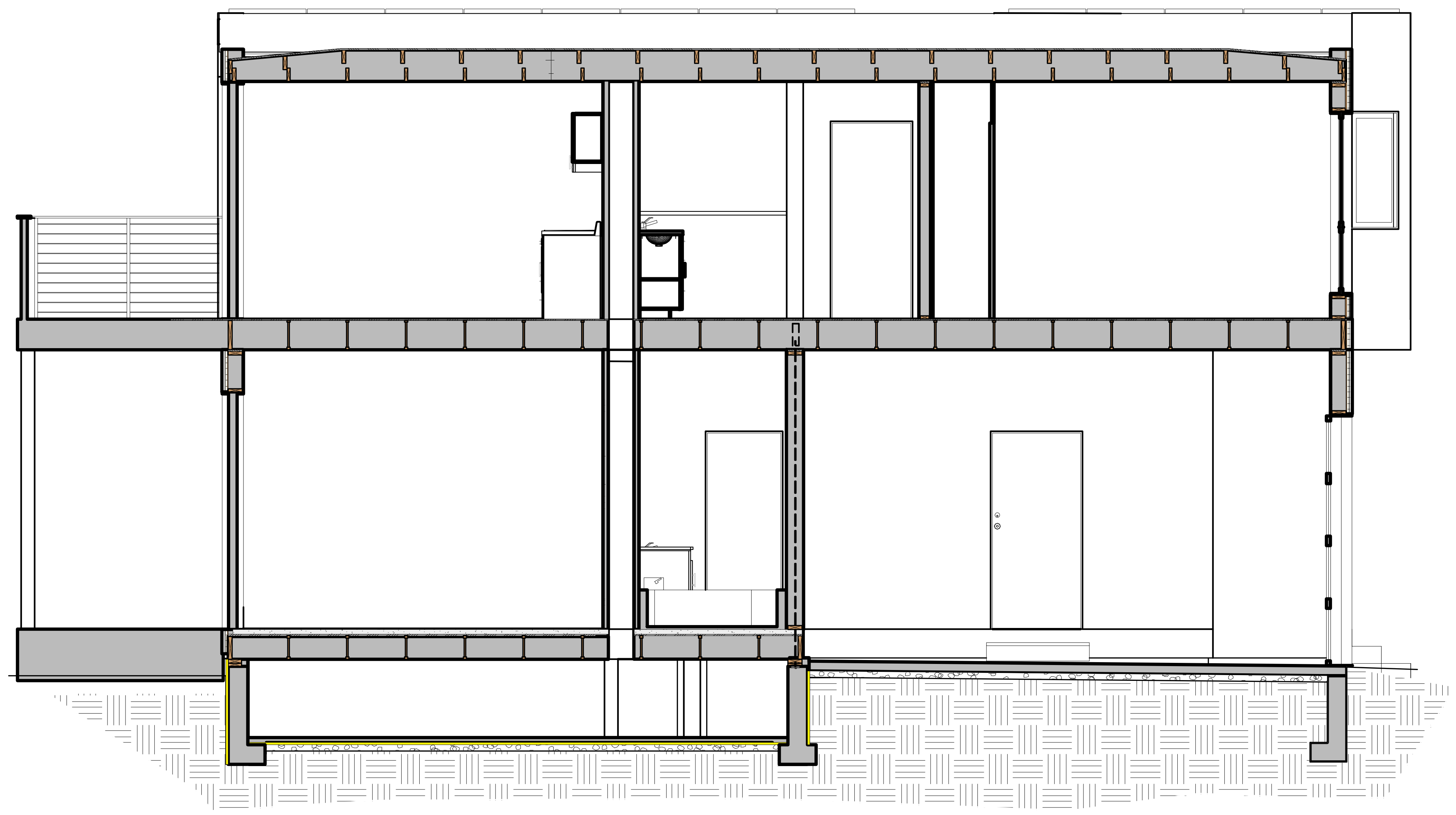
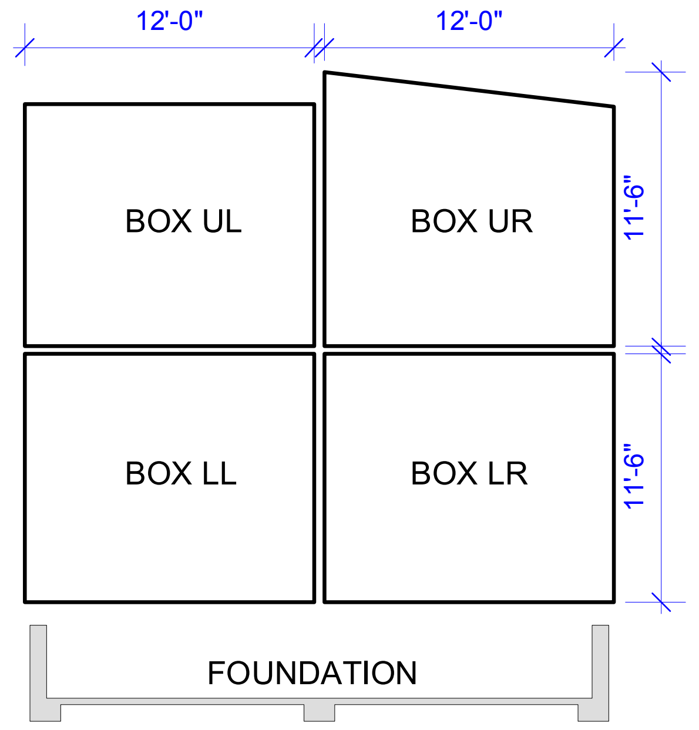


4 SECTION - LOOKING SOUTH

KEY NOTES

1. 1" STEEL TUBE RAIL SUPPORT.
   SEE STAIR DETAIL (DETAIL 8) ON SHEET A6.2.

MODULES



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Seal & Signature:

Revisions:	Date:
1 State Submittal	1.20.09

Lancaster Lofts

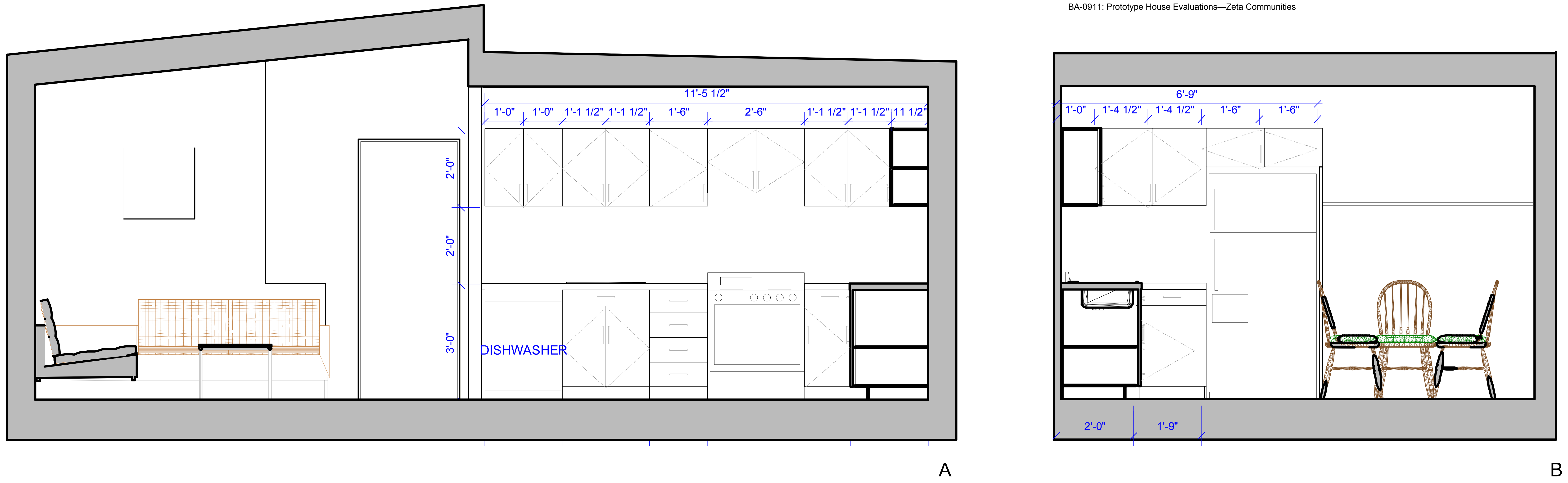
Owner & Developer:
Malpas

Sheet contents:

SECTIONS

Drawn by: NJB, MC Checked: DS
Scale: 1/4"=1'0" Date: 01.20.09
ZETA Project No.: 0811

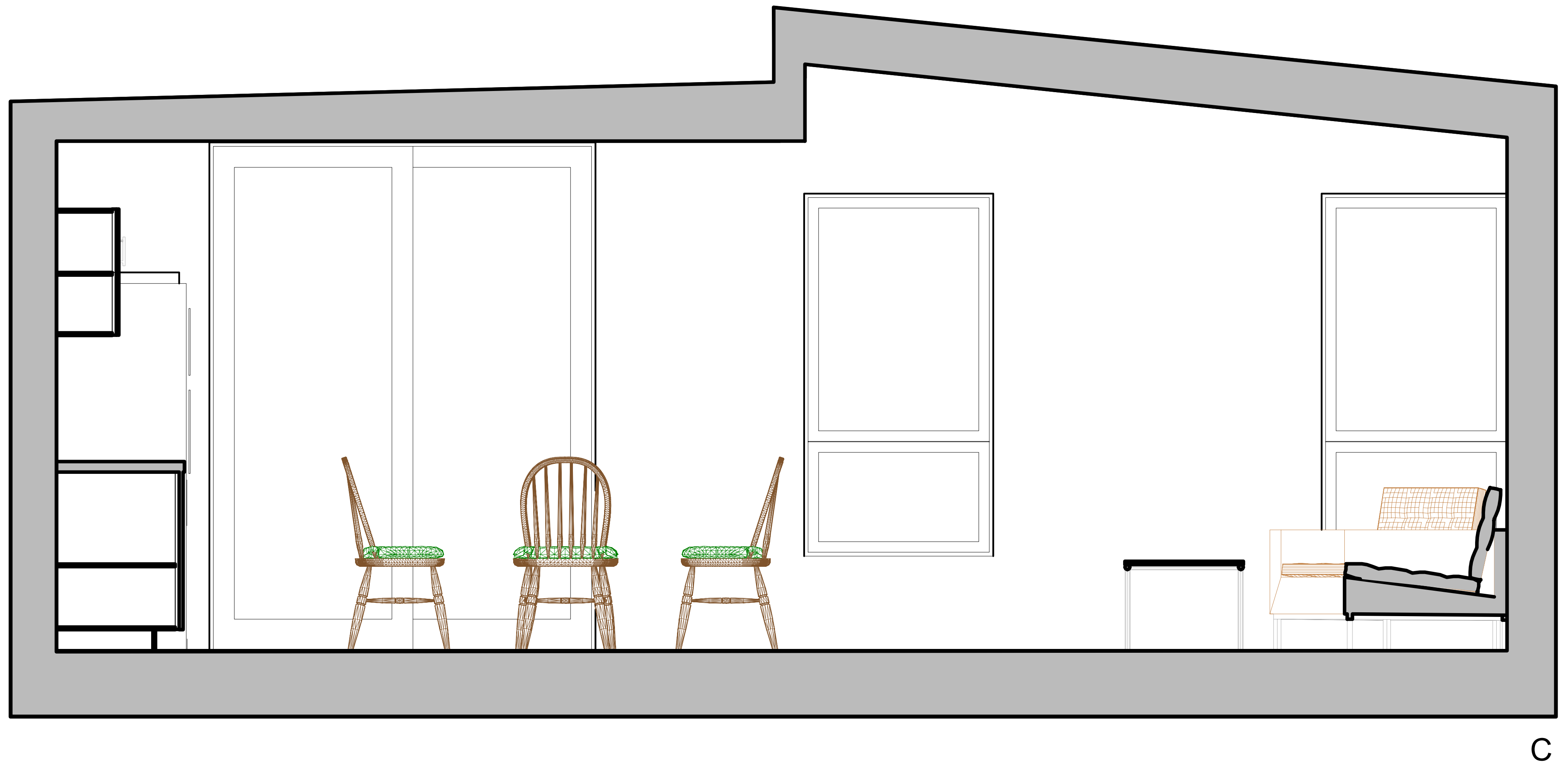
A4.1



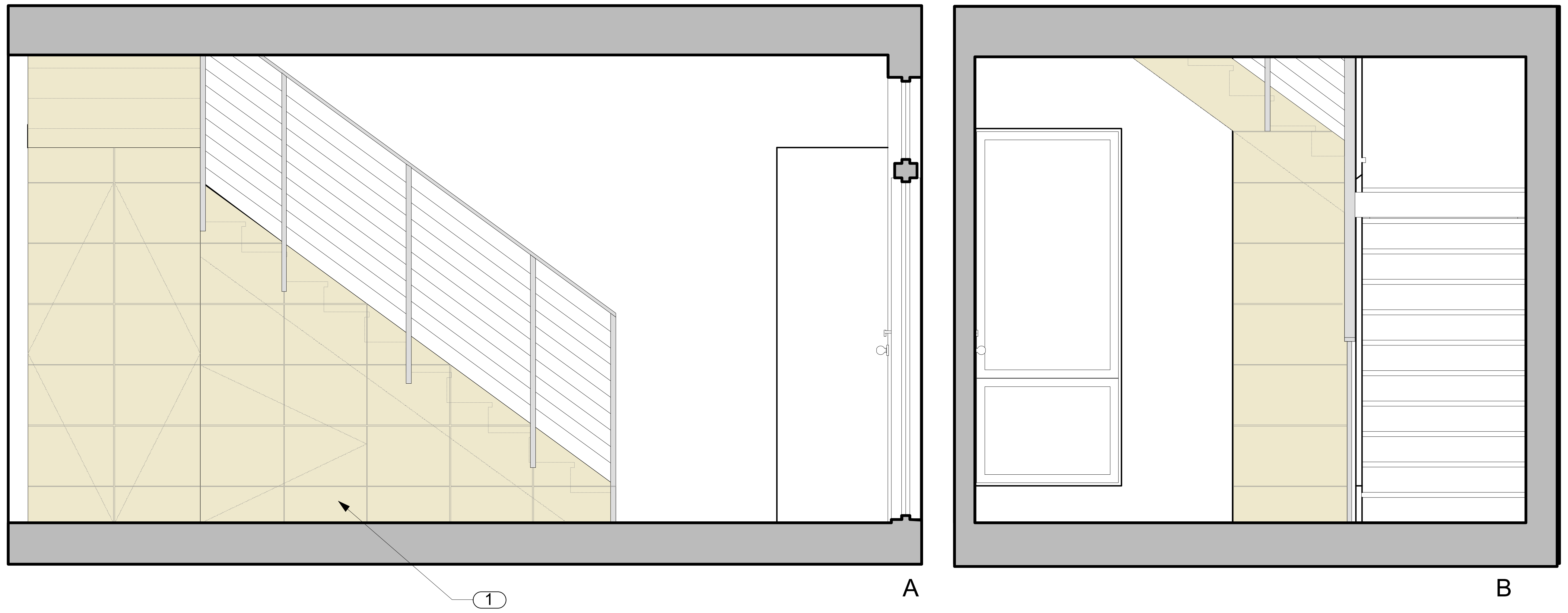
1 INTERIOR ELEVATION - KITCHEN

KEY NOTES

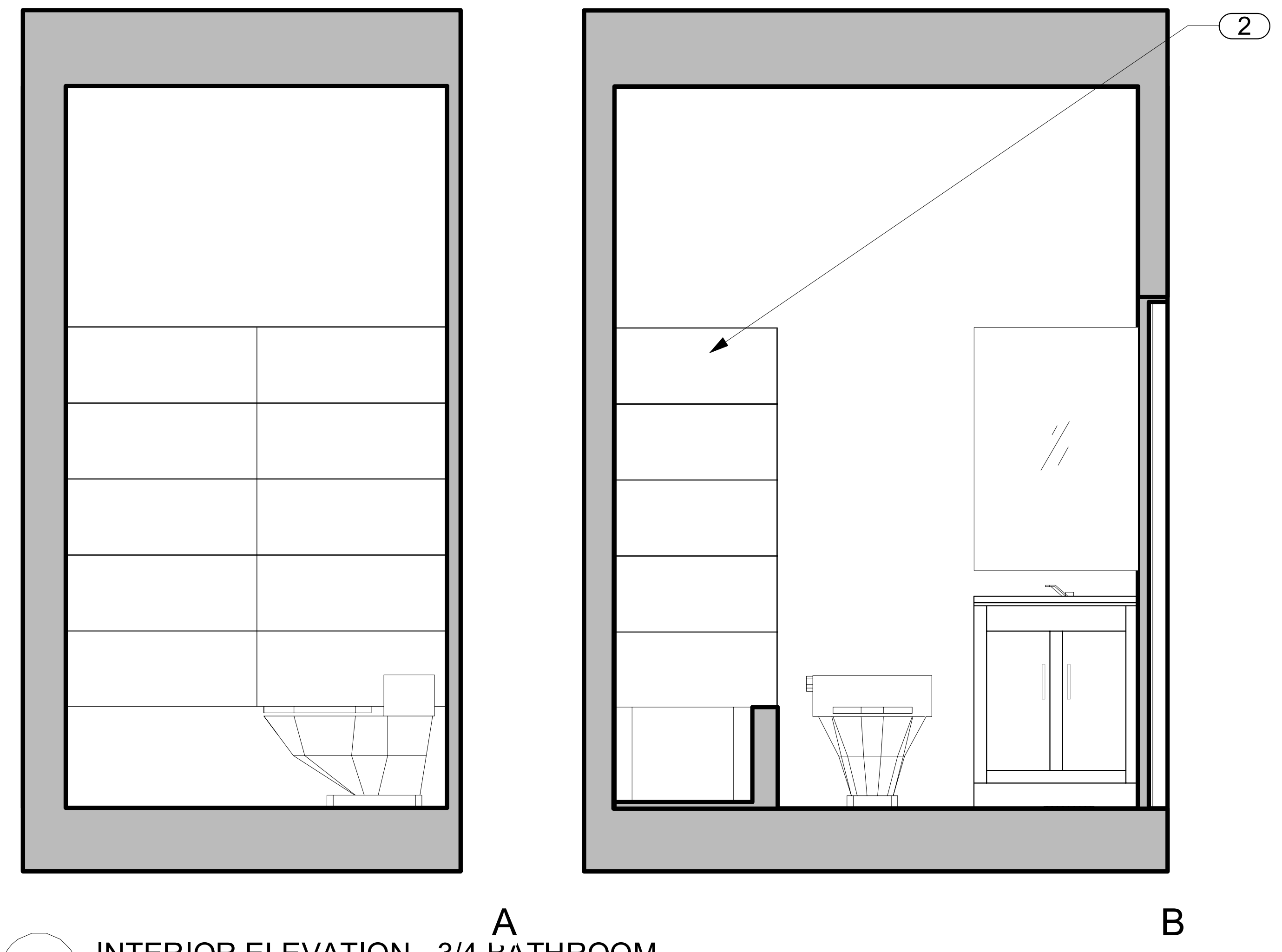
1. VENEER PLYWOOD
2. CERAMIC TILE



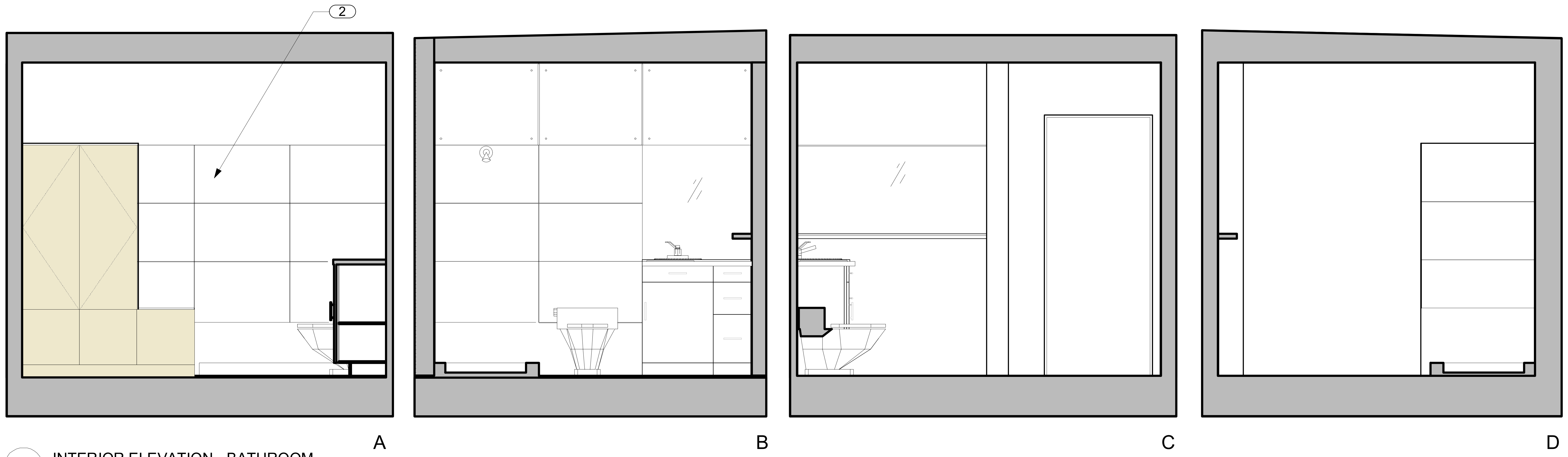
1 INTERIOR ELEVATION - KITCHEN



2 INTERIOR ELEVATION - FOYER



3 INTERIOR ELEVATION - 3/4 BATHROOM



4 INTERIOR ELEVATION - BATHROOM

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Seal & Signature:

Revisions:	Date:
1 State Submittal	1.20.09

Lancaster Lofts

Owner & Developer:
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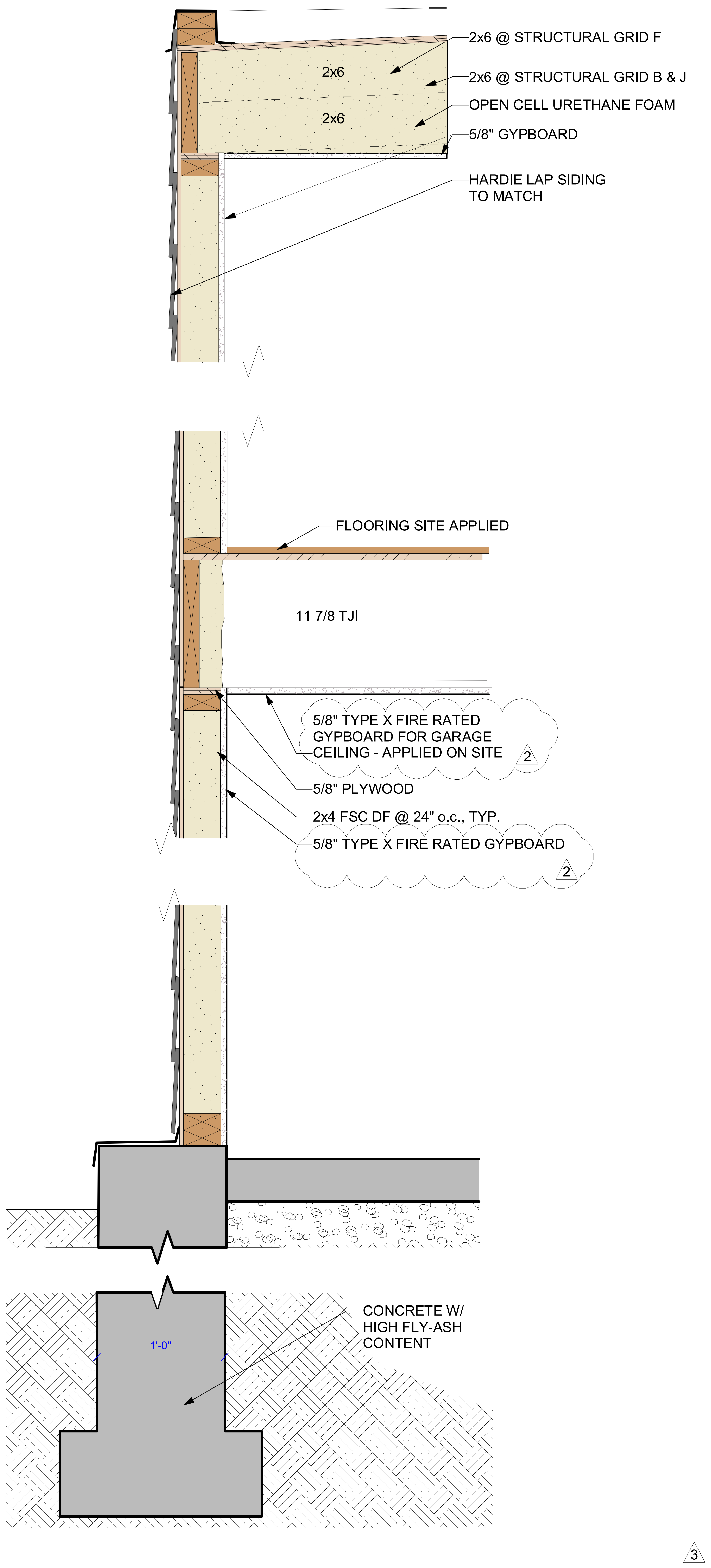
Sheet contents:

INTERIOR
ELEVATIONS

Drawn by: NJB, MC Checked: DS
Scale: 1/2"=1'0" Date: 01.20.09
ZETA Project No.: 0811

A5.1

NOTE: SECTION @ HIGH POINT @ STRUCTURAL GRID F



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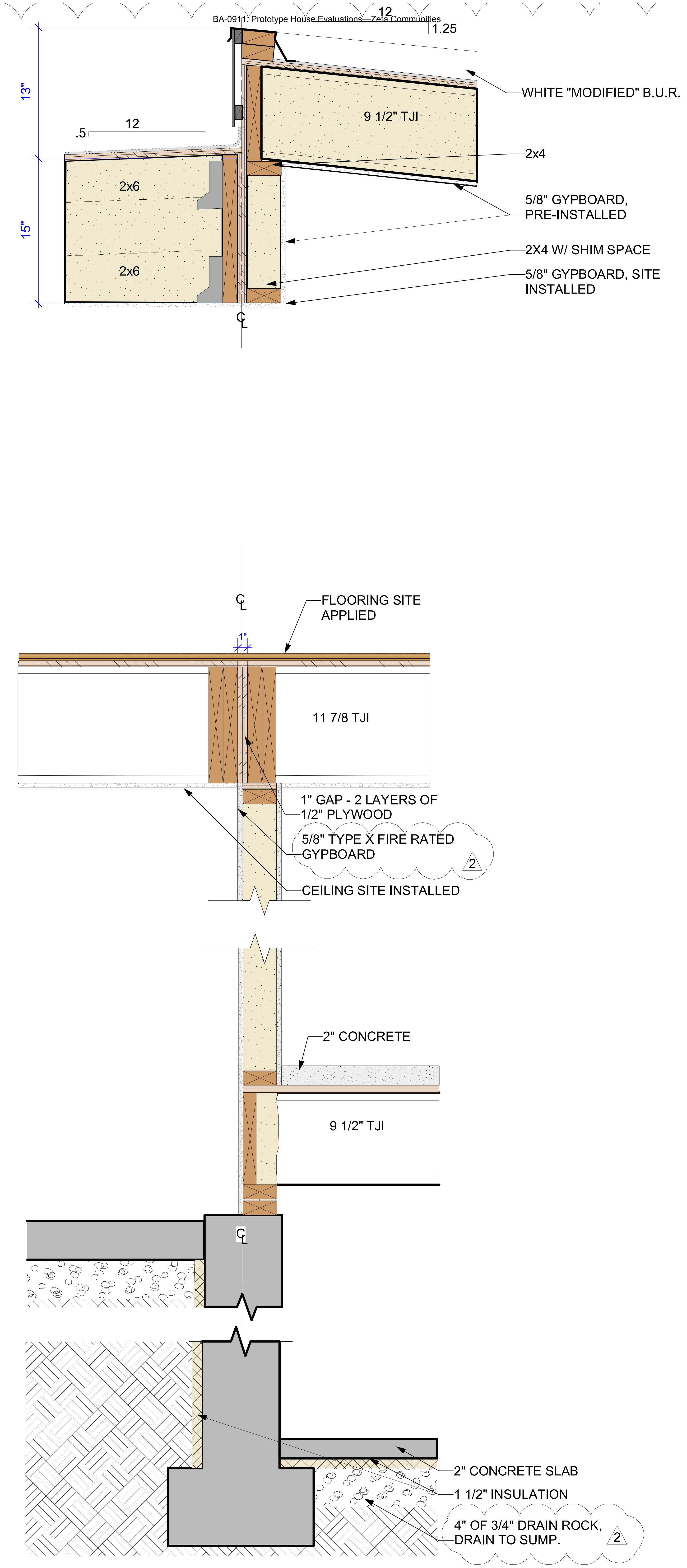

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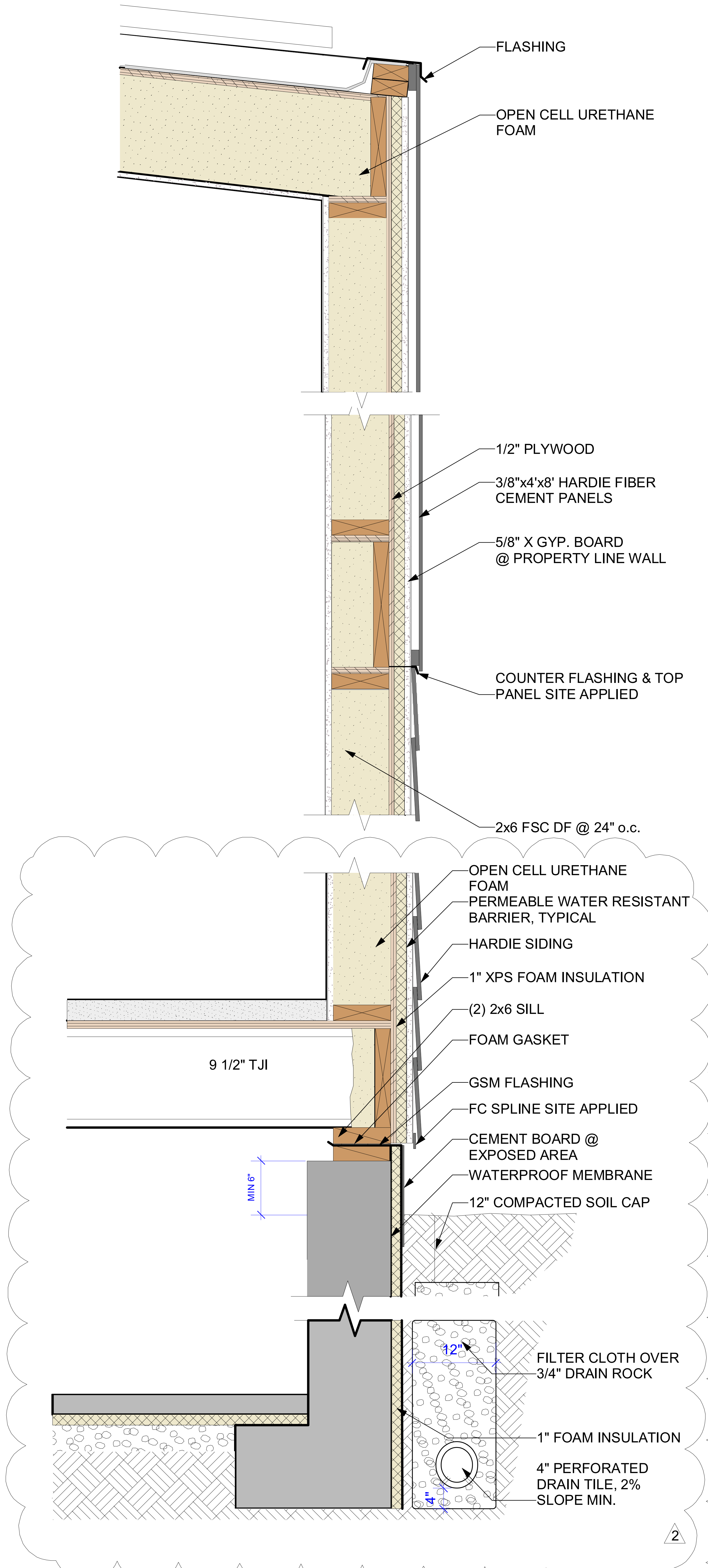

3 SECTION

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Revisions:	Date:
1 State Submittal	1.20.09
2 Re-submittal	2.09.09
3 Revision as one unit	10.15.09
4 As builts	10.20.09

610 Lancaster 3
Owner & Developer:
Malpas

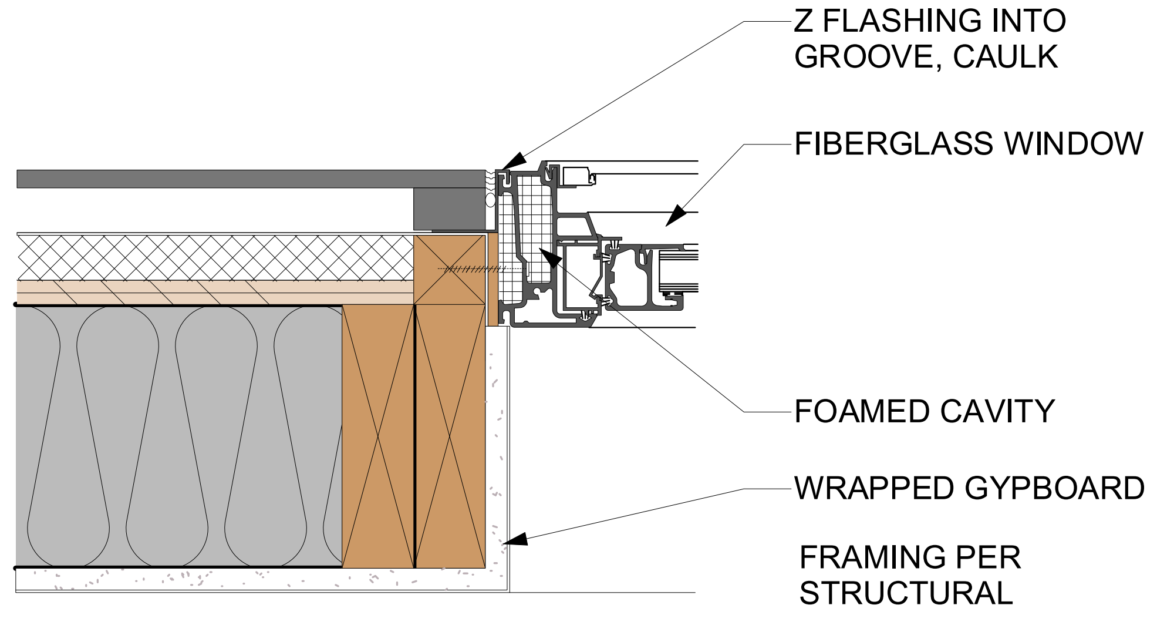
Sheet contents:

DETAILS

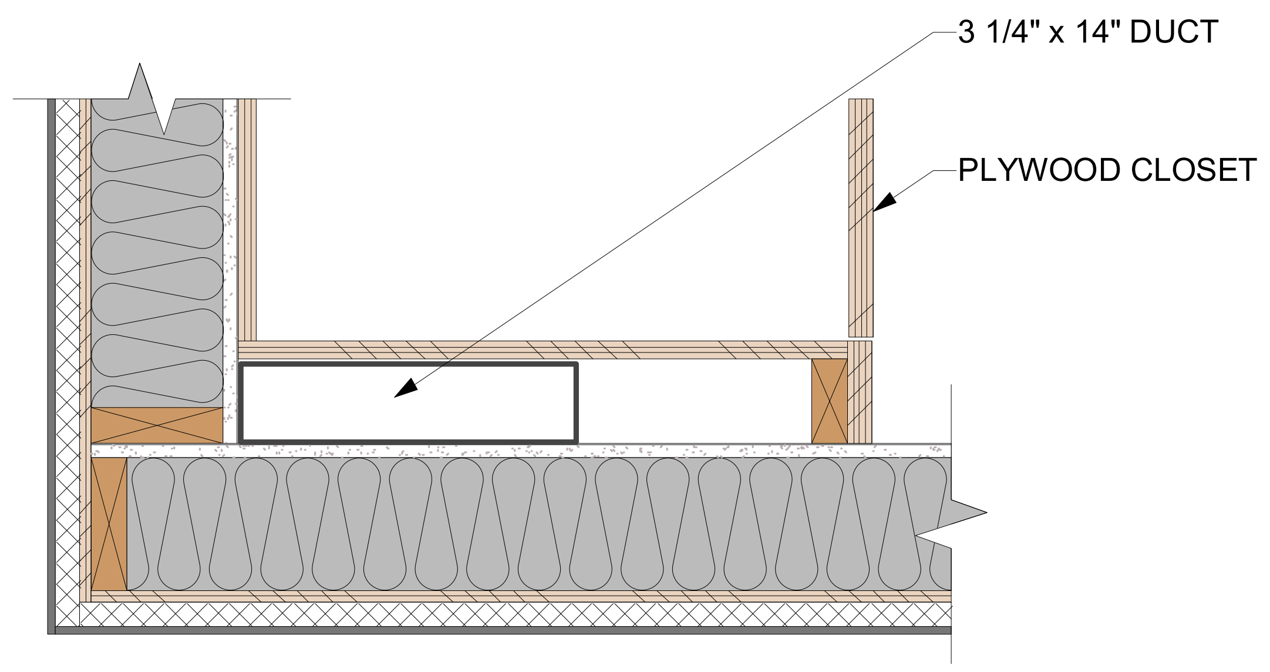
Drawn by: NJB, MC Checked: DS
Scale: 1/4"=1'0" Date: 02.27.09
ZETA Project No.: 0811

A6.1

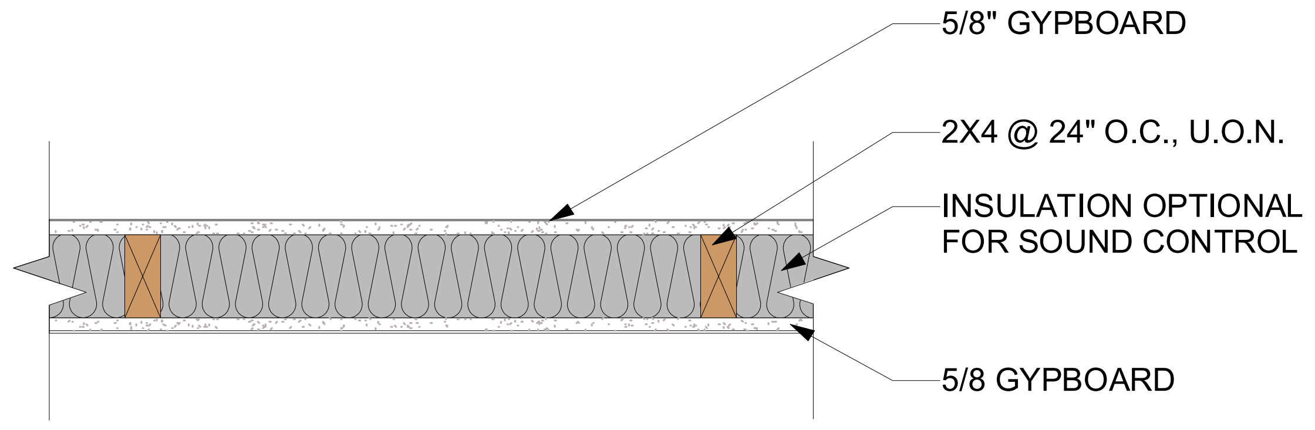
4



1 WINDOW FRAMING - JAMB
Scale: 3" = 1'-0"



5 CLOSET @ DUCT
Scale: 1 1/2" = 1'-0"



A WALL TYPE - INT. 2X4
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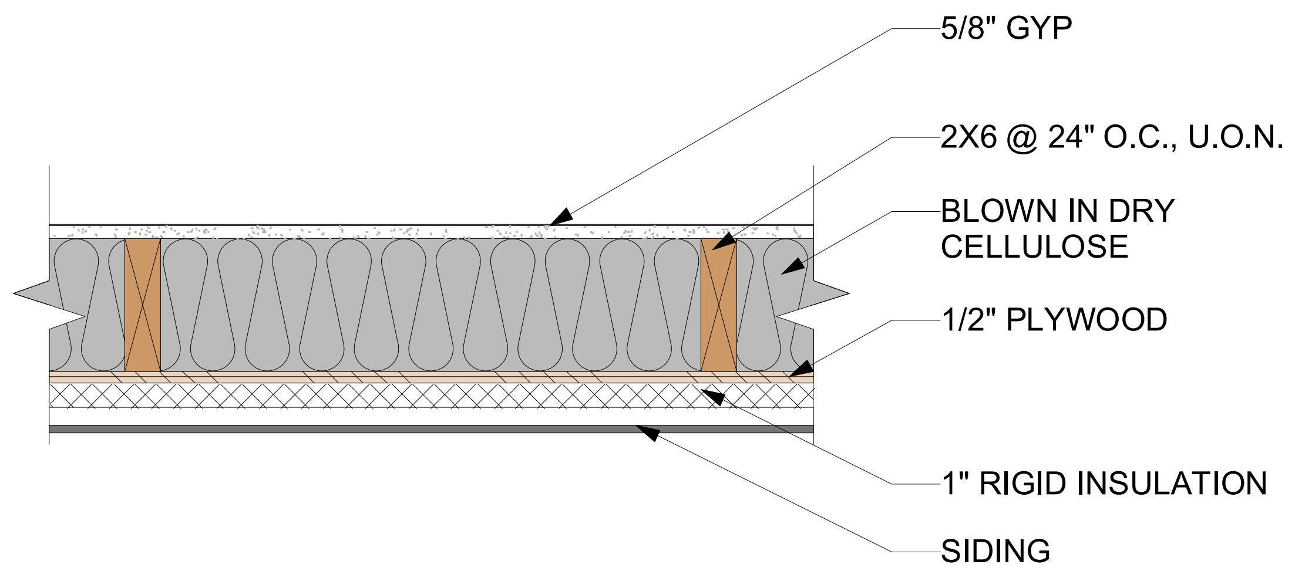
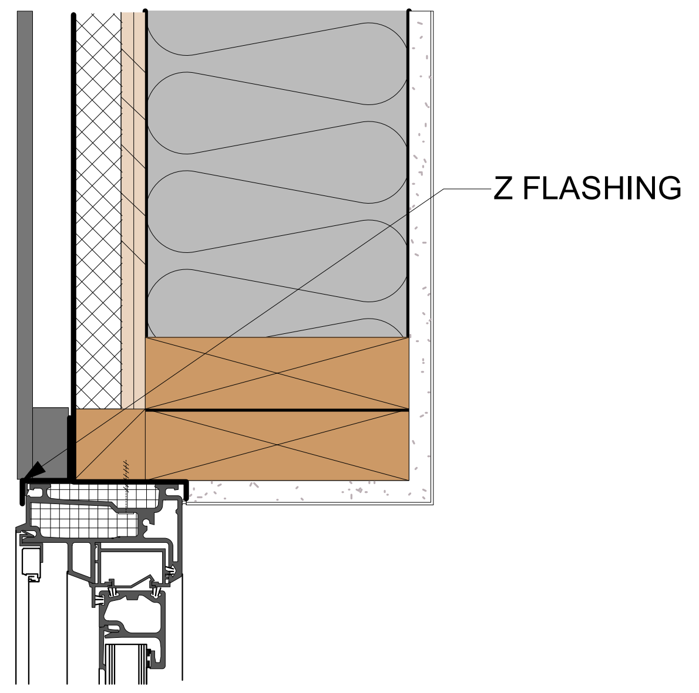
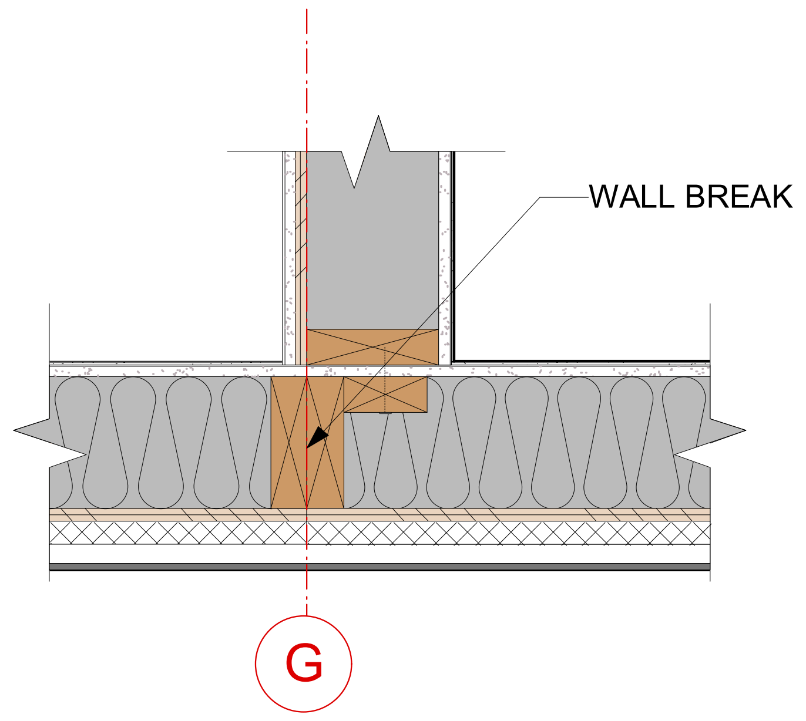


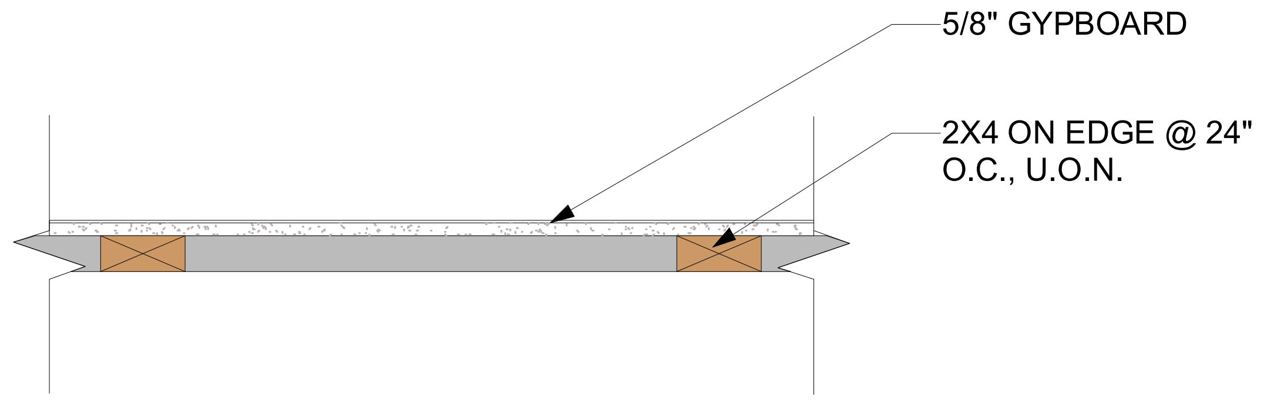
E WALL TYPE - EXT. 2X6
Scale: 1 1/2" = 1'-0"



2 WINDOW FRAMING - HEAD
Scale: 3" = 1'-0"



6 WALL FRAMING - LINE G
Scale: 1 1/2" = 1'-0"



B WALL TYPE - PLUMBING CORE
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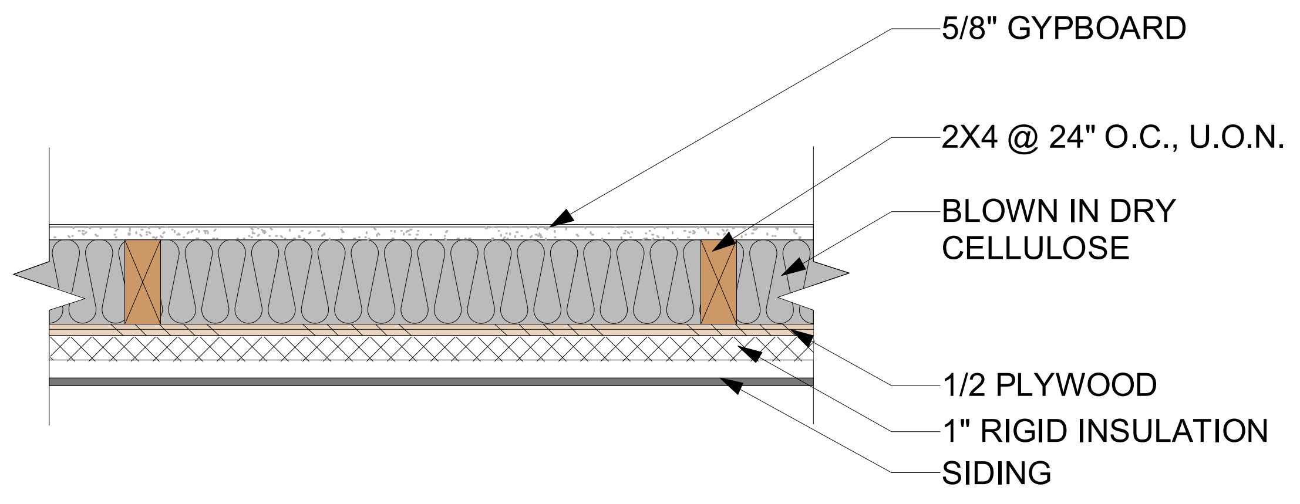

F WALL TYPE - EXT. 2X4
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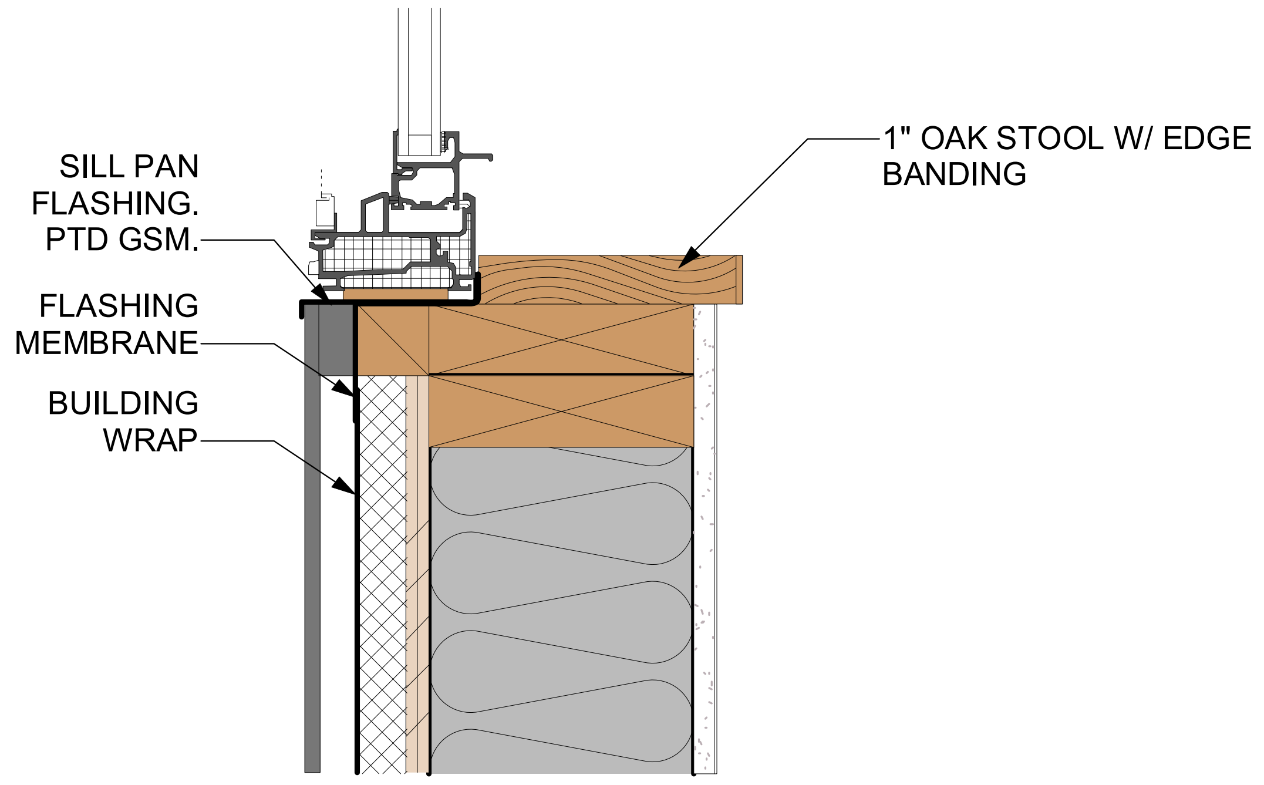

3 WINDOW FRAMING - SILL
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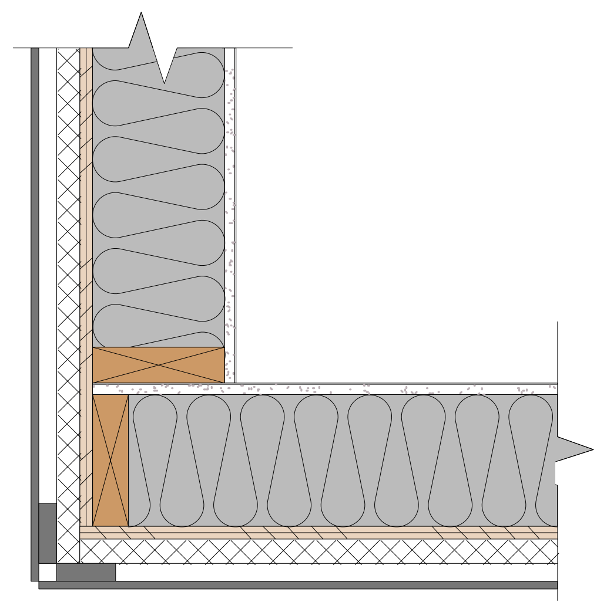

7 WALL FRAMING - CORNER
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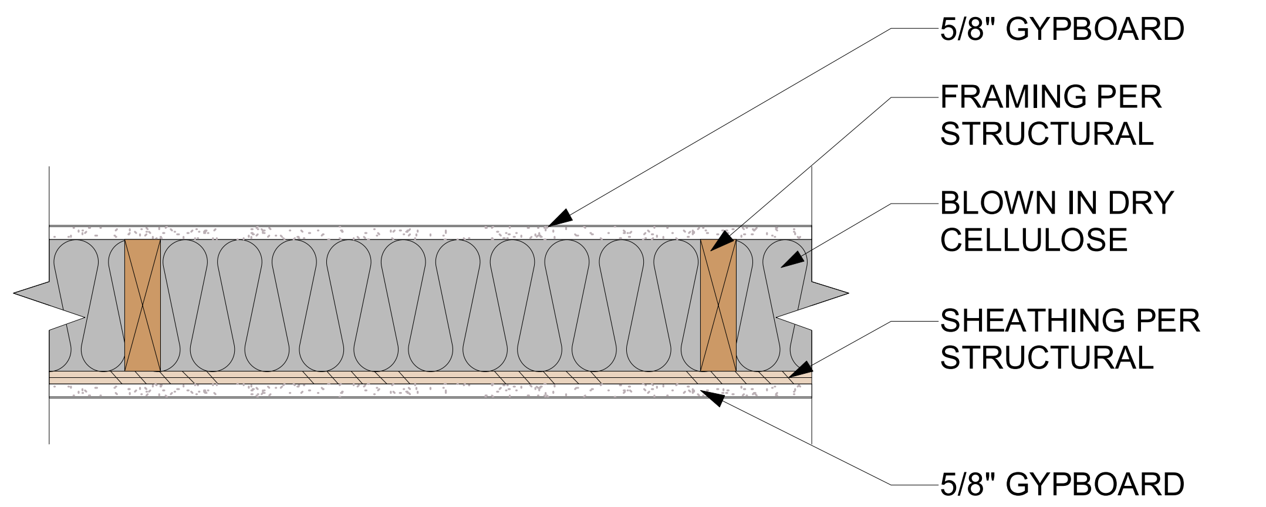

C WALL TYPE - INT. SHEAR WALL
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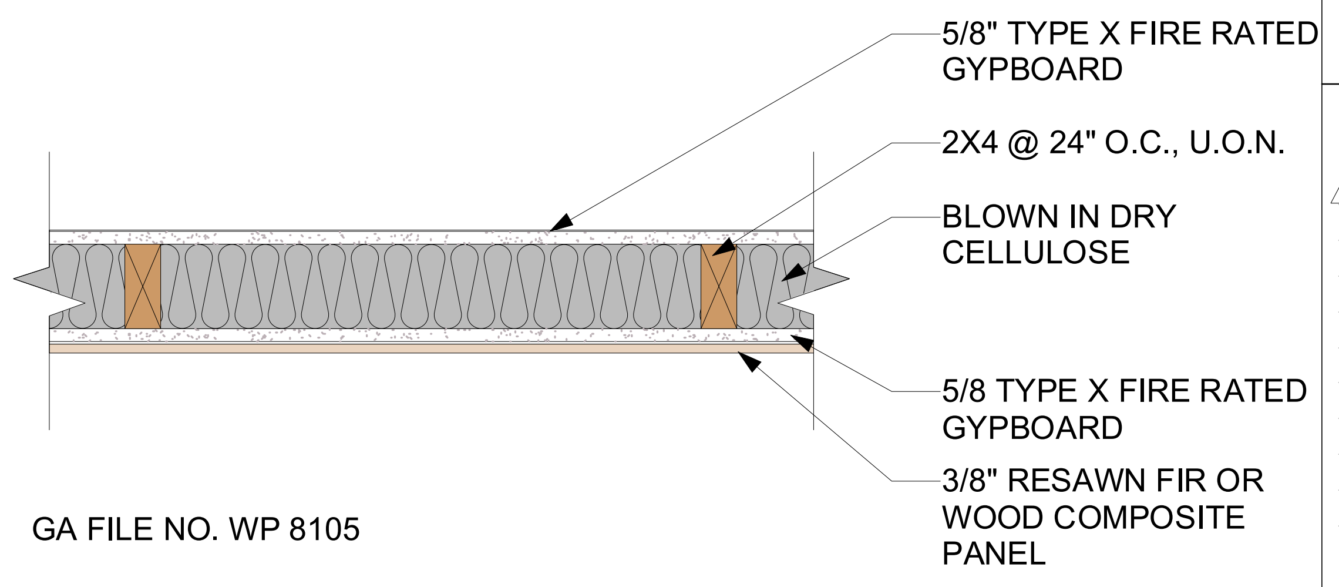
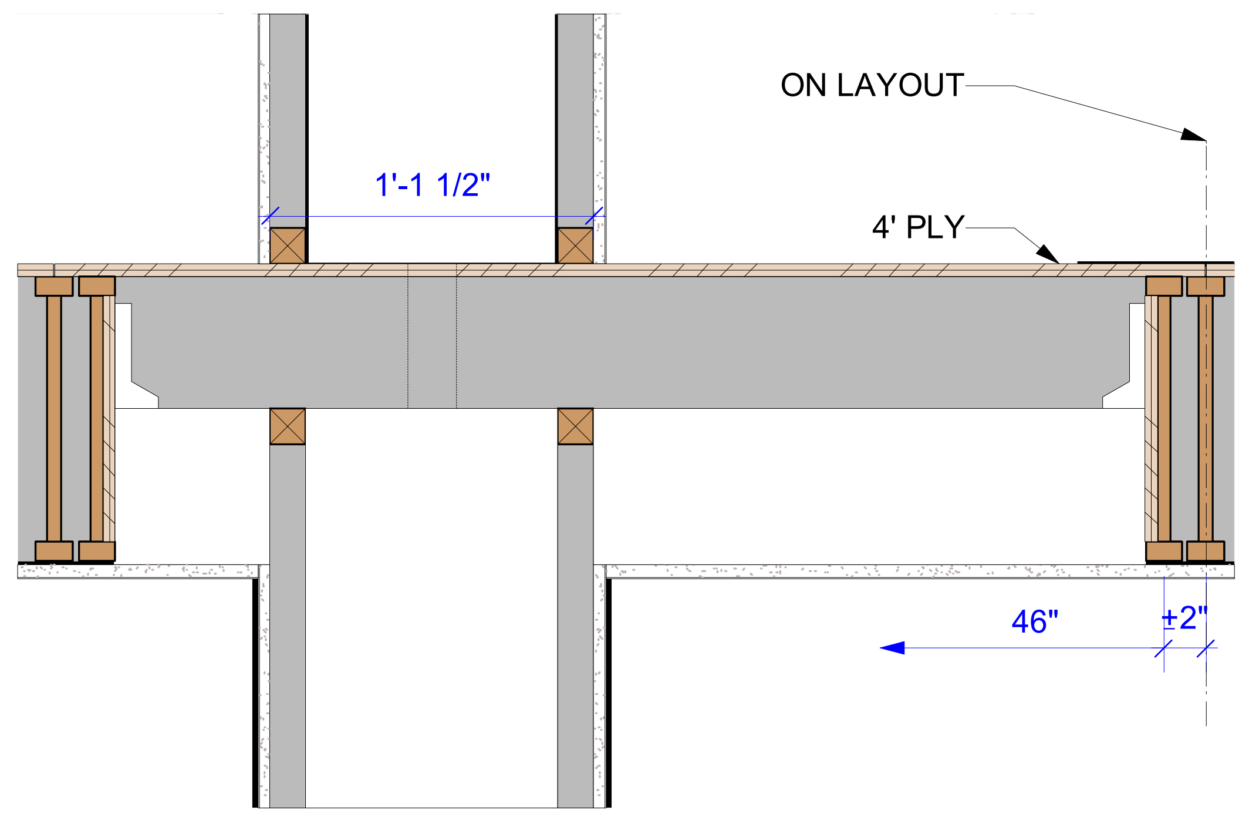
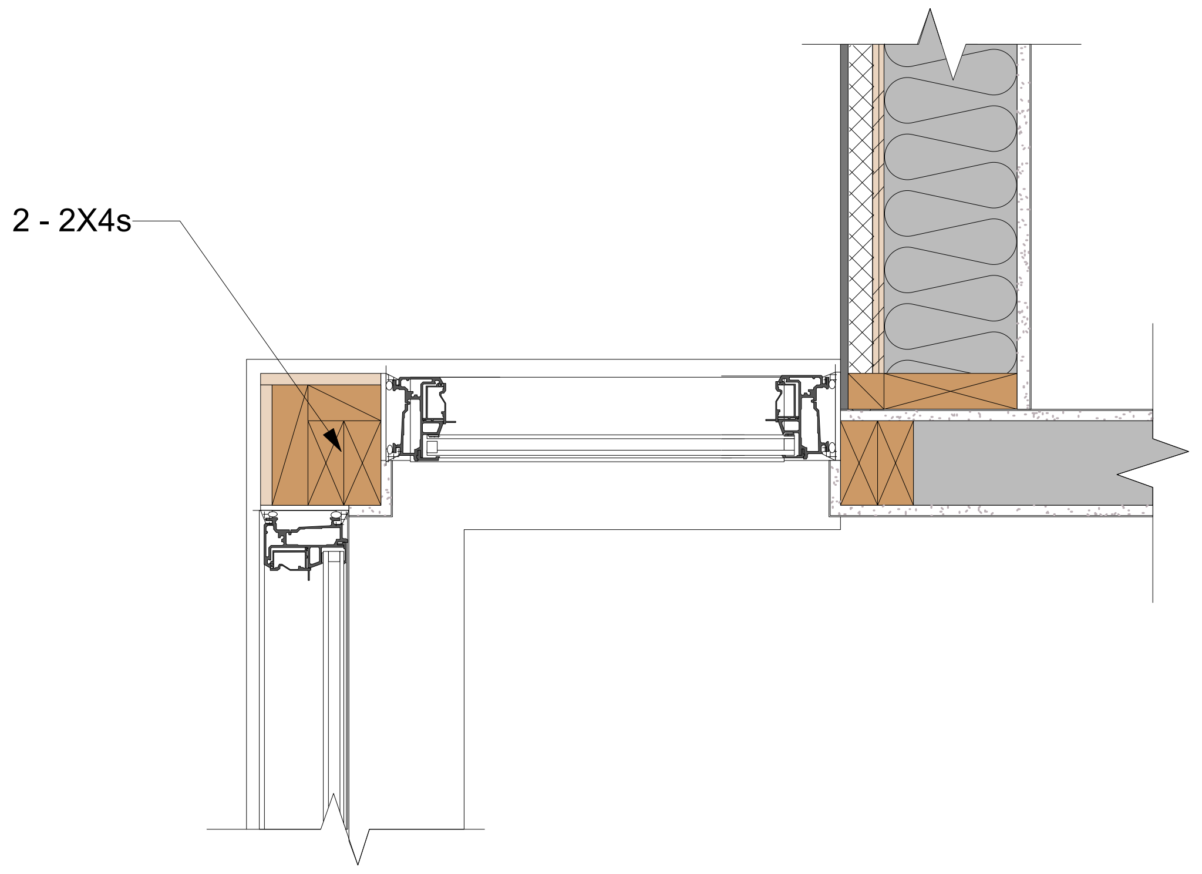


G WALL TYPE - EXT. 2X4 PARTY WALL
Scale: 1 1/2" = 1'-0"



4 UTILITY CORE FRAMING
NOTE: S.S.D.
Scale: 1 1/2" = 1'-0"



8 CORNER WINDOW
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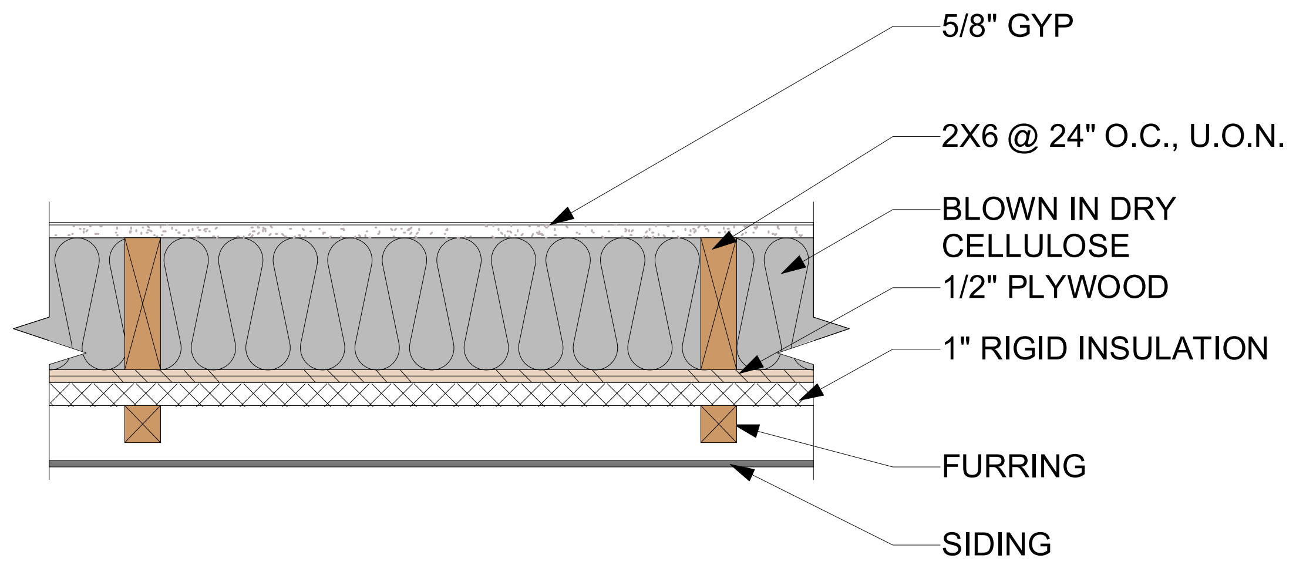

D WALL TYPE - EXT. 2X6 W/ FURRING
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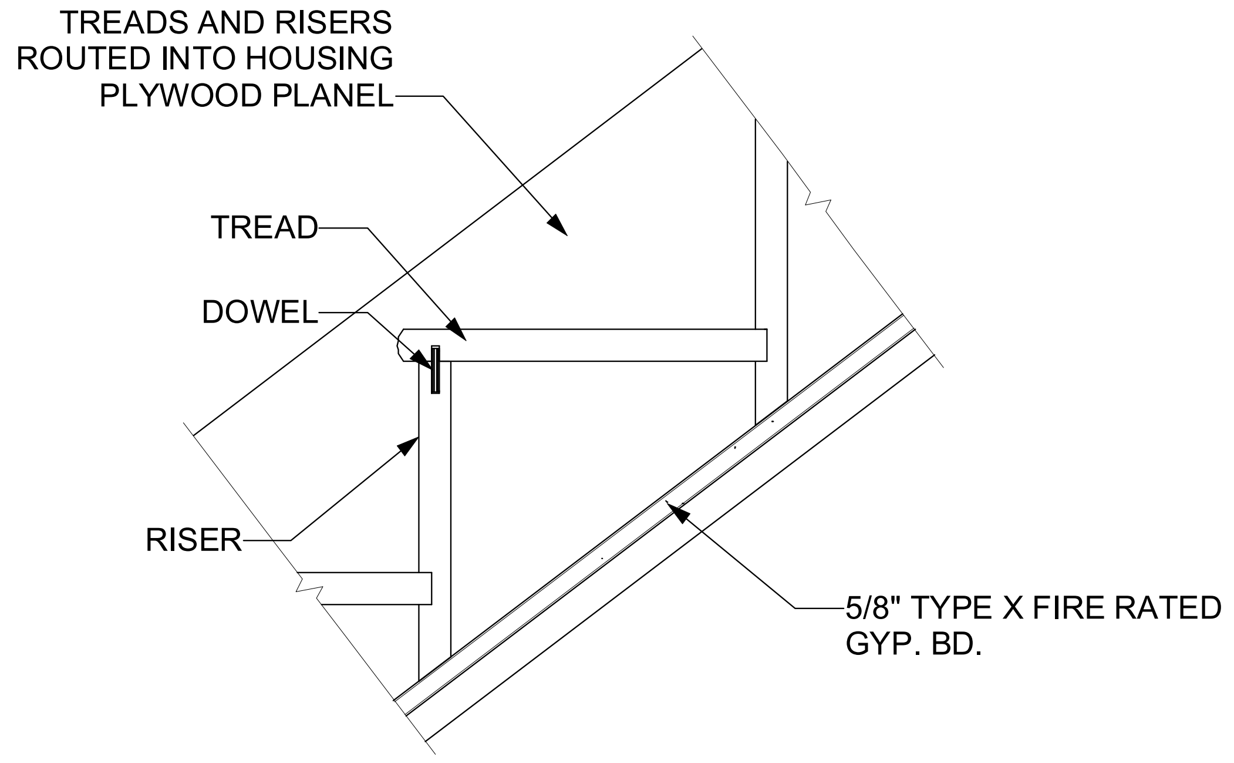

8 TYP. STAIR TREAD
Scale: 2" = 1'-0"

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Seal & Signature:

Revisions:	Date:
1 State Submittal	1.20.09

Lancaster Lofts

Owner & Developer:
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Sheet contents:
DETAILS

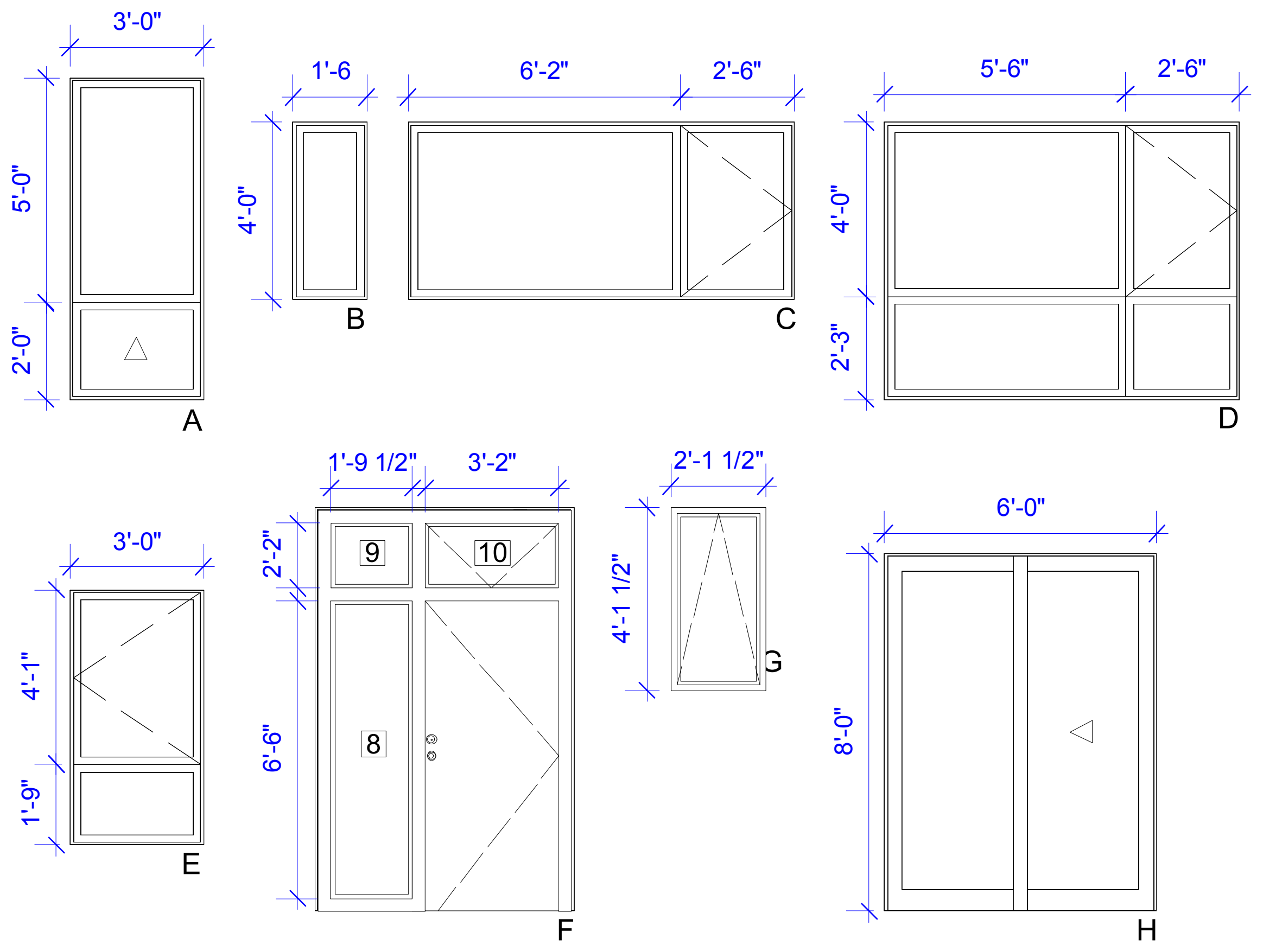
Drawn by: NJB, MC Checked: DS
Scale: Date: 01.20.09
ZETA Project No.: 0811

A6.2

WINDOW SCHEDULE 01

#	LOCATION	W	H	TYPE		NOTES
1	WORK	3'0"	7'0"	A	SINGLE HUNG	2'0" VENT, VENT TEMPERED
2	WORK	3'0"	7'0"	A	SINGLE HUNG	2'0" VENT, VENT TEMPERED
3	BEDRM 2	8'8"	4'0"	C	FIXED/CASEMENT	2 PANES TOTAL, SLIDER VENT 2'6" X 4'0", EXIT WINDOW
4	BEDRM 2	1'6"	4'0"	B	FIXED	
5	BEDRM 1	8"0"	6'3"	D	FIXED/CSMT OVER FIXED/FIXED	4 PANES TOTAL, CSMT 2'6" X 4'0", EXIT WINDOW, LOWER TEMPERED
6	LIVING RM	3'0"	5'10"	E	CSMT OVER FIXED	2 PANES TOTAL, CASEMENT: 4'1" X 3'0", FIXED: 1'9" X 3'0", CASEMENT FRAME
7	LIVING RM	3'0"	5'10"	E	CSMT OVER FIXED	2 PANES TOTAL, CASEMENT: 4'1" X 3'0", FIXED: 1'9" X 3'0", CASEMENT FRAME, NOTE #7 IS REV. SWING
8	ENTRY	1'9 1/2"	6'6"	F	FIXED	TEMPERED
9	ENTRY	1'9 1/2"	2'2"	F	FIXED	
10	ENTRY	3'2"	2'2"	F	HOPPER	
SKYLIGHT						
A		2' 1 1/2"	4' 1 1/2"	G	SKYLIGHT	CURB MTD, ELEC. OPERATED

NOTES
1 Width and Height are rough opening sizes
2 Frames are fiberglass, with nail on fins if available, without wood jamb extensions,
3 Glazing to be dual, with Low-E soft coat; optional pricing for triple glazing w/Heat Mirror.
4 Provide R rating of window assemblies.
5 Flashing: head Z flashing, jamb z flash if not provided, and sill pan flashing by G.C.
6 Provide alternate price for #1 and #2 as awning.
7 Skylight size is outside of 2x4 curb



DOOR SCHEDULE 01

MARK	LOCATION	W	H	THK.	TYPE	MANUF. #	FINISH	GLAZING	REMARKS
1	ENTRY	3'0"	6'8"	1 3/4"	WD	TBD	PT. GRADE	---	swing simple, transom, 2'5" sidelight
2	GARAGE TO OUTSIDE	6'0"	8'6"	1 3/4"	WD	TBD	PT. GRADE	FULL	overhead garage door
3	GARAGE TO FOYER	3'0"	6'8"	1 3/4"	WD	TBD	PT. GRADE	---	swing simple
4	GARAGE TO MECHANICAL	2'6"	6'8"	1 3/8"	WD	TBD	PT. GRADE	---	swing simple, 10x10 grill
5	HALL TO BATHROOM	2'6"	6'8"	1 3/8"	WD	TBD	PT. GRADE	---	swing simple
6	WORK AREA TO OUTSIDE	6'0"	8'0"	1 3/4"	WD	TBD	PT. GRADE	FULL	slider
7	HALL TO BEDROOM 2	2'6"	6'8"	1 3/8"	WD	TBD	PT. GRADE	---	swing simple
8	HALL TO BEDROOM 1	2'6"	6'8"	1 3/8"	WD	TBD	PT. GRADE	---	swing simple
9	HALL TO CLOSET	1'8"	6'8"	1 3/8"	WD	TBD	PT. GRADE	---	swing simple
10	HALL TO BATHROOM	2'6"	6'8"	1 3/8"	WD	TBD	PT. GRADE	---	swing simple
11	BATHROOM TO CLOSET	3'6"	6'8"	1 3/8"	WD	TBD	PT. GRADE	---	swing bi-part
12	HALL TO LAUNDRY	4'9"	6'8"	1 3/8"	WD	TBD	PT. GRADE	---	bi-part bi-fold, louvered
13	DINING ROOM TO OUTSIDE	6'0"	8'0"	1 3/4"	WD	TBD	PT. GRADE	FULL	slider

3. CONCRETE:
   1) Foundation: Site-built 8" cast in place walls with 8"x15" footings, see Struc. Drawings

4. MASONRY: n.a.

5. METALS:
   1) Railings: Interior metal railings/guardrail at stairway. Exterior cable railings at decks, see elev.

6. FRAMING, CARPENTRY:
   1) Exterior walls to be 2x6 at 24" o.c. typ., with 7/16" OSB w/no added formaldehyde

      Interior walls to be 2x4 at 24" o.c. typ.
   2) Floor Joists to be 2x10 DF#2 at 24" o.c. first floor; 12" I-joists at 2nd floor.
   3) All framing lumber to be FSC, dry.
   4) Garage to be included as part of the lower south unit, with a temporary floor bracing. The garage slab to be site built.
   5) Cabinets: use formaldehyde free MDF (Medite II), wheatboard, or alternative materials, to be custom built CNC cut maple hardwood ply veneers. Countertops to be Paperstone or concrete.

7. THERMAL, MOISTURE
   1) Exterior wall cavity insulation to be blown in cellulose; with 1" XPS foam outside the sheathing.
   2) Roof insulation: dense pack cellulose filling the unvented roof cavity, with 1" R5 rigid insulation board over the sheathing. Celllulose to be borate treated.
   3) Foundation Insulation: R5 rigid outside conc wall and under slab floor:
   4) Floor over conditioned basement area: no insulation.
   5) Lap Siding: Fiber-Cement 8" smooth lap siding, Hardie or equal, painted.
   6) Panel Siding: Hardi "Matrix"5/16: fiber cement panels with ½" reveal joints. Vertical joints over 5/8" Hardi battan, Horizontal joints to have Hardi recommended extruded Fry aluminum reglets. Panels have pre-painted edges and backs, with face and reveals painted out. Matrix panels to have finish nails, countersunk, painted out. Side walls, rear half, to have standard Hardie cement panels, face nailed and painted out.
   7) Flat and low slope roof to be "modified" roofing, with under course pre-installed, and continuous top ply site applied.
   8) Roof outlets: flat roof to slope to corner scuppers, to 2x3 downspouts, to closed subsurface 3" PVC pipes to approved site dissipation area (perhaps to south edge of property.)
   9) Foundation waterproof membrane: Grace Co. Bituthane.

8. WINDOWS, DOORS
   1) Windows to be fiberglass frame, see Window Schedule
      i) Interior oak veneer, clear sealed
   2) Skylight to be dual glazed Low-E, elec. operating opener, by Velux or equal. With exterior or internal shading.
   3) Finish hardware
      i) Provide finish hardware complete and as required for completion of the work including matching fastenings and any auxiliary interconnecting devices necessary for proper function, hardware to be Schlage A series or equal.
   4) Glazing
      i) Double Lo-E insulated glazing minimum for exterior doors and windows, see schedules
      ii) Safety glass (CBC 2406.3)
         (1) All glazed openings in entry doors with a diameter greater than 3"
         (2) All fixed lights within a 24" arc of the vertical edge of an entry door
         (3) All glazing with an exposed individual pane area greater than 9 SF
         (4) All glazing in French & sliding doors
         (5) All glazing with an exposed bottom edge less than 18" above the floor; with an exposed top edge greater than 36" above the floor; or with one or more walking surfaces within 36" horizontally of the plane of the glazing
   5) For window operation, direction or fixed, see elevations and window types drawing.
   6) Emergency windows: 7 sq. ft. w/ min. 24" height, min. 20" width & max. sill height of 44" per UBC 310.4, see window schedule.
   7) Sliding Glass Door: Fiberglass frame, dual glaze, see schedule.
   8) Entrance door: solid wood; side lite to door to be tempered or laminated safety glazing (UBC 2406.2-4)
   9) All required tempered glass panels are to be permanently marked by manufacturer. Provide tempered glass per CBC 2606.4 when glass is:
      i) Within 24" of either side of any door
      ii) Greater than 9 sq. ft. in area w/ bottom edge less than 18" above (& horizontally within 36") of walking surface.
   10) Interior doors to be solid core flush, formaldehyde free. Verify rough openings prior to ordering doors.

9. FINISHES:
   1) Exterior Siding: 2 coats
   2) Interior Walls and Ceilings:
      i) Wall board to be mold resistant at exterior walls, 5/8" typ.
      ii) Low-VOC paint to GS-11/LEED standard (< 50g/L for flat and <150g/L non-flat). Examples:
         (a) Kelly-Moore Enviro-Cote Interior
         (b) Benjamin Moore Eco-Spec Interior
   3) Flooring:
      i) Main floor, Concrete , 2" with steel fiber reinforcing, smooth sealed finish with control joints
      ii) Upper floor: Hardwood
      iii) Stairs: ¾" Maple hardwood ply treads and risers, with hardwood nosings
      iv) Baths and Kitchen floors to be ceramic tile
   4) Ceramic Tiles at bath surround over cement board over water barrier.
   5) Kitchen back splash to be stainless steel or ceramic tile.

10. SPECIALTIES
   1 Bath Mirror/Medicine Cabinet
   2 Toilet Paper holder.
   3 Bath/Shower: Rod and curtain.

11. EQUIPMENT: APPLIANCES
   1) All appliances to be electric, Energy-Star rated where applicable.
      i) Range/Oven: Possible: Kenmore 30 in. Electric Self Cleaning Stainless Steel Range, or inductive.
      ii) Exhaust hood at range.
      iii) Dishwasher: 24" Kenmore Stainless Steel Energy –Star rated
      iv) Washer/Dryer: Frigidaire Laundry Center, 27"W x 31" D, Energy-Star rated (GLEH1642FS)
      v) Refrigerator: Frigidaire Stainless 26 cu. Ft Side By Side

12. FURNISHINGS
   1) Cabinets: see 6.5
   2) Countertops: see 6.6

For additional general notes, see sheet MEP1.1

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Seal & Signature:

Revisions:	Date:
1 State Submittal	1.20.09

Lancaster Lofts

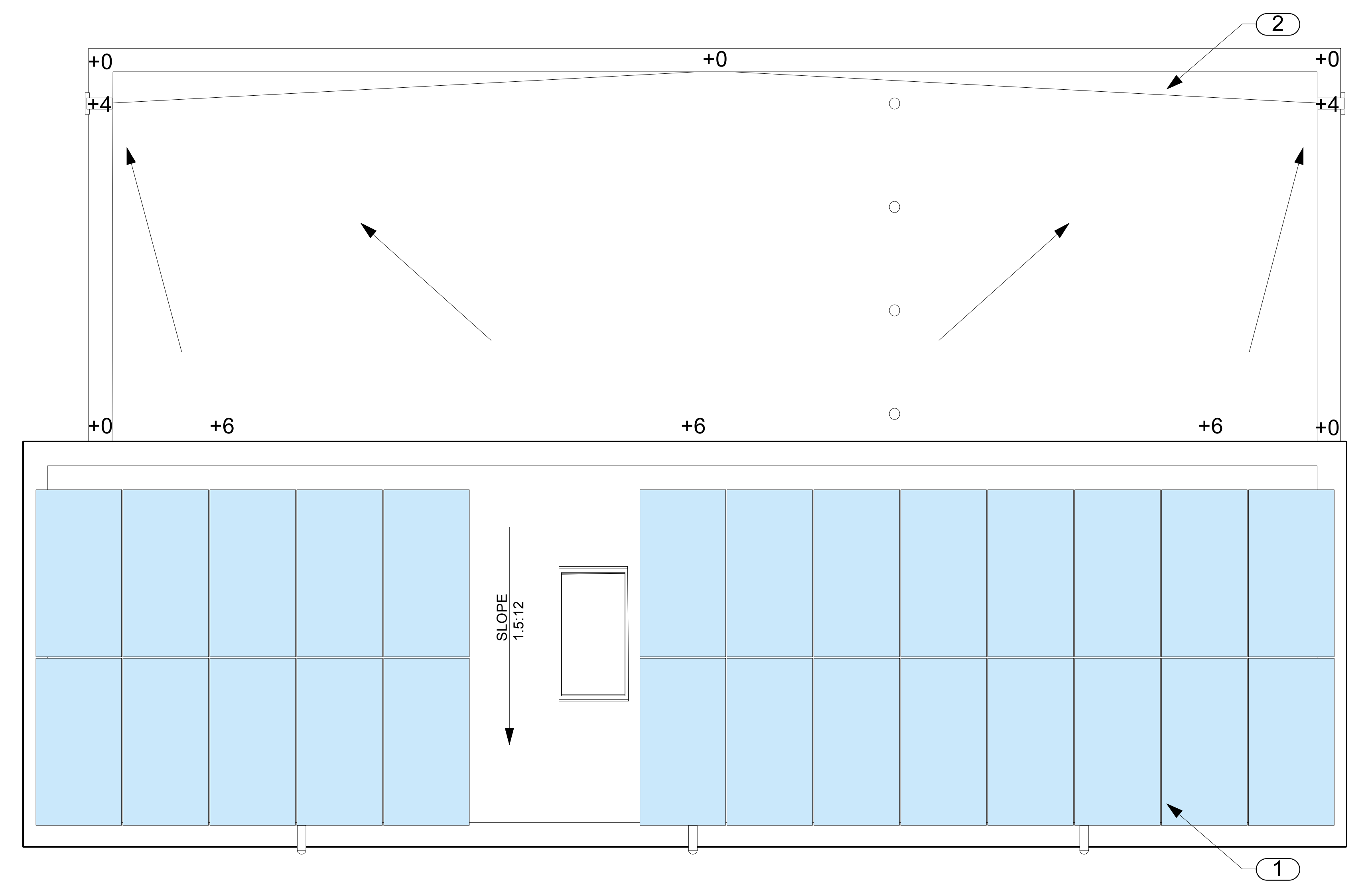
Owner & Developer:
Malpas

Sheet contents:

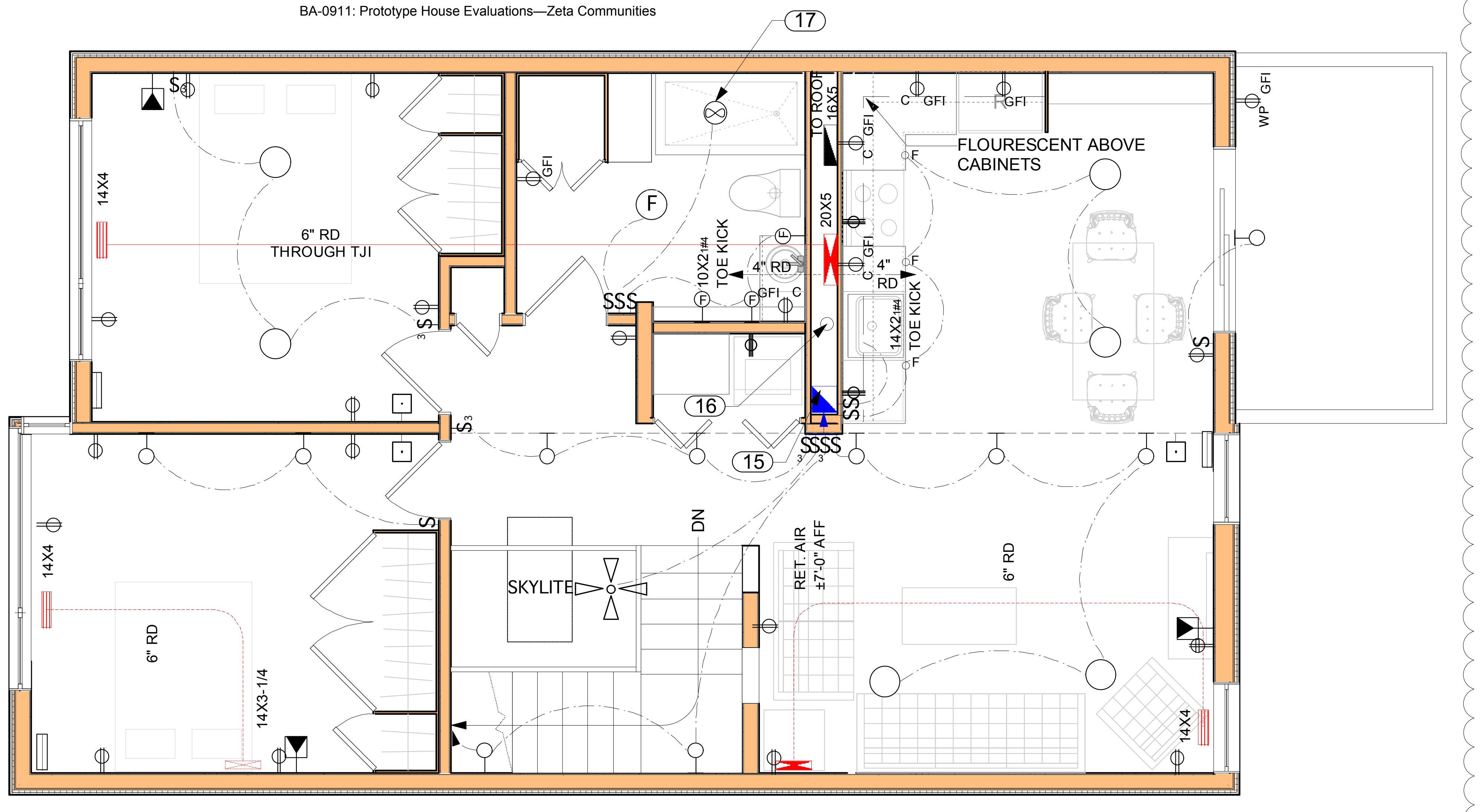
WINDOW & DOOR SCHEDULES

Drawn by: NJB, MC Checked: DS
Scale: 1/4"=1'0" Date: 01.20.09
ZETA Project No.: 0811

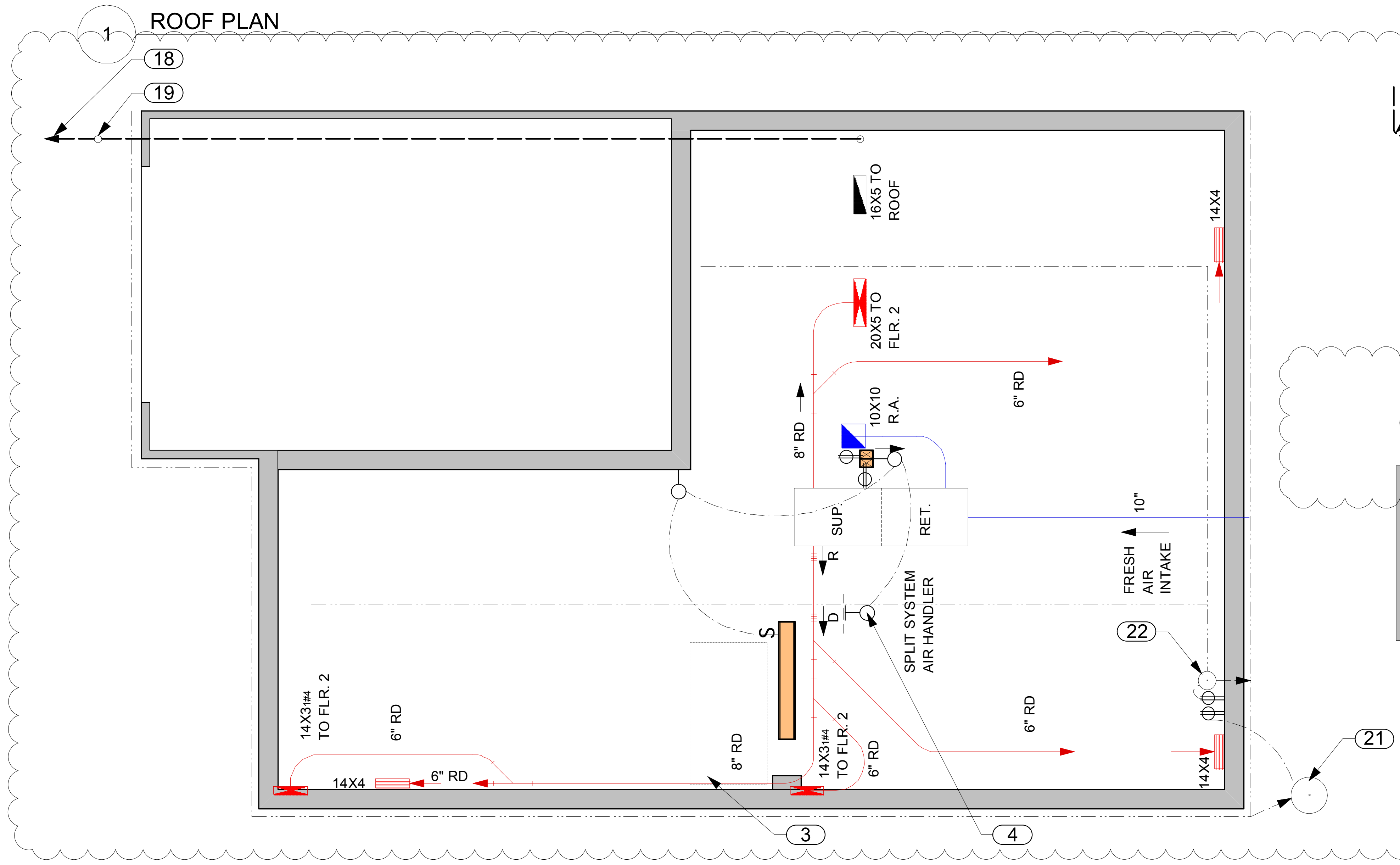
A7.1



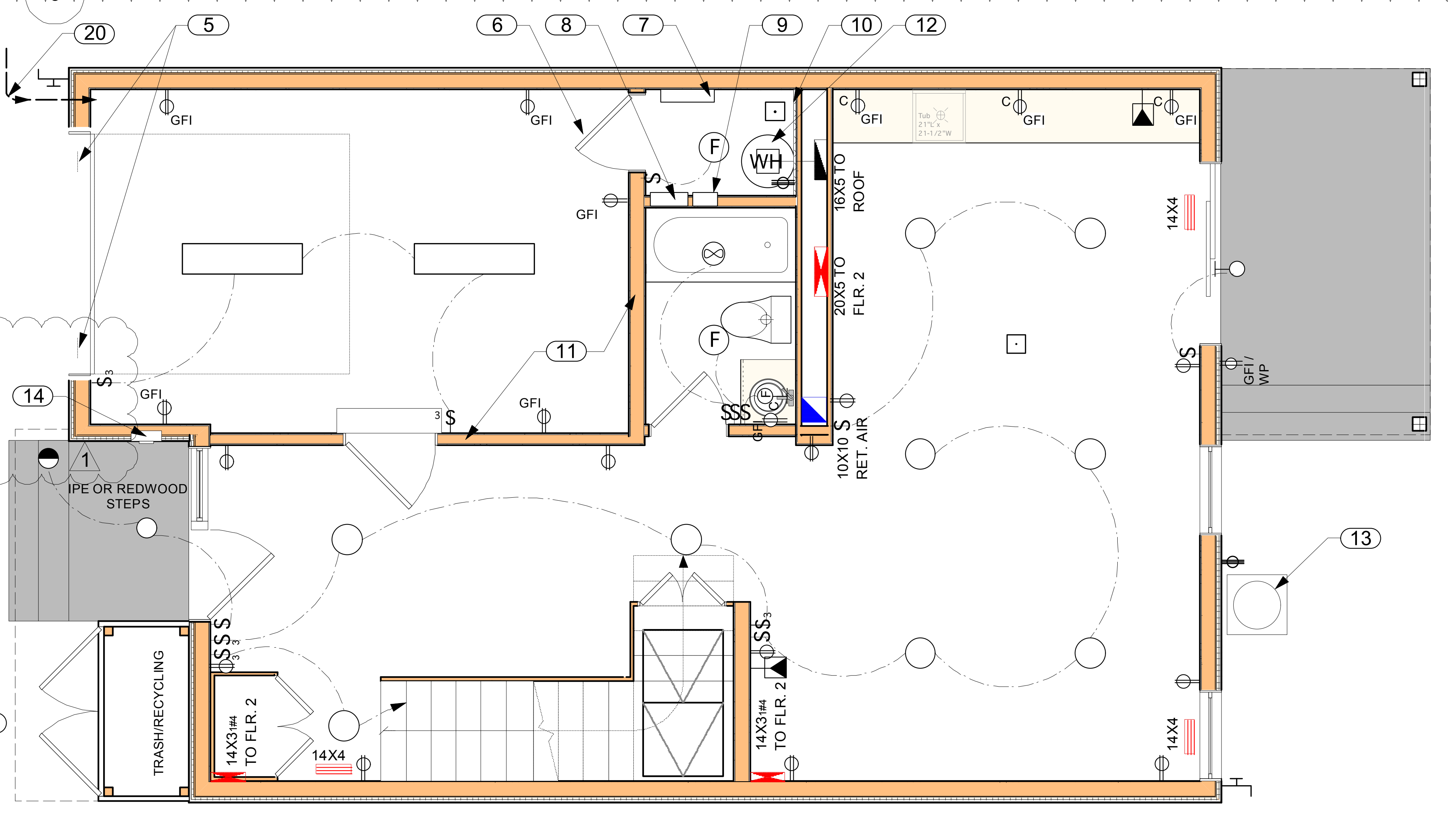
1 ROOF PLAN



3 SECOND FLOOR PLAN



2 FOUNDATION / BASEMENT PLAN



4 FIRST FLOOR PLAN

13. SPECIAL CONSTRUCTION:

1) Photovoltaic System: Crystalline panels with grid intertie system: units to have wiring from mechanical room to roof, with roof brackets. Panels to be site installed.

2) Water Heating: Heat Pump, Air-Tap, with air in from garage and venting thru the utility core to the roof, on standard 40 ga. electric tank (A.O.Smith, or equiv).

3) Waste water heat recovery device, GFX, located in the utility core on 1st floor, preheats incoming water with drain water from upstairs shower and clothes washer.

15: MECHANICAL, PLUMBING

1) Heating/Cooling to be Split System Heat Pump: Goodman 1.5 ton or equal. The condenser is site mounted on the north side, and the air handler and supply ducting is located in the conditioned underfloor area, and is to be site installed. The units are to have the floor registers and the vertical duct risers for the second floor and the air return from the top of the stair well, all pre-installed. Outside air intake to be site done.

4) Plumbing Fixtures:

i) Low flow fixtures typical; white.

ii) Toilets: dual-flush, Toto CST414M, Caroma Royale 305m, or equal

iii) Lav's: white ceramic underslung

iv) Kitchen Sink: Stainless Steel 24": deep single bowl;

Faucet: Low flow:

v) Garbage Disposal: Insinkerator 77 or equiv.

vi) Tub: Americast or porcelin steel 30" x 60"

Bath/Shower Faucet:

vii) Shower Pan: 33" x 60" terrazzo pan w/tile flanges 3 sides (Florestone),

Shower Faucet:

16: ELECTRICAL

1) House to have a 200 amp panel in the mechanical room with provision for the site installed grid intertie PV system.

2) Light Fixtures: all CFL or LED bulbs, with dedicated fluorescent fixtures in Kitchen and bath as required by Code.

3) Low-voltage: Phone/Data wired complete to control panels in Utility Room.

4) Custom House Controller for HVAC system: as specified by Bldg Science.

HVAC KEY

◩	RETURN AIR DUCT
⊠	SUPPLY DUCT
▥	FLOOR REGISTER
→ R	DUCT RISE
→ D	DUCT DECLINE
⟋	WYE DUCT
—	ROUND SUPPLY DUCT
→	DIRECTION OF FLOW

X

⊖	Duplex Outlet - 16" A.F.F.
⊖	Split-Wired Duplex Outlet
⊖	220 Volt Duplex Outlet
H	High Outlet - 48" A.F.F.
C	Counter Outlet - 42" A.F.F. w/ GFI
GFI	Device equip'd w / Grnd. Fault Interupter
WP	Weather proof Device
WP/S	W. Proof Device, light sensor controlled
$\$$	Switch + 48" A.F.F.
$\$_3$	Three-Way Switch + 48" A.F.F.
$\$_D$	Dimmer Switch + 48" A.F.F.
$\$^3_D$	Dimmer Switch, Three-Way + 48" A.F.F.
$\$_T$ $\$^3_T$	Switch Timer/Motion Sensor+ 48" A.F.F.
○	Flourescent - Ceiling, surface mounted
○	Spot Light
⊢○	Light Fixture - Wall Mounted u = up d = down
▭	Fluorescent - 1' x 4'
F	Fluorescent (high efficacy)
▷—	Single Telephone Jack
▶—	Data Jack: 2- Cat 5, 2- RG-6
□—	TV Jack
⊡	Smoke Detector - 110 V w/ batt. back-up
T	Thermostat
J	Junction Box
▭	Meter and Main Panel
	Exhaust Fan
— — —	Flourescent tubes above cabinet
⊢	Hose Bib, Water Tab
✣	Ceiling Fan
TMV	Thermostatic mixing valve
▷—	Shower head

KEY NOTES

* NOTE: MEHCANICAL PLANS TYP. OF EACH UNIT

1. SOLAR PV PANELS ON GRID 4" OFF ROOF
2. CRICKET
3. HATCH
4. LIGHT FIXTURE ATTACHED TO JOIST ABOVE
5. 2 - 8X8 VENT GRILLS ABOVE DOOR
6. 10X10 VENT GRILL IN DOOR
7. PV INVERTER
8. CIRCUIT PANEL
9. PHONE DATA
10. 1" RIGID INSULATION
11. GARAGE CEILING AND WALLS INSULATED
12. HEAT PUMP WATER HEATER. STRAP BRACE TO WALL.
13. CONDENSER UNIT ON CONCRETE PAD.
14. ELECTRIC METER & PV DISCONNECT
15. 10X10 RETURN AIR ± 7' A.F.F.
16. GFX WASTE WATER HEAT EXCHANGER
17. PANASONIC HEAT EXCHANGER BATH VENT
18. (N) 4" CAST IRON LATERAL PIPE OUT TO STREET
19. (N) CLEAN OUT
20. 1" WATER SUPPLY PIPE
21. SUMP PUMPS TO CURB W/ 4" SUB-SURFACE DRAIN PIPES.
22. BACK UP SUMP W/ 3" DRAIN PIPES.

1

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Seal & Signature:

Revisions:	Date:
1 State Submittal	1.20.09

Lancaster Lofts

Owner & Developer:
Malpas

Sheet contents:

MECHANICAL
PLANS

Drawn by: NJB, MC Checked: DS
Scale: 3/16"=1'0" Date: 01.20.09
ZETA Project No.: 0811

MEP1.1

APPLIANCE SCHEDULE:

	Type	Model #	Amp	Volt.	Notes
1	Range/Oven	Kenmore 450003	50	240	Model 4500 Induction, slide in
2	Exhaust Hood	Kenmore 52613	15	120	Stain.Stl 30", mtd 24" above range
3	Dishwasher	Kenmore 13843	15	120	Stain.Stl.24"
4	Washer/Dryer	Frigidaire Laundry Center: GLEH1642FS	30	240	27"W X 31" D
5	Refrigerator	Frigidaire Stainless 26 cu. Ft. Side by Side	20	120	
6	Disposal	In-sinkerator	20	120	
7	Garage Door Opnr		15	120	

EQUIPMENT SCHEDULE

	NAME	TYPE	MODEL#	Conn.	REMARKS
1	Heat Pump	Split system	Goodman 1.5 ton	20a,220	Var. Spd. Fan, Merv13,10"dia.fresh air
2	Water Heater	Heat Pump	Air-Tap	30a,220	air in from garage and venting through utility core to roof, on standard 40 gallon electric tank
3	Waste Water Heat Recovery		GFX	3/4" copper	
4	PV System		210,SunnyBoy Inv.	20a,220	Crystalline panels with grid intertie

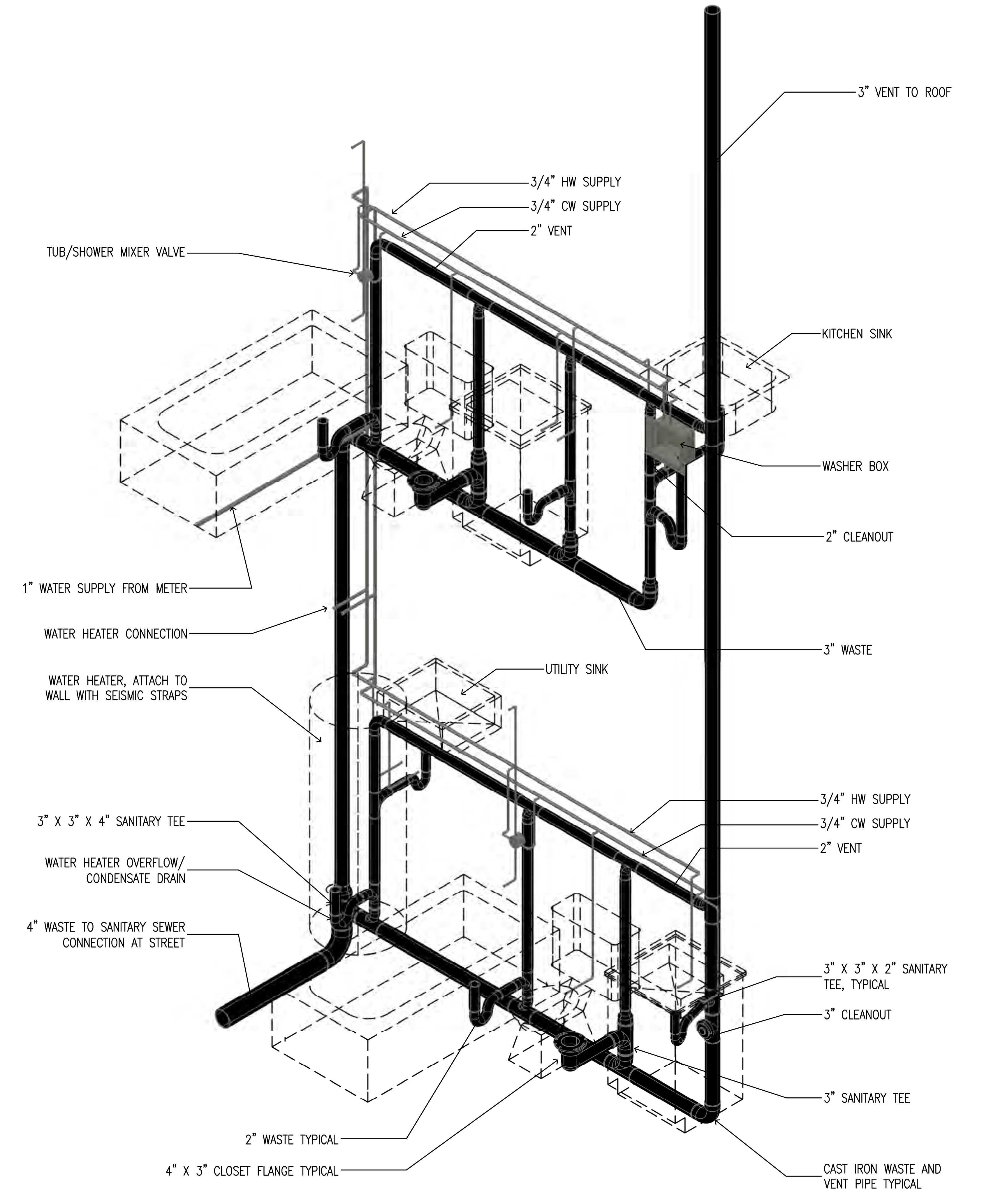
ELECTRICAL LOAD CALCULATION

	A	V	VA	Notes:
Area of house	1500sf@3w		4500	
Sm. Appliance circ.	2@1500		3000	
Laundry circ.			1500	
Sub Total			9000	
1st 3000va @100%			3000	
Balance @.35			2100	
Net Gen Ltg & Sm.Appl:			**5100**	
Range	50	240	8000	
Washer/Dryer	30	240	7200	
Heat Pump HVAC	20	240	4800	
Net Gen.Lgtg, Sm.Appl, Laun, range,HVAC,dryr.:			**25100**	
"Fastened in Place" appliances:				
Washer/Dryer	30	240	7200	
Dishwasher	15	120	1800	
Disposal	7.2	120	864	
Water Heater	30	240	7200	
Garage Door opener	5.8	120	696	
Sump Pump	8	120	960	
total fastened in place:			18720	
at 75%			**14040**	
Total:			**39140**	
Add 25% of Heat Pump			1200	
TOTAL LOAD			**40340**	
SERVICE	200	240	48000	

CIRCUIT PANEL SCHEDULE

		amp	voltage	Notes:	REMARKS
1	Kitchen sm appl	15	120		Electric Self-Cleaning Range
2		15	120		
3	Dining/Living	15	120		
4	Bedrooms	15	120	AFCI typ,see note	
5	Baths	20	120	GFCI typ, see note	
6	Entry,	15	120		
7	Work Area	20	120		
8	Laundry	20	120		
9	Garage	20	120		
10	Range	50	120/240	inductive	
12	Water Heater	12	120	Heat Pump	
13	Water Heater	30	240	back up tank	
15	Heat Pump	20	240		
17	Air Handler	20	120		
18	Wash/Dryer	30	120/240		
20	Dishwasher	15	120		
21	PV Inverter	20	120		
22	Refrigerator	20	120		
23	Ceiling Fan	15	120		
24	Disposal	15	120		

Note: Provide GFCI and AFCI protection as required by the Nat.Elec.Code Sections 210.8(A) and 210.12(B)



1 PLUMBING LAYOUT

1

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Revisions:	Date:
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Malpas

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SCHEDULES & PLUMBING LAYOUT

Drawn by: NJB, MC Checked: DS
Scale: Date: 01.20.09
ZETA Project No.: 0811

MEP1.2

TITLE 24 REPORT

Title 24 Report for:

Lancaster Lofts Unit 1 (South Unit)
612 Lancaster St
Oakland, CA 94601

Project Designer:

Dan Smith & Assiciates, Architects
1107 Virginia St.
Berkeley, CA 94702
510 526-1935

Report Prepared By:

Gene Clements
Gene Clements, Architect
2348 McKinley Avenue
Berkeley, CA 94703
(510) 549-1124

Job Number:

923

Date:

1/9/09

The EnergyPro computer program has been used to perform the calculations summarized in this compliance report. This program has approval and is authorized by the California Energy Commission for use with both the Residential and Nonresidential 2005 Building Energy Efficiency Standards.

This program developed by EnergySoft, LLC - www.energysoft.com.

EnergyPro 4.4 by EnergySoft | Job Number: 923 | User Number: 5020

TABLE OF CONTENTS

EnergyPro 4.4 by EnergySoft | Job Number: 923 | User Number: 5020

Certificate Of Compliance : Residential (Part 1 of 3) CF-1R

Project Title: Lancaster Lofts Unit 1 (South Unit)
Date: 1/9/09
Project Address: 612 Lancaster St Oakland
Building Permit #:
Documentation Author: Gene Clements, Architect
Telephone: (510) 549-1124
Plan Check/Date:
Compliance Method: EnergyPro
Climate Zone: CA Climate Zone 03
Field Check/Date:

TDV (kBtu/sf-yr)	Standard Design	Proposed Design	Compliance Margin
Space Heating	18.60	9.48	9.12
Space Cooling	5.69	3.17	2.52
Fans	1.01	0.58	0.42
Domestic Hot Water	12.99	15.03	-2.04
Pumps	0.00	0.00	0.00
Totals	38.28	28.26	10.03
Percent better than Standard:			26.2%

BUILDING COMPLIES - NO HERS VERIFICATION REQUIRED

Building Type: ☒ Single Family ☐ Addition ☐ Multi Family ☐ Existing + Add/Alt
Building Front Orientation: (SW) 240 deg
Fuel Type: Natural Gas
Fenestration:
Area: 311 ft² **Avg. U:** 0.31
Ratio: 19.1% **Avg. SHGC:** 0.51

Total Conditioned Floor Area: 1,625 ft²
Existing Floor Area: n/a ft²
Raised Floor Area: 297 ft²
Slab on Grade Area: 0 ft²
Average Ceiling Height: 8.8 ft
Number of Dwelling Units: 1.00
Number of Stories: 2

BUILDING ZONE INFORMATION

Zone Name	Floor Area	Volume	# of Units	Zone Type	Thermostat Type	Vent Hgt.	Vent Area
Heating	1,625	14,326	1.00	Conditioned	Setback	8	n/a

OPAQUE SURFACES

Type	Frame	Area	U-Fac.	Insulation Cav.	Insulation Cont.	Act. Azm.	Tilt	Gains Y	Gains N	Condition Status	JA IV Reference	Location / Comments
Wall	Wood	214	0.057	R-19	R-5.0	30	90	☒	☐	New	09-A5	Lower Floor
Wall	Wood	139	0.102	R-13	R-0.0	30	90	☒	☐	New	09-A3	Lower Floor
Door	None	20	1.450	None	R-0.0	30	90	☒	☐	New	28-A1	Lower Floor
Wall	Wood	174	0.057	R-19	R-5.0	120	90	☒	☐	New	09-A5	Lower Floor
Wall	Wood	372	0.057	R-19	R-5.0	210	90	☒	☐	New	09-A5	Lower Floor
Wall	Wood	198	0.057	R-19	R-5.0	300	90	☒	☐	New	09-A5	Lower Floor
Door	None	38	1.450	None	R-0.0	300	90	☒	☐	New	28-A1	Lower Floor
Floor	Wood	225	0.046	R-13	R-0.0	0	180	☐	☒	New	20-A3	Upper Floor
Floor	Wood	71	0.064	R-13	R-0.0	0	180	☐	☒	New	21-A3	Upper Floor
Wall	Wood	356	0.057	R-19	R-5.0	30	90	☒	☐	New	09-A5	Upper Floor
Wall	Wood	129	0.057	R-19	R-5.0	120	90	☒	☐	New	09-A5	Upper Floor
Wall	Wood	362	0.057	R-19	R-5.0	210	90	☒	☐	New	09-A5	Upper Floor
Wall	Wood	136	0.057	R-19	R-5.0	300	90	☒	☐	New	09-A5	Upper Floor
Roof	Wood	953	0.032	R-30	R-5.0	30	0	☒	☐	New	02-A9	Upper Floor

Run Initiation Time: 01/09/09 10:02:45 Run Code: 1231524165

EnergyPro 4.4 by EnergySoft | User Number: 5020 | Job Number: 923 | Page: 3 of 8

Certificate Of Compliance : Residential (Part 2 of 3) CF-1R

Project Title: Lancaster Lofts Unit 1 (South Unit)
Date: 1/9/09

FENESTRATION SURFACES

#	Type			Area	U-Factor[1]		SHGC[2]		True Azm.	Tilt	Cond. Stat.	Glazing Type	Location/ Comments
1	Window	Right	(SE)	91.5	0.310	NFRC	0.52	NFRC	120	90	New	Inline Fiberglass	Lower Floor
2	Window	Left	(NW)	29.9	0.310	NFRC	0.52	NFRC	300	90	New	Inline Fiberglass	Lower Floor
3	Window	Rear	(NE)	6.0	0.310	NFRC	0.52	NFRC	30	90	New	Inline Fiberglass	Upper Floor
4	Window	Right	(SE)	91.5	0.310	NFRC	0.52	NFRC	120	90	New	Inline Fiberglass	Upper Floor
5	Window	Left	(NW)	84.6	0.310	NFRC	0.52	NFRC	300	90	New	Inline Fiberglass	Upper Floor
6	Skylight	Rear	(NE)	7.5	0.400	NFRC	0.28	NFRC	30	0	New	Velux Skylights	Upper Floor

1. Indicate source either from NFRC or Table 116A. 2. Indicate source either from NFRC or Table 116B.

INTERIOR AND EXTERIOR SHADING

#	Exterior Shade Type	SHGC	Window Hgt.	Window Wd.	Overhang Len.	Overhang Hgt.	Overhang LExt.	Overhang RExt.	Left Fin Dist.	Left Fin Len.	Left Fin Hgt.	Right Fin Dist.	Right Fin Len.	Right Fin Hgt.
1	Bug Screen	0.76												
2	Bug Screen	0.76												
3	Bug Screen	0.76												
4	Bug Screen	0.76												
5	Bug Screen	0.76												
6	None	1.00												

THERMAL MASS FOR HIGH MASS DESIGN

Type	Area (sf)	Thick. (in.)	Heat Cap.	Cond.	Inside R-Val.	JA IV Reference	Condition Status	Location/ Comments

PERIMETER LOSSES

Type	Length	R-Val.	Insulation Location	JA IV Reference	Condition Status	Location/ Comments

Run Initiation Time: 01/09/09 10:02:45 Run Code: 1231524165

EnergyPro 4.4 by EnergySoft | User Number: 5020 | Job Number: 923 | Page: 4 of 8

Certificate Of Compliance : Residential (Part 3 of 3) CF-1R

Project Title: Lancaster Lofts Unit 1 (South Unit)
Date: 1/9/09

HVAC SYSTEMS

Location	Heating Type	Minimum Eff	Cooling Type	Minimum Eff	Condition Status	Thermostat Type
Heating	Split Heat Pump	7.70 HSPF	Split Heat Pump	13.5 SEER	New	Setback

HVAC DISTRIBUTION

Location	Heating	Cooling	Duct Location	Duct R-Value	Condition Status	Ducts Tested?
Heating	Ductless / with Fan	Ductless	n/a	n/a	New	No

Hydronic Piping

System Name	Pipe Length	Pipe Diameter	Insul. Thick.

WATER HEATING SYSTEMS

System Name	Water Heater Type	Distribution	# in Syst.	Rated Input (Btu/hr)	Tank Cap. (gal)	Condition Status	Energy Factor or RE	Standby Loss (%)	Tank Insul. R-Value Ext.
Airtap Heat Pump	Heat Pump	No Pipe Insulation	1	5,500	0	New	2.11	n/a	n/a

Multi-Family Central Water Heating Details

Control	Hot Water Pump #	Hot Water Pump HP	Hot Water Pump Type	Hot Water Piping Length (ft) In Plenum	Outside	Buried	Add 1/2" Insulation

REMARKS

COMPLIANCE STATEMENT

This certificate of compliance lists the building features and specifications needed to comply with Title 24, Parts 1 and 6 of the California Code of Regulations, and the administrative regulations to implement them. This certificate has been signed by the individual with overall design responsibility. The undersigned recognizes that compliance using duct design, duct sealing, verification of refrigerant charge and TXVs, insulation installation quality, and building envelope sealing require installer testing and certification and field verification by an approved HERS rater.

Designer or Owner (per Business & Professions Code)
Name:
Title/Firm: Dan Smith & Assiciates, Architects
Address: 1107 Virginia St.
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Telephone: 510 526-1935 Lic. #:
(signature) (date)

Documentation Author
Name: Gene Clements
Title/Firm: Gene Clements, Architect
Address: 2348 McKinley Avenue
Berkeley, CA 94703
Telephone: (510) 549-1124
(signature) Gene Clements (date)

Enforcement Agency
Name:
Title/Firm:
Address:
Telephone:
(signature) (date)

Run Initiation Time: 01/09/09 10:02:45 Run Code: 1231524165

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Mandatory Measures Summary: Residential (Page 1 of 2) MF-1R

NOTE: Lowrise residential buildings subject to the Standards must contain these measures regardless of the compliance approach used. More stringent compliance requirements from the Certificate of Compliance supercede the items marked with an asterisk (*) below. When this checklist is incorporated into the permit documents, the features noted shall be considered by all parties as minimum component performance specifications for the mandatory measures whether they are shown elsewhere in the documents or on this checklist only.

DESCRIPTION — Check or initial applicable boxes or check NA if not applicable and included with the permit application documentation.	N/A	DESIGNER	ENFORCE-MENT
Building Envelope Measures			
*§ 150(a): Minimum R-19 in wood ceiling insulation or equivalent U-factor in metal frame ceiling.	☐	☒	☐
§ 150(b): Loose fill insulation manufacturer's labeled R-Value:____________.	☐	☒	☐
*§ 150(c): Minimum R-13 wall insulation in wood framed walls or equivalent U-factor in metal frame walls (does not apply to exterior mass walls).	☐	☒	☐
*§ 150(d): Minimum R-13 raised floor insulation in framed floors or equivalent U-factor.	☐	☒	☐
§ 150(e): Installation of Fireplaces, Decorative Gas Appliances and Gas Logs.			
1. Masonry and factory-built fireplaces have:			
a. closable metal or glass door covering the entire opening of the firebox	☐	☐	☐
b. outside air intake with damper and control, flue damper and control	☐	☐	☐
2. No continuous burning gas pilot lights allowed.	☐	☐	☐
§ 150(f): Air retarding wrap installed to comply with §151 meets requirements specified in the ACM Residential Manual.	☐	☐	☐
§ 150(g): Vapor barriers mandatory in Climate Zones 14 and 16 only.	☐	☐	☐
§ 150(l): Slab edge insulation - water absorption rate for the insulation alone without facings no greater than 0.3%, water vapor permeance rate no greater than 2.0 perm/inch.	☐	☐	☐
§ 118: Insulation specified or installed meets insulation installation quality standards. Indicate type and include CF-6R Form: ______________________	☐	☒	☐
§ 116-17: Fenestration Products, Exterior Doors, and Infiltration/Exfiltration Controls.			
1. Doors and windows between conditioned and unconditioned spaces designed to limit air leakage.	☐	☒	☐
2. Fenestration products (except field fabricated) have label with certified U-Factor, certified Solar Heat Gain Coefficient (SHGC), and infiltration certification.	☐	☒	☐
3. Exterior doors and windows weatherstripped; all joints and penetrations caulked and sealed.	☐	☒	☐
Space Conditioning, Water Heating and Plumbing System Measures			
§ 110-13: HVAC equipment, water heaters, showerheads and faucets certified by the Energy Commission.	☐	☒	☐
§ 150(h): Heating and/or cooling loads calculated in accordance with ASHRAE, SMACNA or ACCA.	☐	☒	☐
§ 150(i): Setback thermostat on all applicable heating and/or cooling systems.	☐	☒	☐
§ 150(j): Water system pipe and tank insulation and cooling systems line insulation.			
1. Storage gas water heaters rated with an Energy Factor less than 0.58 must be externally wrapped with insulation having an installed thermal resistance of R-12 or greater.	☐	☐	☐
2. Back-up tanks for solar systems, unfired storage tanks, or other indirect hot water tanks have R-12 external insulation or R-16 internal insulation and indicated on the exterior of the tank showing the R-value.	☐	☐	☐
3. The following piping is insulated according to Table 150-A/B or Equation 150-A Insulation Thickness:			
1. First 5 feet of hot and cold water pipes closest to water heater tank, non-recirculating systems, and entire length of recirculating sections of hot water pipes shall be insulated to Table 150B.	☐	☐	☐
2. Cooling system piping (suction, chilled water, or brine lines), piping insulated between heating source and indirect hot water tank shall be insulated to Table 150-B and Equation 150-A.	☐	☐	☐
4. Steam hydronic heating systems or hot water systems > 15 psi, meet requirements of Table 123-A.	☐	☐	☐
5. Insulation must be protected from damage, including that due to sunlight, moisture, equipment maintenance, and wind.	☐	☐	☐
6. Insulation for chilled water piping and refrigerant suction piping includes a vapor retardant or is enclosed entirely in conditioned space.	☐	☐	☐
7. Solar water-heating systems/collectors are certified by the Solar Rating and Certification Corporation.	☐	☐	☐

EnergyPro 4.4 by EnergySoft | User Number: 5020 | Job Number: 923 | Page: 6 of 8

Mandatory Measures Summary: Residential (Page 2 of 2) MF-1R

NOTE: Lowrise residential buildings subject to the Standards must contain these measures regardless of the compliance approach used. More stringent compliance requirements from the Certificate of Compliance supercede the items marked with an asterisk (*) below. When this checklist is incorporated into the permit documents, the features noted shall be considered by all parties as minimum component performance specifications for the mandatory measures whether they are shown elsewhere in the documents or on this checklist only.

DESCRIPTION — Instructions: Check or initial applicable boxes when completed or check N/A if not applicable.	N/A	DESIGNER	ENFORCE-MENT
Space Conditioning, Water Heating and Plumbing System Measures: (continued)			
§ 150(m): Ducts and Fans			
1. All ducts and plenums installed, sealed and insulated to meet the requirements of the CMC Sections 601, 602, 603, 604, 605, and Standard 6-5; supply-air and return-air ducts and plenums are insulated to a minumum installed level of R-4.2 or enclosed entirely in conditioned space. Openings shall be sealed with mastic, tape or other duct-closure system that meets the applicable requirements of UL 181, UL 181A, or UL 181B or aerosol sealant that meets the requirements of UL 723. If mastic or tape is used to seal openings greater than 1/4 inch, the combination of mastic and either mesh or tape shall be used.	☐	☐	☐
2. Building cavities, support platforms for air handlers, and plenums defined or constructed with materials other than sealed sheet metal, duct board or flexible duct shall not be used for conveying conditioned air. Building cavities and support platforms may contain ducts. Ducts installed in cavities and support platforms shall not be compressed to cause reductions in the cross-sectional area of the ducts.	☐	☐	☐
3. Joints and seams of duct systems and their components shall not be sealed with cloth back rubber adhesive duct tapes unless such tape is used in combination with mastic and draw bands.	☐	☒	☐
4. Exhaust fan systems have back draft or automatic dampers.	☐	☒	☐
5. Gravity ventilating systems serving conditioned space have either automatic or readily accessible, manually operating dampers.	☐	☒	☐
6. Protection of Insulation. Insulation shall be protected from damage, including that due to sunlight, moisture, equipment maintenance, and wind. Cellular foam insulation shall be protected as above or painted with a coating that is water retardant and provides shielding from solar radiation that can cause degradation of the material.	☐	☐	☐
7. Flexible ducts cannot have porous inner cores.	☐	☒	☐
§ 114: Pool and Spa Heating Systems and Equipment			
1. A thermal efficiency that complies with the Appliance Efficiency Regulations, on-off switch mounted outside of the heater, weatherproof operating instructions, no electric resistance heating and no pilot light.	☐	☐	☐
2. System is installed with:			
a. At least 36" of pipe between filter and heater for future solar heating.	☐	☐	☐
b. Cover for outdoor pools or outdoor spas.	☐	☐	☐
3. Pool system has directional inlets and a circulation pump time switch.	☐	☐	☐
§ 115: Gas fired fan-type central furnaces, pool heaters, spa heaters or household cooking appliances have no continuously burning pilot light. (Exception: Non-electrical cooking appliances with pilot < 150 Btu/hr)	☐	☒	☐
§ 118 (i): Cool Roof material meets specified criteria	☐	☐	☐
Lighting Measures			
§ 150(k)1: HIGH EFFICACY LUMINAIRES OTHER THAN OUTDOOR HID: contain only high efficacy lamps as outlined in Table 150-C, and do not contain a medium screw base socket (E24/E26). Ballasts for lamps 13 Watts or greater are electric and have an output frequency no less than 20 kHz.	☐	☐	☐
§ 150(k)1: HIGH EFFICACY LUMINAIRES - OUTDOOR HID: contain only high efficacy lamps as outlined in Table 150-C, luminaire has factory installed HID ballast.	☐	☐	☐
§ 150(k)2: Permanently installed luminaires in kitchens shall be high efficacy luminaires. Up to 50% of the Wattage, as determined in Section 130(c), of permanently installed luminaires in kitchens may be in luminaires that are not high efficacy luminaires, provided that these luminaires are controlled by switches separate from those controlling the high efficacy luminaires.	☐	☒	☐
§ 150(k)3: Permanently installed luminaires in bathrooms, garages, laundry rooms, utility rooms shall be high efficacy luminaires. OR are controlled by an occupant sensor(s) certfied to comply with Section 119(d).	☐	☒	☐
§ 150(k)4: Permanently installed luminaires located other than in kitchens, bathrooms, garages, laundry rooms, and utility rooms shall be high efficacy luminaires (except closets less than 70 ft²) OR are controlled by a dimmer switch OR are controlled by an occupant sensor that complies with Section 119(d) that does not turn on automatically or have an always on option.	☐	☒	☐
§ 150(k)5: Luminaires that are recessed into insulated ceilings are approved for zero clearance insulation cover (IC) and are certified to ASTM E283 and labeled as air tight (AT) to less than 2.0 CFM at 75 Pascals.	☐	☒	☐
§ 150(k)6: Luminaires providing outdoor lighting and permanently mounted to a residential building or to other buildings on the same lot shall be high efficacy luminaires (not including lighting around swimming pools/water features or other Article 680 locations) OR are controlled by occupant sensors with integral photo control certified to comply with Section 119(d).	☐	☒	☐
§ 150(k)7: Lighting for parking lots for 8 or more vehicles shall have lighting that complies with Sections 130, 132, and 147. Lighting for parking garages for 8 or more vehicles shall have lighting that complies with Section 130, 131, and 146.	☐	☐	☐
§ 150(k)8: Permanently installed lighting in the enclosed, non-dwelling spaces of low-rise residential buildings with four or more dwelling units shall be high efficacy luminaires OR are controlled by occupant sensor(s) certified to comply with Section 119(d).	☐	☐	☐

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ROOM LOAD SUMMARY

PROJECT NAME: Lancaster Lofts Unit 1 (South Unit)
DATE: 1/9/09
SYSTEM NAME: Heating
FLOOR AREA: 1,625

ROOM LOAD SUMMARY

			ROOM COOLING PEAK			COIL COOLING PEAK			COIL HTG. PEAK	
ZONE NAME	ROOM NAME	Mult.	CFM	SENSIBLE	LATENT	CFM	SENSIBLE	LATENT	CFM	SENSIBLE
Lower Floor	Lower Floor	1	624	10,125	971	624	10,125	971	314	9,299
Upper Floor	Upper Floor	1	810	13,151	1,048	810	13,151	1,048	304	8,990
		PAGE TOTAL				1,434	23,275	2,019	618	18,289
		TOTAL				1,434	23,275	2,019	618	18,289

EnergyPro 4.4 by EnergySoft | User Number: 5020 | Job Number: 923 | Page: 8 of 8

ZETA Communities

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PHOTOVOLTAICS
GARY GERBER
SUN LIGHT & POWER
1035 FOLGER AVE
BERKELEY, CA 94710
510.845.2997

Seal & Signature:

Revisions:	Date:
1 State Submittal	1.20.09

Lancaster Lofts

Owner & Developer:
Malpas

Sheet contents:
T24
UNIT 1

Drawn by: NJB, MC Checked: DS
Scale: 1/4"=1'0" Date: 01.20.09
ZETA Project No.: 0811

MEP2.1
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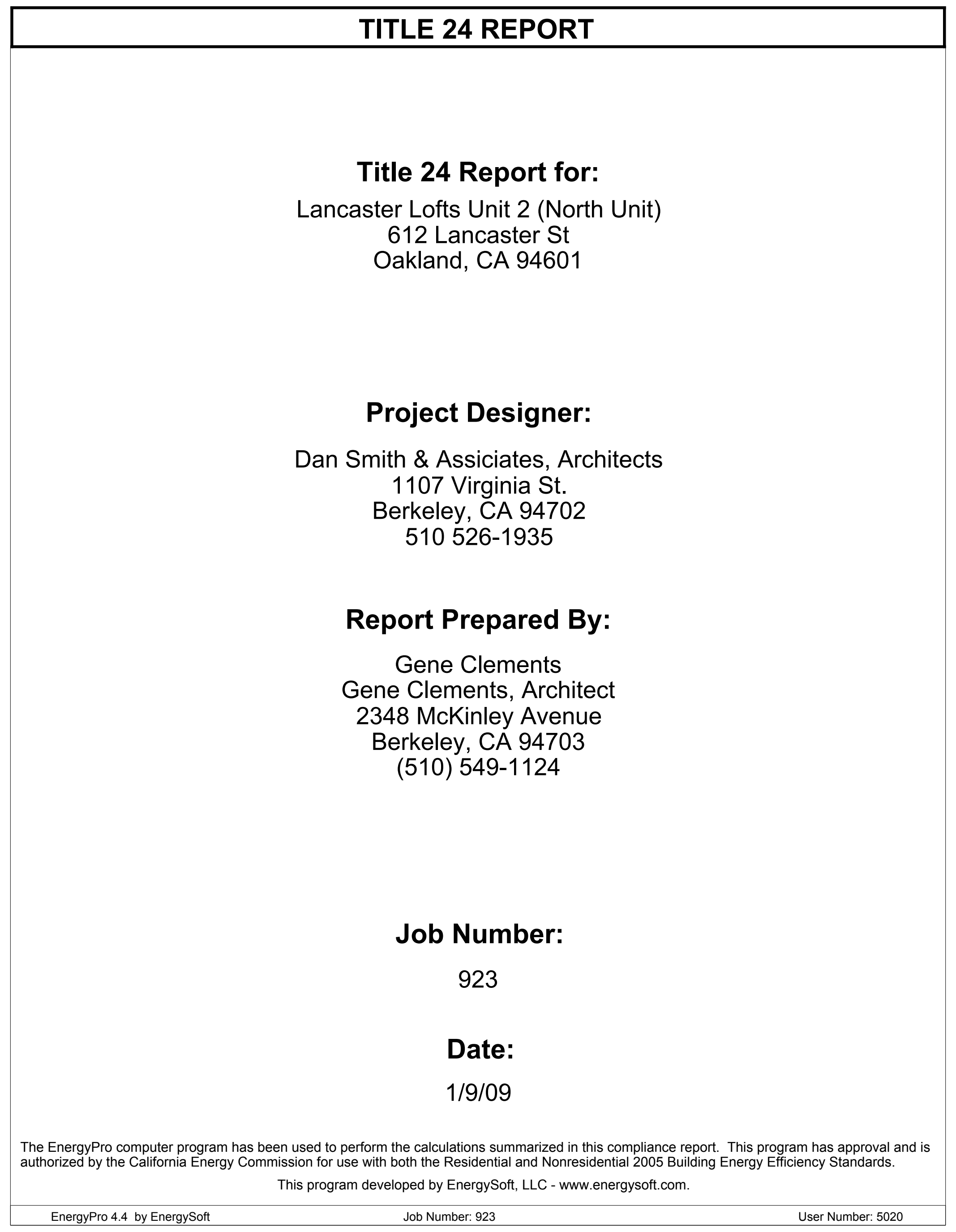


TITLE 24 REPORT

Title 24 Report for:

Lancaster Lofts Unit 2 (North Unit)
612 Lancaster St
Oakland, CA 94601

Project Designer:

Dan Smith & Assiciates, Architects
1107 Virginia St.
Berkeley, CA 94702
510 526-1935

Report Prepared By:

Gene Clements
Gene Clements, Architect
2348 McKinley Avenue
Berkeley, CA 94703
(510) 549-1124

Job Number:

923

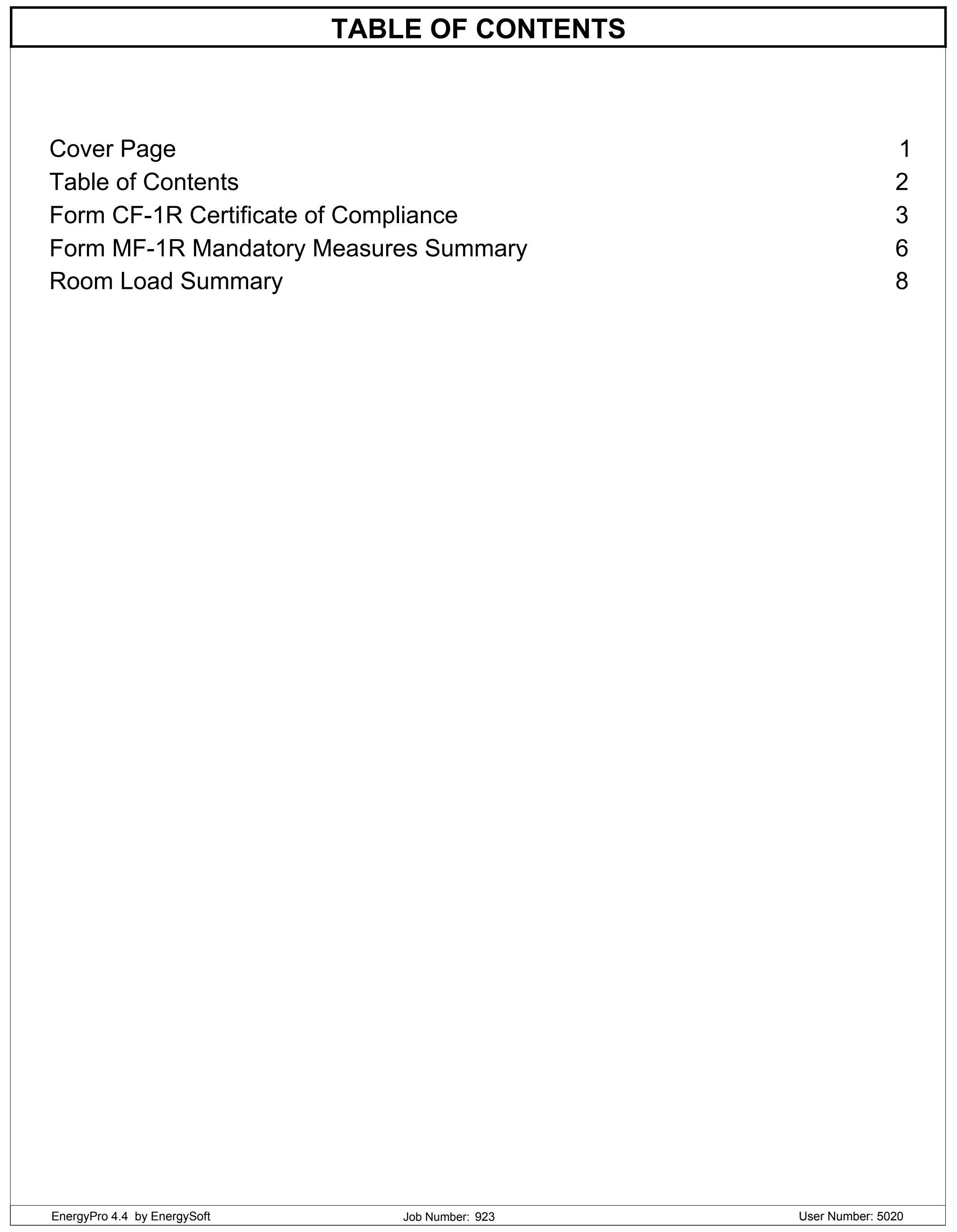
Date:

1/9/09

The EnergyPro computer program has been used to perform the calculations summarized in this compliance report. This program has approval and is authorized by the California Energy Commission for use with both the Residential and Nonresidential 2005 Building Energy Efficiency Standards.

This program developed by EnergySoft, LLC - www.energysoft.com.

EnergyPro 4.4 by EnergySoft | Job Number: 923 | User Number: 5020



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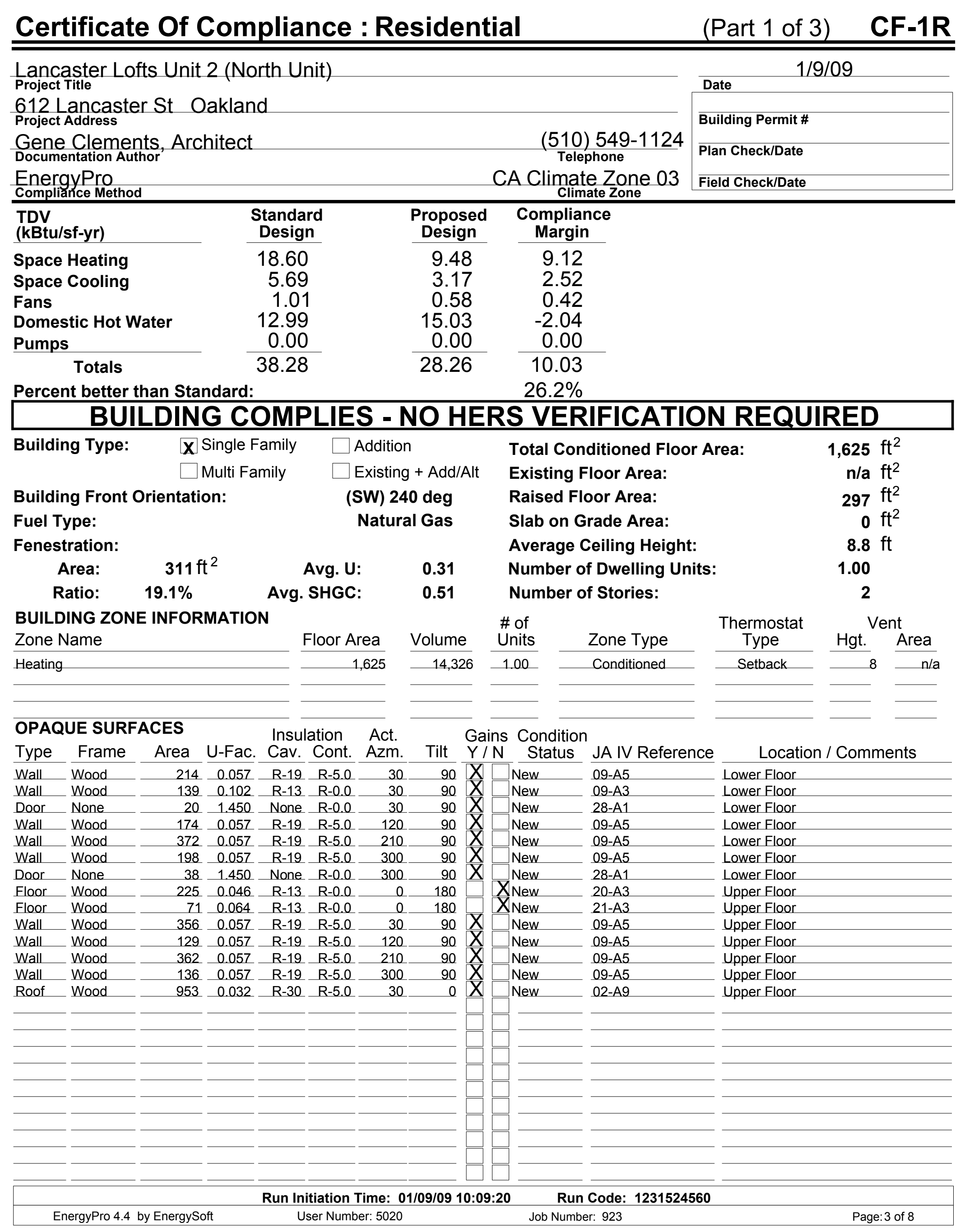

Certificate Of Compliance : Residential (Part 1 of 3) CF-1R

Project Title: Lancaster Lofts Unit 2 (North Unit)
Date: 1/9/09
Project Address: 612 Lancaster St Oakland
Documentation Author: Gene Clements, Architect
Telephone: (510) 549-1124
Compliance Method: EnergyPro
Climate Zone: CA Climate Zone 03
Building Permit #:
Plan Check/Date:
Field Check/Date:

TDV (kBtu/sf-yr)	Standard Design	Proposed Design	Compliance Margin
Space Heating	18.60	9.48	9.12
Space Cooling	5.69	3.17	2.52
Fans	1.01	0.58	0.42
Domestic Hot Water	12.99	15.03	-2.04
Pumps	0.00	0.00	0.00
Totals	38.28	28.26	10.03
Percent better than Standard:			26.2%

BUILDING COMPLIES - NO HERS VERIFICATION REQUIRED

Building Type: ☒ Single Family ☐ Addition ☐ Multi Family ☐ Existing + Add/Alt
Building Front Orientation: (SW) 240 deg
Fuel Type: Natural Gas
Fenestration:
Area: 311 ft^2 Avg. U: 0.31
Ratio: 19.1% Avg. SHGC: 0.51
Total Conditioned Floor Area: 1,625 ft^2
Existing Floor Area: n/a ft^2
Raised Floor Area: 297 ft^2
Slab on Grade Area: 0 ft^2
Average Ceiling Height: 8.8 ft
Number of Dwelling Units: 1.00
Number of Stories: 2

BUILDING ZONE INFORMATION

Zone Name	Floor Area	Volume	# of Units	Zone Type	Thermostat Type	Vent Hgt.	Vent Area
Heating	1,625	14,326	1.00	Conditioned	Setback	8	n/a

OPAQUE SURFACES

Type	Frame	Area	U-Fac.	Insulation Cav.	Insulation Cont.	Act. Azm.	Tilt	Gains Y	Gains N	Condition Status	JA IV Reference	Location / Comments
Wall	Wood	214	0.057	R-19	R-5.0	30	90	☒	☐	New	09-A5	Lower Floor
Wall	Wood	139	0.102	R-13	R-0.0	30	90	☒	☐	New	09-A3	Lower Floor
Door	None	20	1.450	None	R-0.0	30	90	☒	☐	New	28-A1	Lower Floor
Wall	Wood	174	0.057	R-19	R-5.0	120	90	☒	☐	New	09-A5	Lower Floor
Wall	Wood	372	0.057	R-19	R-5.0	210	90	☒	☐	New	09-A5	Lower Floor
Wall	Wood	198	0.057	R-19	R-5.0	300	90	☒	☐	New	09-A5	Lower Floor
Door	None	38	1.450	None	R-0.0	300	90	☒	☐	New	28-A1	Lower Floor
Floor	Wood	225	0.046	R-13	R-0.0	0	180	☐	☒	New	20-A3	Upper Floor
Floor	Wood	71	0.064	R-13	R-0.0	0	180	☐	☒	New	21-A3	Upper Floor
Wall	Wood	356	0.057	R-19	R-5.0	30	90	☒	☐	New	09-A5	Upper Floor
Wall	Wood	129	0.057	R-19	R-5.0	120	90	☒	☐	New	09-A5	Upper Floor
Wall	Wood	362	0.057	R-19	R-5.0	210	90	☒	☐	New	09-A5	Upper Floor
Wall	Wood	136	0.057	R-19	R-5.0	300	90	☒	☐	New	09-A5	Upper Floor
Roof	Wood	953	0.032	R-30	R-5.0	30	0	☒	☐	New	02-A9	Upper Floor

Run Initiation Time: 01/09/09 10:09:20 Run Code: 1231524560
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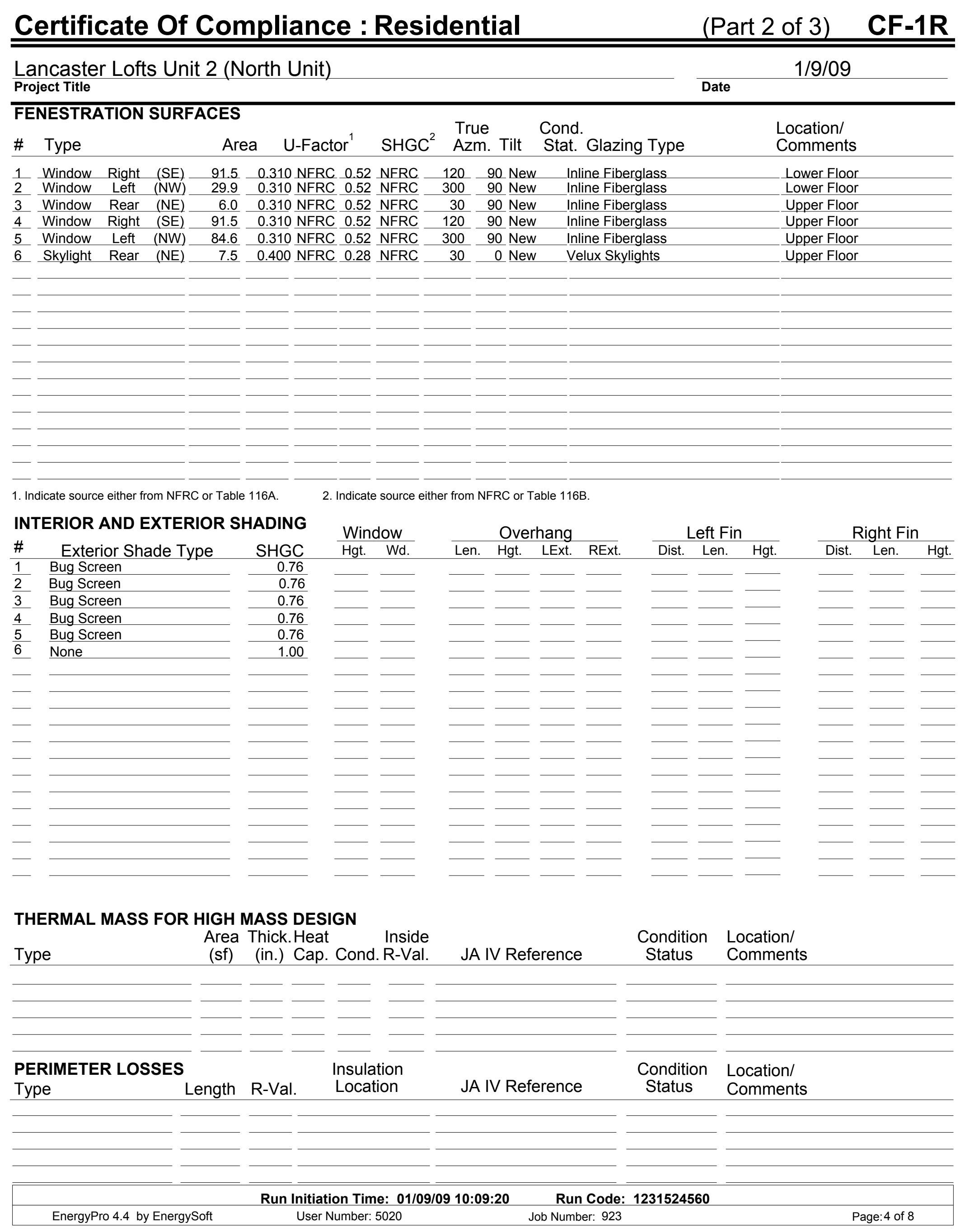

Certificate Of Compliance : Residential (Part 2 of 3) CF-1R

Project Title: Lancaster Lofts Unit 2 (North Unit)
Date: 1/9/09

FENESTRATION SURFACES

#	Type			Area	U-Factor[1]		SHGC[2]		True Azm.	Tilt	Cond. Stat.	Glazing Type	Location/ Comments
1	Window	Right	(SE)	91.5	0.310	NFRC	0.52	NFRC	120	90	New	Inline Fiberglass	Lower Floor
2	Window	Left	(NW)	29.9	0.310	NFRC	0.52	NFRC	300	90	New	Inline Fiberglass	Lower Floor
3	Window	Rear	(NE)	6.0	0.310	NFRC	0.52	NFRC	30	90	New	Inline Fiberglass	Upper Floor
4	Window	Right	(SE)	91.5	0.310	NFRC	0.52	NFRC	120	90	New	Inline Fiberglass	Upper Floor
5	Window	Left	(NW)	84.6	0.310	NFRC	0.52	NFRC	300	90	New	Inline Fiberglass	Upper Floor
6	Skylight	Rear	(NE)	7.5	0.400	NFRC	0.28	NFRC	30	0	New	Velux Skylights	Upper Floor

[1] Indicate source either from NFRC or Table 116A. [2] Indicate source either from NFRC or Table 116B.

INTERIOR AND EXTERIOR SHADING

#	Exterior Shade Type	SHGC	Window Hgt.	Window Wd.	Overhang Len.	Overhang Hgt.	Overhang LExt.	Overhang RExt.	Left Fin Dist.	Left Fin Len.	Left Fin Hgt.	Right Fin Dist.	Right Fin Len.	Right Fin Hgt.
1	Bug Screen	0.76												
2	Bug Screen	0.76												
3	Bug Screen	0.76												
4	Bug Screen	0.76												
5	Bug Screen	0.76												
6	None	1.00												

THERMAL MASS FOR HIGH MASS DESIGN

Type	Area (sf)	Thick. (in.)	Heat Cap.	Cond.	Inside R-Val.	JA IV Reference	Condition Status	Location/ Comments

PERIMETER LOSSES

Type	Length	R-Val.	Insulation Location	JA IV Reference	Condition Status	Location/ Comments

Run Initiation Time: 01/09/09 10:09:20 Run Code: 1231524560
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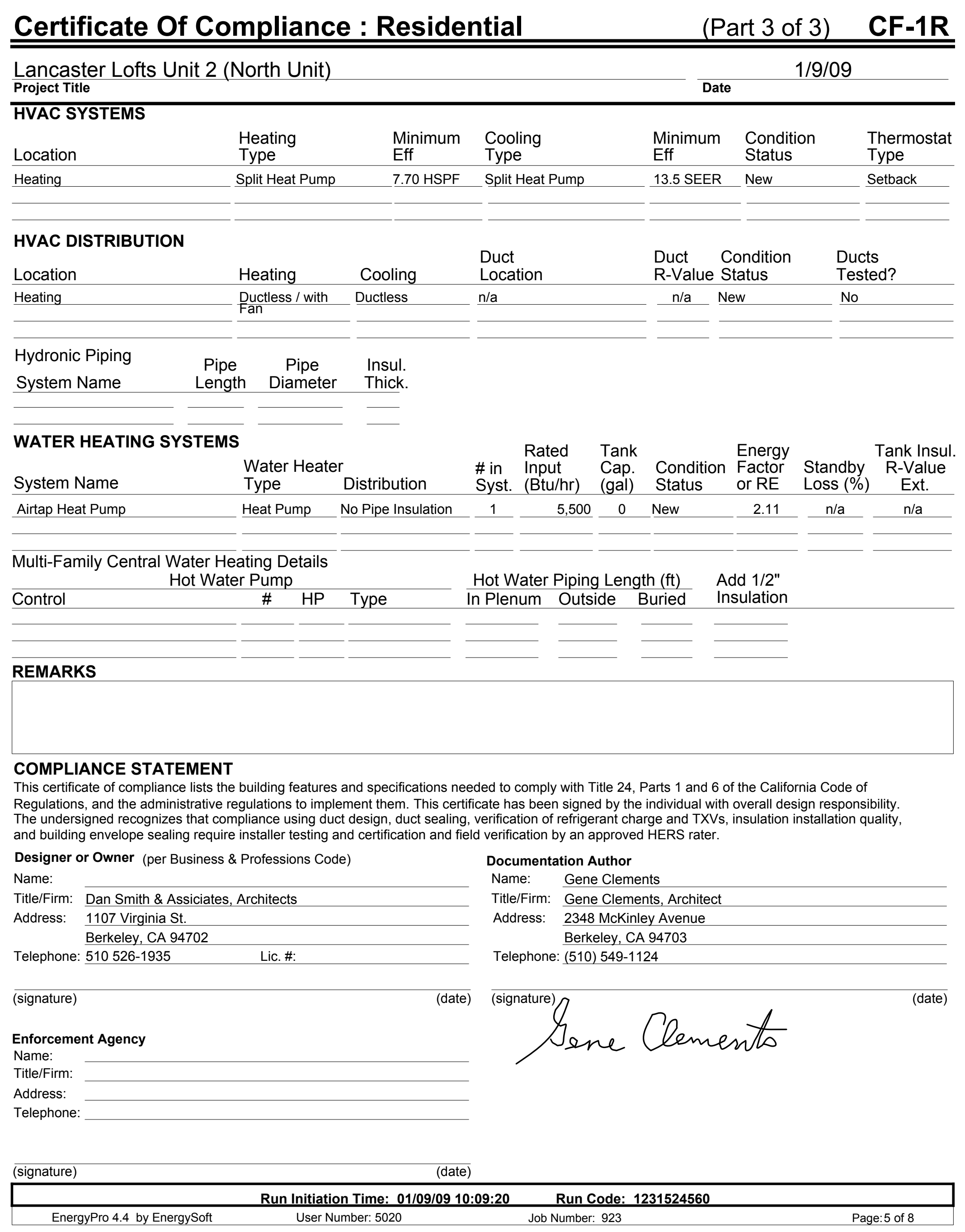

Certificate Of Compliance : Residential (Part 3 of 3) CF-1R

Project Title: Lancaster Lofts Unit 2 (North Unit)
Date: 1/9/09

HVAC SYSTEMS

Location	Heating Type	Minimum Eff	Cooling Type	Minimum Eff	Condition Status	Thermostat Type
Heating	Split Heat Pump	7.70 HSPF	Split Heat Pump	13.5 SEER	New	Setback

HVAC DISTRIBUTION

Location	Heating	Cooling	Duct Location	Duct R-Value	Condition Status	Ducts Tested?
Heating	Ductless / with Fan	Ductless	n/a	n/a	New	No

Hydronic Piping System Name	Pipe Length	Pipe Diameter	Insul. Thick.

WATER HEATING SYSTEMS

System Name	Water Heater Type	Distribution	# in Syst.	Rated Input (Btu/hr)	Tank Cap. (gal)	Condition Status	Energy Factor or RE	Standby Loss (%)	Tank Insul. R-Value Ext.
Airtap Heat Pump	Heat Pump	No Pipe Insulation	1	5,500	0	New	2.11	n/a	n/a

Multi-Family Central Water Heating Details

Control	Hot Water Pump #	HP	Type	Hot Water Piping Length (ft) In Plenum	Outside	Buried	Add 1/2" Insulation

REMARKS

COMPLIANCE STATEMENT

This certificate of compliance lists the building features and specifications needed to comply with Title 24, Parts 1 and 6 of the California Code of Regulations, and the administrative regulations to implement them. This certificate has been signed by the individual with overall design responsibility. The undersigned recognizes that compliance using duct design, duct sealing, verification of refrigerant charge and TXVs, insulation installation quality, and building envelope sealing require installer testing and certification and field verification by an approved HERS rater.

Designer or Owner (per Business & Professions Code)
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Berkeley, CA 94702
Telephone: 510 526-1935 Lic. #:
(signature) (date)

Documentation Author
Name: Gene Clements
Title/Firm: Gene Clements, Architect
Address: 2348 McKinley Avenue
Berkeley, CA 94703
Telephone: (510) 549-1124
(signature) Gene Clements (date)

Enforcement Agency
Name:
Title/Firm:
Address:
Telephone:
(signature) (date)

Run Initiation Time: 01/09/09 10:09:20 Run Code: 1231524560
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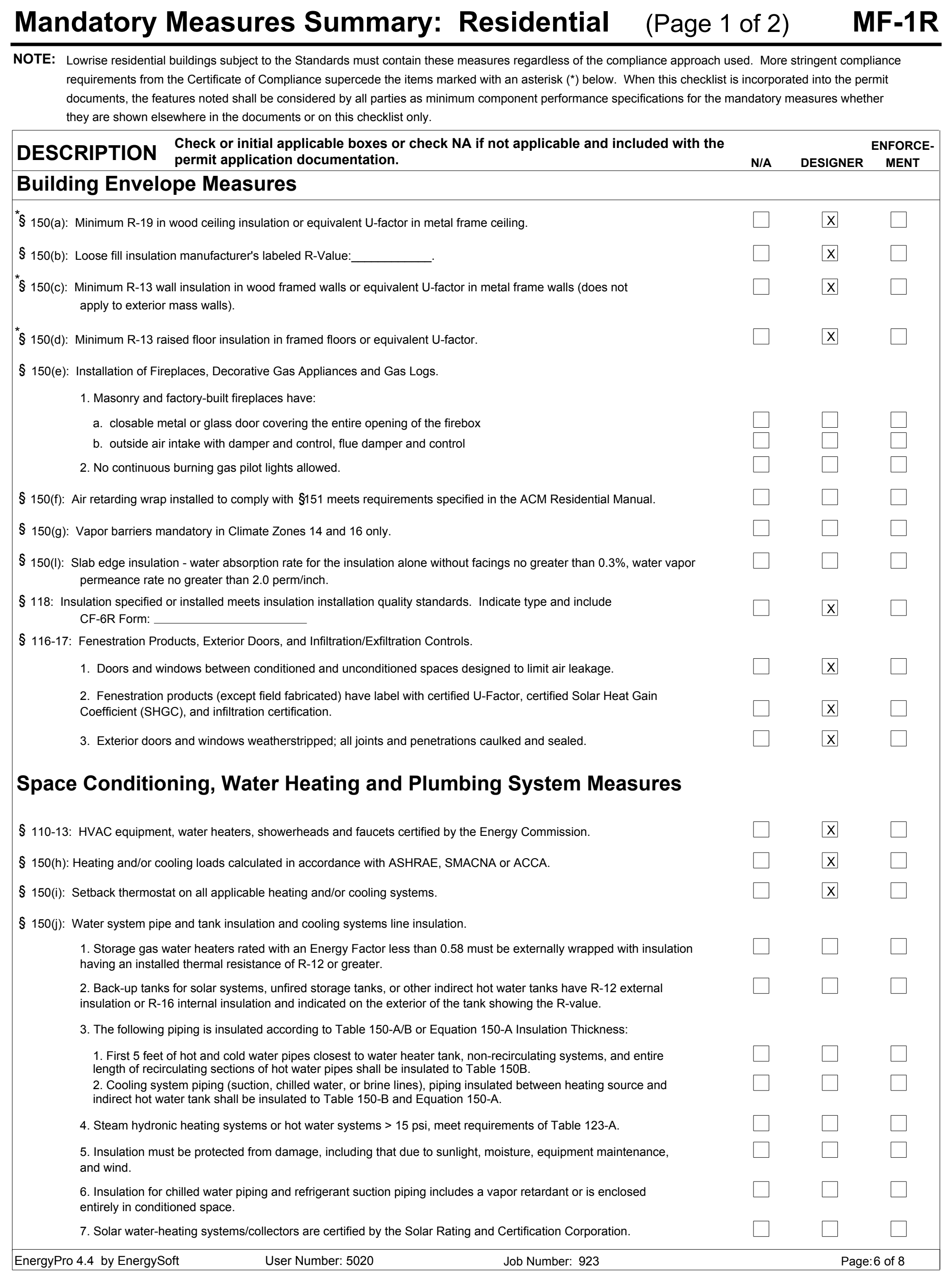

Mandatory Measures Summary: Residential (Page 1 of 2) MF-1R

NOTE: Lowrise residential buildings subject to the Standards must contain these measures regardless of the compliance approach used. More stringent compliance requirements from the Certificate of Compliance supercede the items marked with an asterisk (*) below. When this checklist is incorporated into the permit documents, the features noted shall be considered by all parties as minimum component performance specifications for the mandatory measures whether they are shown elsewhere in the documents or on this checklist only.

DESCRIPTION Check or initial applicable boxes or check NA if not applicable and included with the permit application documentation.	N/A	DESIGNER	ENFORCEMENT
Building Envelope Measures			
*§ 150(a): Minimum R-19 in wood ceiling insulation or equivalent U-factor in metal frame ceiling.	☐	☒	☐
§ 150(b): Loose fill insulation manufacturer's labeled R-Value:____________.	☐	☒	☐
*§ 150(c): Minimum R-13 wall insulation in wood framed walls or equivalent U-factor in metal frame walls (does not apply to exterior mass walls).	☐	☒	☐
*§ 150(d): Minimum R-13 raised floor insulation in framed floors or equivalent U-factor.	☐	☒	☐
§ 150(e): Installation of Fireplaces, Decorative Gas Appliances and Gas Logs.			
1. Masonry and factory-built fireplaces have:			
a. closable metal or glass door covering the entire opening of the firebox	☐	☐	☐
b. outside air intake with damper and control, flue damper and control	☐	☐	☐
2. No continuous burning gas pilot lights allowed.	☐	☐	☐
§ 150(f): Air retarding wrap installed to comply with §151 meets requirements specified in the ACM Residential Manual.	☐	☐	☐
§ 150(g): Vapor barriers mandatory in Climate Zones 14 and 16 only.	☐	☐	☐
§ 150(l): Slab edge insulation - water absorption rate for the insulation alone without facings no greater than 0.3%, water vapor permeance rate no greater than 2.0 perm/inch.	☐	☐	☐
§ 118: Insulation specified or installed meets insulation installation quality standards. Indicate type and include CF-6R Form: ____________	☐	☒	☐
§ 116-17: Fenestration Products, Exterior Doors, and Infiltration/Exfiltration Controls.			
1. Doors and windows between conditioned and unconditioned spaces designed to limit air leakage.	☐	☒	☐
2. Fenestration products (except field fabricated) have label with certified U-Factor, certified Solar Heat Gain Coefficient (SHGC), and infiltration certification.	☐	☒	☐
3. Exterior doors and windows weatherstripped; all joints and penetrations caulked and sealed.	☐	☒	☐
Space Conditioning, Water Heating and Plumbing System Measures			
§ 110-13: HVAC equipment, water heaters, showerheads and faucets certified by the Energy Commission.	☐	☒	☐
§ 150(h): Heating and/or cooling loads calculated in accordance with ASHRAE, SMACNA or ACCA.	☐	☒	☐
§ 150(i): Setback thermostat on all applicable heating and/or cooling systems.	☐	☒	☐
§ 150(j): Water system pipe and tank insulation and cooling systems line insulation.			
1. Storage gas water heaters rated with an Energy Factor less than 0.58 must be externally wrapped with insulation having an installed thermal resistance of R-12 or greater.	☐	☐	☐
2. Back-up tanks for solar systems, unfired storage tanks, or other indirect hot water tanks have R-12 external insulation or R-16 internal insulation and indicated on the exterior of the tank showing the R-value.	☐	☐	☐
3. The following piping is insulated according to Table 150-A/B or Equation 150-A Insulation Thickness:			
1. First 5 feet of hot and cold water pipes closest to water heater tank, non-recirculating systems, and entire length of recirculating sections of hot water pipes shall be insulated to Table 150B.	☐	☐	☐
2. Cooling system piping (suction, chilled water, or brine lines), piping insulated between heating source and indirect hot water tank shall be insulated to Table 150-B and Equation 150-A.	☐	☐	☐
4. Steam hydronic heating systems or hot water systems > 15 psi, meet requirements of Table 123-A.	☐	☐	☐
5. Insulation must be protected from damage, including that due to sunlight, moisture, equipment maintenance, and wind.	☐	☐	☐
6. Insulation for chilled water piping and refrigerant suction piping includes a vapor retardant or is enclosed entirely in conditioned space.	☐	☐	☐
7. Solar water-heating systems/collectors are certified by the Solar Rating and Certification Corporation.	☐	☐	☐

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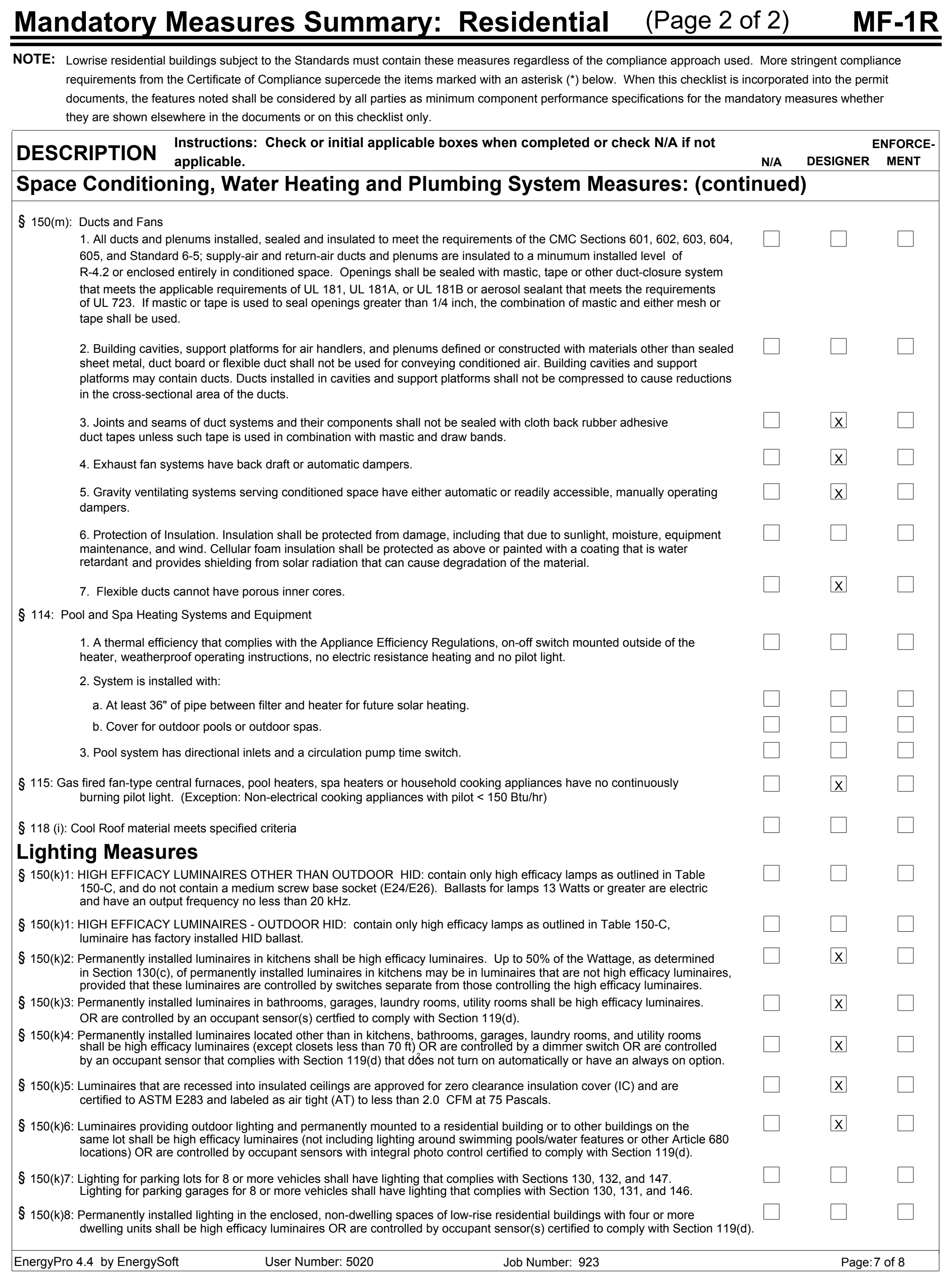

Mandatory Measures Summary: Residential (Page 2 of 2) MF-1R

NOTE: Lowrise residential buildings subject to the Standards must contain these measures regardless of the compliance approach used. More stringent compliance requirements from the Certificate of Compliance supercede the items marked with an asterisk (*) below. When this checklist is incorporated into the permit documents, the features noted shall be considered by all parties as minimum component performance specifications for the mandatory measures whether they are shown elsewhere in the documents or on this checklist only.

DESCRIPTION Instructions: Check or initial applicable boxes when completed or check N/A if not applicable.	N/A	DESIGNER	ENFORCEMENT
Space Conditioning, Water Heating and Plumbing System Measures: (continued)			
§ 150(m): Ducts and Fans			
1. All ducts and plenums installed, sealed and insulated to meet the requirements of the CMC Sections 601, 602, 603, 604, 605, and Standard 6-5; supply-air and return-air ducts and plenums are insulated to a minumum installed level of R-4.2 or enclosed entirely in conditioned space. Openings shall be sealed with mastic, tape or other duct-closure system that meets the applicable requirements of UL 181, UL 181A, or UL 181B or aerosol sealant that meets the requirements of UL 723. If mastic or tape is used to seal openings greater than 1/4 inch, the combination of mastic and either mesh or tape shall be used.	☐	☐	☐
2. Building cavities, support platforms for air handlers, and plenums defined or constructed with materials other than sealed sheet metal, duct board or flexible duct shall not be used for conveying conditioned air. Building cavities and support platforms may contain ducts. Ducts installed in cavities and support platforms shall not be compressed to cause reductions in the cross-sectional area of the ducts.	☐	☐	☐
3. Joints and seams of duct systems and their components shall not be sealed with cloth back rubber adhesive duct tapes unless such tape is used in combination with mastic and draw bands.	☐	☒	☐
4. Exhaust fan systems have back draft or automatic dampers.	☐	☒	☐
5. Gravity ventilating systems serving conditioned space have either automatic or readily accessible, manually operating dampers.	☐	☒	☐
6. Protection of Insulation. Insulation shall be protected from damage, including that due to sunlight, moisture, equipment maintenance, and wind. Cellular foam insulation shall be protected as above or painted with a coating that is water retardant and provides shielding from solar radiation that can cause degradation of the material.	☐	☐	☐
7. Flexible ducts cannot have porous inner cores.	☐	☒	☐
§ 114: Pool and Spa Heating Systems and Equipment			
1. A thermal efficiency that complies with the Appliance Efficiency Regulations, on-off switch mounted outside of the heater, weatherproof operating instructions, no electric resistance heating and no pilot light.	☐	☐	☐
2. System is installed with:			
a. At least 36" of pipe between filter and heater for future solar heating.	☐	☐	☐
b. Cover for outdoor pools or outdoor spas.	☐	☐	☐
3. Pool system has directional inlets and a circulation pump time switch.	☐	☐	☐
§ 115: Gas fired fan-type central furnaces, pool heaters, spa heaters or household cooking appliances have no continuously burning pilot light. (Exception: Non-electrical cooking appliances with pilot < 150 Btu/hr)	☐	☒	☐
§ 118 (i): Cool Roof material meets specified criteria	☐	☐	☐
Lighting Measures			
§ 150(k)1: HIGH EFFICACY LUMINAIRES OTHER THAN OUTDOOR HID: contain only high efficacy lamps as outlined in Table 150-C, and do not contain a medium screw base socket (E24/E26). Ballasts for lamps 13 Watts or greater are electric and have an output frequency no less than 20 kHz.	☐	☐	☐
§ 150(k)1: HIGH EFFICACY LUMINAIRES - OUTDOOR HID: contain only high efficacy lamps as outlined in Table 150-C, luminaire has factory installed HID ballast.	☐	☐	☐
§ 150(k)2: Permanently installed luminaires in kitchens shall be high efficacy luminaires. Up to 50% of the Wattage, as determined in Section 130(c), of permanently installed luminaires in kitchens may be in luminaires that are not high efficacy luminaires, provided that these luminaires are controlled by switches separate from those controlling the high efficacy luminaires.	☐	☒	☐
§ 150(k)3: Permanently installed luminaires in bathrooms, garages, laundry rooms, utility rooms shall be high efficacy luminaires. OR are controlled by an occupant sensor(s) certfied to comply with Section 119(d).	☐	☒	☐
§ 150(k)4: Permanently installed luminaires located other than in kitchens, bathrooms, garages, laundry rooms, and utility rooms shall be high efficacy luminaires (except closets less than 70 ft^2) OR are controlled by a dimmer switch OR are controlled by an occupant sensor that complies with Section 119(d) that does not turn on automatically or have an always on option.	☐	☒	☐
§ 150(k)5: Luminaires that are recessed into insulated ceilings are approved for zero clearance insulation cover (IC) and are certified to ASTM E283 and labeled as air tight (AT) to less than 2.0 CFM at 75 Pascals.	☐	☒	☐
§ 150(k)6: Luminaires providing outdoor lighting and permanently mounted to a residential building or to other buildings on the same lot shall be high efficacy luminaires (not including lighting around swimming pools/water features or other Article 680 locations) OR are controlled by occupant sensors with integral photo control certified to comply with Section 119(d).	☐	☒	☐
§ 150(k)7: Lighting for parking lots for 8 or more vehicles shall have lighting that complies with Sections 130, 132, and 147. Lighting for parking garages for 8 or more vehicles shall have lighting that complies with Section 130, 131, and 146.	☐	☐	☐
§ 150(k)8: Permanently installed lighting in the enclosed, non-dwelling spaces of low-rise residential buildings with four or more dwelling units shall be high efficacy luminaires OR are controlled by occupant sensor(s) certified to comply with Section 119(d).	☐	☐	☐

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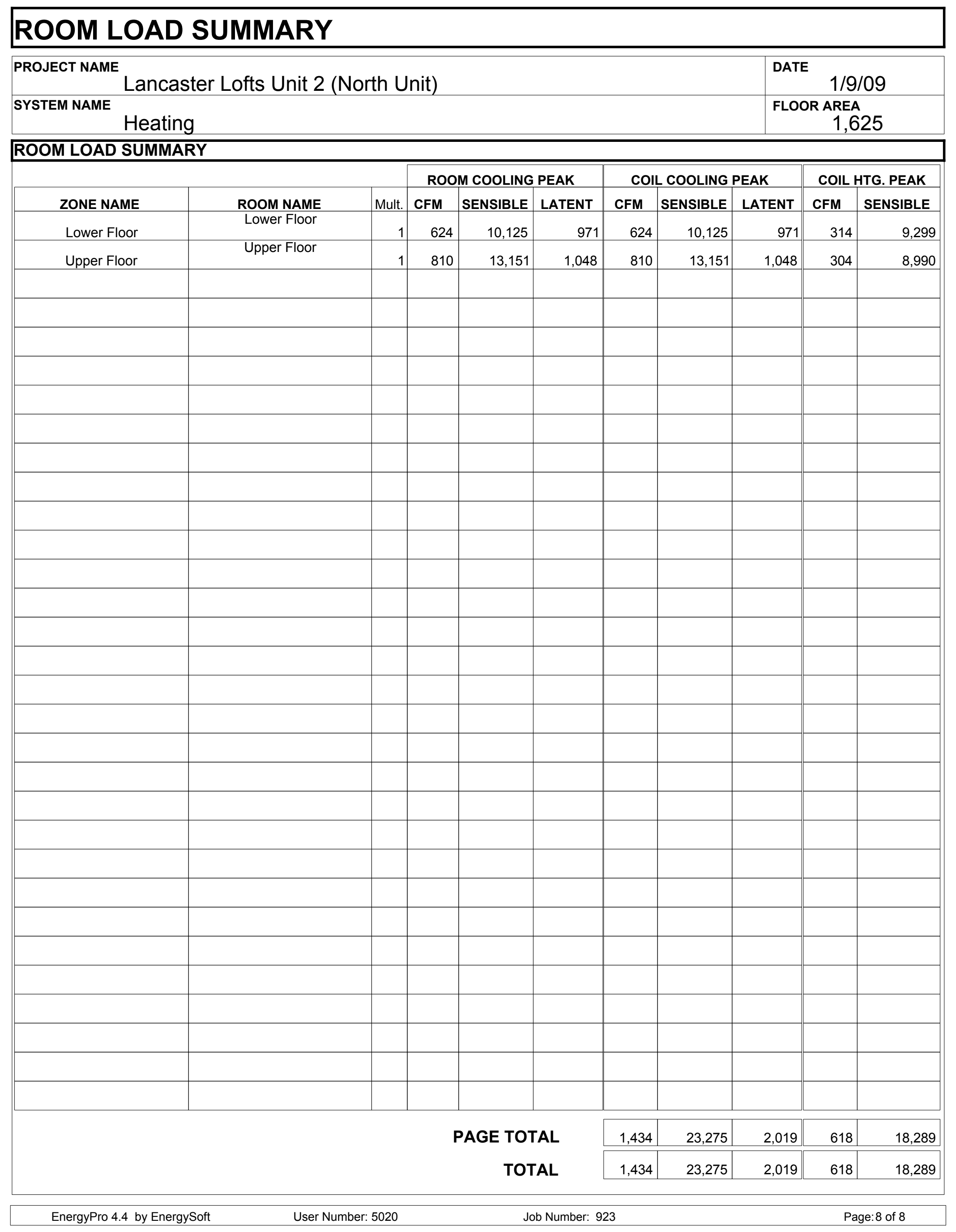

ROOM LOAD SUMMARY

PROJECT NAME: Lancaster Lofts Unit 2 (North Unit)
DATE: 1/9/09
SYSTEM NAME: Heating
FLOOR AREA: 1,625

ROOM LOAD SUMMARY

			ROOM COOLING PEAK			COIL COOLING PEAK			COIL HTG. PEAK	
ZONE NAME	ROOM NAME	Mult.	CFM	SENSIBLE	LATENT	CFM	SENSIBLE	LATENT	CFM	SENSIBLE
Lower Floor	Lower Floor	1	624	10,125	971	624	10,125	971	314	9,299
Upper Floor	Upper Floor	1	810	13,151	1,048	810	13,151	1,048	304	8,990
	PAGE TOTAL		1,434	23,275	2,019	618	18,289			
	TOTAL		1,434	23,275	2,019	618	18,289			

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ZETA Communities

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BERKELEY, CA 94703-1720
510.549.2019

PHOTOVOLTAICS
GARY GERBER
SUN LIGHT & POWER
1035 FOLGER AVE
BERKELEY, CA 94710
510.845.2997

Seal & Signature:

Revisions:	Date:
1 State Submittal	1.20.09

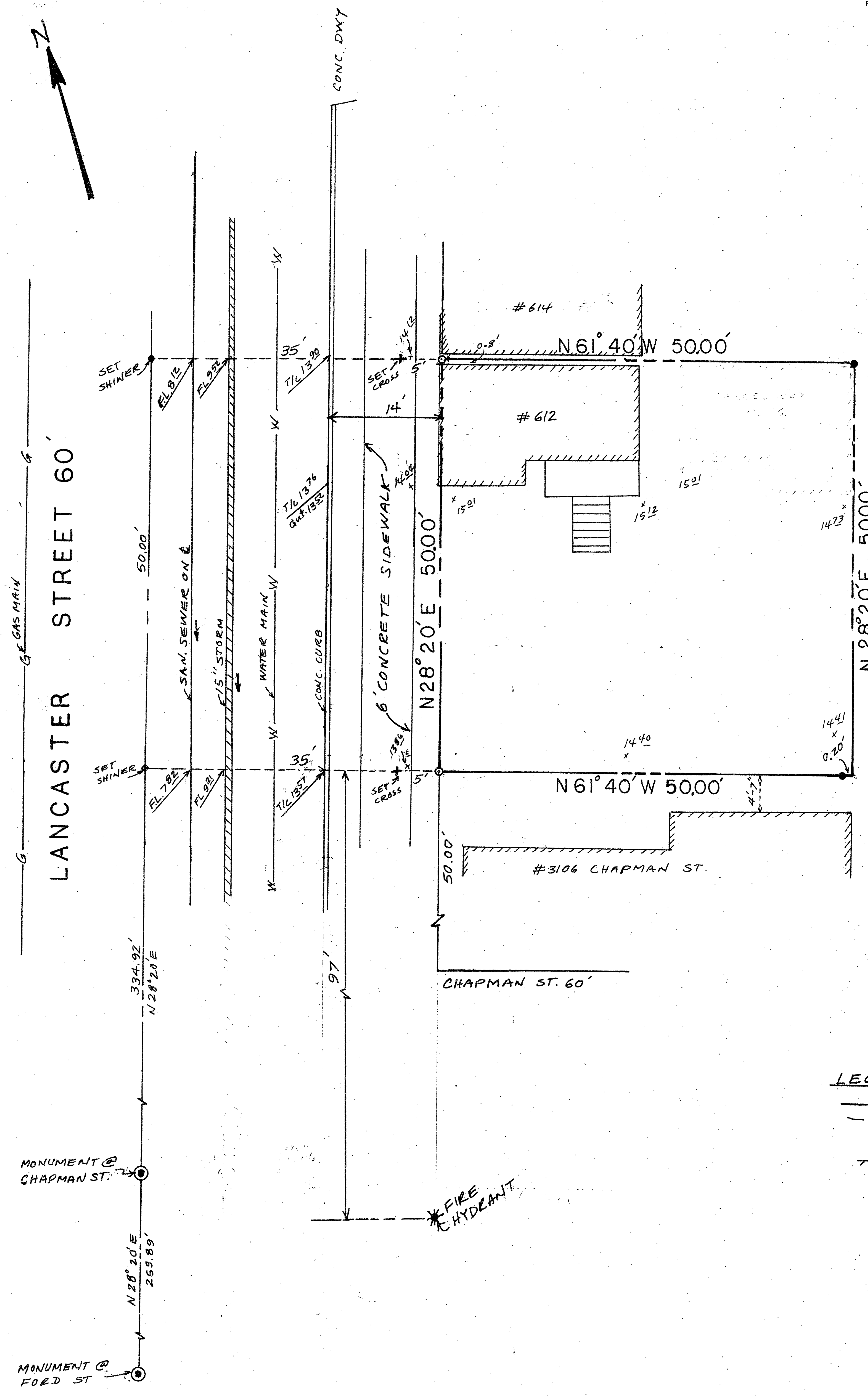
Lancaster Lofts

Owner & Developer:
Malpas

Sheet contents:
T24
UNIT 2

Drawn by: NJB, MC Checked: DS
Scale: 1/4"=1'0" Date: 01.20.09
ZETA Project No.: 0811

MEP2.2
1



NOTES

1. ALL EXISTING GRADES AND CONTOURS ARE BASED UPON THE CITY OF OAKLAND DATUM.
2. THE NEAREST FIRE HYDRANT IS 97 FEET TO THE SOUTH AS SHOWN.
3. THERE ARE NO HORIZONTAL OR SHARP VERTICAL CURVES WITHIN 300 FEET OF THE FRONTAGE
4. NO OBJECTS WITHIN 50 FEET OF THE FRONTAGE TO RESTRICT DRIVER SIGHT.
5. THERE ARE NO BUS STOPS, BUT THERE ARE UNMARKED CROSSWALKS WITHIN 100 FEET OF FRONTAGE.

SURVEYOR'S CERTIFICATE

THIS MAP CORRECTLY REPRESENTS A FIELD SURVEY MADE BY ME OR UNDER MY DIRECTION IN CONFRMANCE WITH THE REQUIREMENTS OF THE LAND SURVEYOR'S ACT AT THE REQUEST OF BILL MALPAS ON APRIL 2, 2007.

I HEREBY STATE THAT EXISTING GRADES AND CONTOURS DELINEATED UPON THIS PLAT ARE BASED UPON CITY OF OAKLAND DATUM.

I FURTHER STATE THAT THE PARCEL DELINEATED UPON THIS SURVEY IS THE SAME AS THAT SHOWN ON THE EQUALIZED COUNTY ASSESSMENT ROLL AS A UNIT.

I HEREBY FURTHER STATE THAT IN ACCORDANCE WITH THE PROFESSIONAL LAND SURVEYOR'S ACT THE PERFORMANCE OF THIS SURVEY REQUIRES THAT A RECORD OF SURVEY BE FILED WITH THE ALAMEDA COUNTY SURVEYOR AND I WILL FILE SAME IN A TIMELY MANNER; AND IF CHANGES ARE NECESSARY TO THIS SURVEY SUBMITTED TO THE CITY OF OAKLAND DUE TO PROCESSING OF A RECORD OF SURVEY, I WILL SUBMIT A CORRECTED COPY OF THIS SURVEY TO THE CITY.

A. Moghaddas
No. 27185
EXPIRES 3-31-2009

SIGNED: A. Moghaddas
RCE NO. 27185
DATE 1-15-2009
LICENSE EXPIRES 3-31-2009

LEGEND

———— - - - - PROPERTY LINE
——— - - - - - MONUMENT LINE
⊙ FOUND CITY MONUMENT
/////////// BLDG. WALL
● SET 1/2" REBAR & CAP RCE #27185
⊙ SET NAIL & TAG RCE 27185

612 LANCASTER STREET
OAKLAND CALIFORNIA

A PORTION OF LOTS 6 AND 7 BLOCK 2 BREED AND BANCROFT RESUBDIVISION OF A PORTION OF ALAMEDA TRACT, BOOK 22 PAGE 85 ALAMEDA COUNTY RECORDS

FOR: BILL MALPAS
612 LANCASTER STREET
OAKLAND CA. 94601
TEL 415-760-0194

BY: AHMAD MOGHADDAS
1631 BERKELEY WAY
BERKELEY CA 94703

JANUARY 2009 SCALE: 1"=8'

Appendix D.10.7.2
Energy Modeling

September 11, 2008

Zeta Communities
3145 Geary Boulevard, #733
San Francisco, CA 94118
tel 415.753.1810
fax 415.564.6911
ATTN: Naomi Porat
nporat@zetacommunities.com

Re: Building America Energy Analysis of Zeta Prototype Plan (Standalone house at Pittsburg site)

Dear Ms. Porat:

The following report covers the modeled energy performance of the Zeta Communities Prototype, which is to be built at the Pittsburg, CA plant site. In addition to verifying performance with respect to the Building America program requirements, several other notes are included on optimizing the overall energy performance, and potential troublesome details in assembly of the building.

Note that the energy modeling here does not include any simulations of the use of the crawl space as a "thermal flywheel", nor any design logic for the controller.

If you have any questions or comments about this report, please contact Kohta Ueno of Building Science Consulting (kohta@buildingscience.com), or as per contact information shown.

Sincerely,

Kohta Ueno

Cc: Betsy Pettit, FAIA; John Straube, Ph.D., P.Eng. (Building Science Corporation)
Daniel Smith; Dietmar Lorenz (Daniel Smith & Associates, Architects)

1. Introduction

Building America Program Requirements

All projects in the Building America program must meet the BSC Building America Performance Criteria, which includes requirements for energy efficiency, ventilation, combustion safety, and testing specifications. In addition, many recommended upgrades for building durability, resource efficiency, and minimizing ecological impact are also presented on that page. The requirements are presented on BSC's website (http://www.buildingscienceconsulting.com/buildingamerica/targets.htm).

The overall target is to achieve a reduction in source energy use of 40% relative to the Building America Benchmark; this reduction includes all end uses: not just heating, cooling, and hot water, but also lighting, appliance, and miscellaneous plug loads. Information on the Benchmark can be found at: http://www.eere.energy.gov/buildings/building_america/pa_resources.html.

Climate Loads

Buildings should be designed to suit their environments or climates. In the home building industry, we have accepted that design and construction must be responsive to varying seismic risks, wind loads and snow loads. We also consider soil conditions, frost depth, orientation and solar radiation. Yet we typically ignore the variances in temperature, rainfall, exterior and interior humidity and their interaction.

The building is sited in the San Francisco, CA area; at 3164 HDD 65°F and 265 CDH 74° F, this is a Marine climate according to BSC's hygrothermal region classification (http://www.buildingscienceconsulting.com/designsthatwork/hygro-thermal.htm); this climate is defined as follows:

- A mean temperature of coldest month between 27°F (3°C) and 65°F (18°C)
- A warmest month mean of less than 72°F (22°C)
- At least four months with mean temperatures over 50°F (10°C)
- A dry season in summer. The month with the heaviest precipitation in the cold season has at least three times as much precipitation as the month with the least precipitation in the rest of the year. The cold season is October through March in the Northern Hemisphere and April through September in the Southern Hemisphere.

The site is in DOE Climate Zone 3C (Marine); this climate map can be found at http://www.energycodes.gov/implement/pdfs/color_map_climate_zones_Mar03.pdf

The historical (typical year) weather data is graphed in Figure 1; the total rainfall is 22 inches per year, which would be considered a "moderate" rain loading. The rainfall is distributed roughly evenly throughout the year. The temperatures shown on the graph are monthly averages.

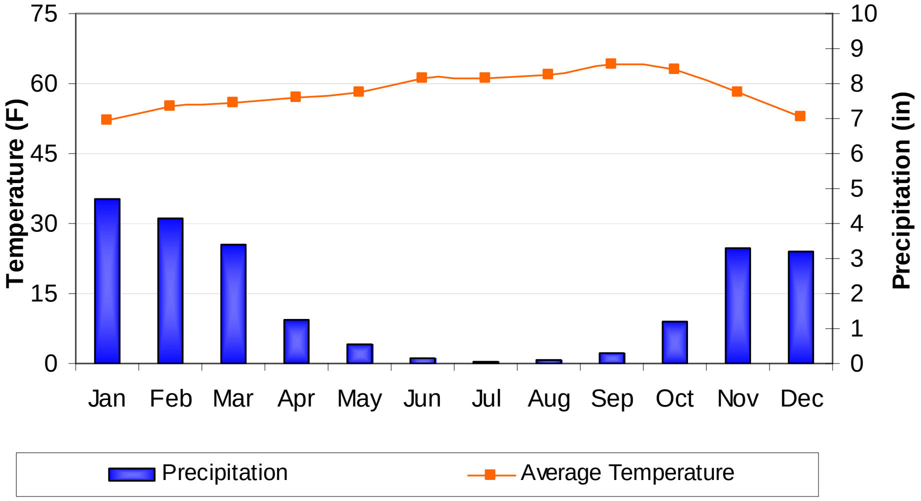


Figure 1: Average weather data for San Francisco, CA

For completeness, the weather data from 2007 (as a sample year) is shown in Figure 2; it includes both temperature and dewpoint (absolute air moisture content), as well as rainfall data. It demonstrates that the current temperature data tracks reasonably closely to historical averages.

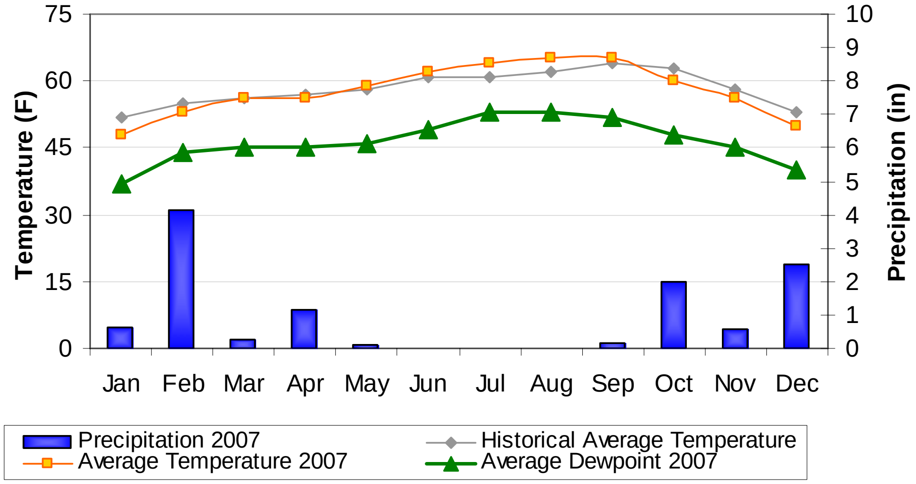


Figure 2: 2007 weather data for San Francisco, CA

The installation site for the Prototype is at the Pittsburg, CA plant site, which has different weather patterns relative to the San Francisco development site. 2007 weather data for at the Buchanan Field airport (Concord, CA; KCCR) is plotted below in Figure 3. It is clear that there are much warmer summers and slightly colder winters than in San Francisco, due to the inland location. However, rainfall and dewpoint patterns match relatively closely to SF.

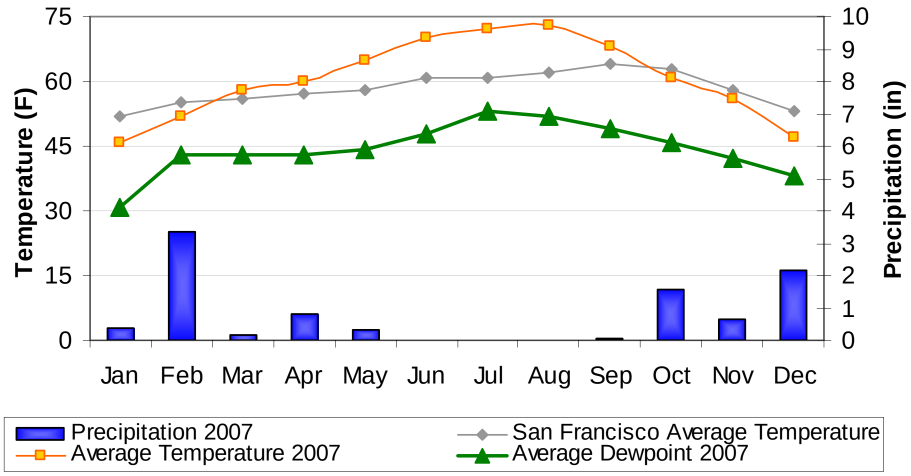


Figure 3: 2007 weather data for Concord, CA (KCCR)

Unfortunately, our simulation does not allow the addition of weather files, so all runs were done using the San Francisco climate. But this means that the cooling loads will be more significant for the Pittsburg prototype, relative to the Bayview site. However, additional simulations were run with the Sacramento climate, as described in "Simulations in Alternate (Sacramento) Climate."

2. Energy Performance Simulations

Parametric Simulations

Computer energy simulations were run on several parametric options, using FSEC's (Florida Solar Energy Center) EnergyGauge USA (v. USRCBB 2.7) software, which is a DOE-2.2 based simulation. A series of incremental improvements were made going from the "Benchmark," which is a standard residence, similar in size and shape to the unit in question, with characteristics that meet basic energy code requirements. The Benchmark characteristics are set by the Building America program. The specifics of the Benchmark and the improvements shown below are seen in tables in Section 7, Building Simulation Characteristics. The parametric study of incremental changes is shown in Figure 4 and Table 1 below. The loads are shown in terms of source energy (i.e., the primary energy needed to generate the electricity, as opposed to the site metered energy). The resulting consumption is divided into heating, cooling, domestic hot water, lighting, and other electrical loads (dishwasher, clothes washing & drying, cooking, refrigerator, miscellaneous electrical loads). The target of a 40% reduction in total energy use is shown by the brown line. The numbers are the top of the bar are the "percent savings relative to Benchmark" (with the goal of 40%).

The simulations results include predicted energy usage and savings, using a price of $0.1314 per kWh.

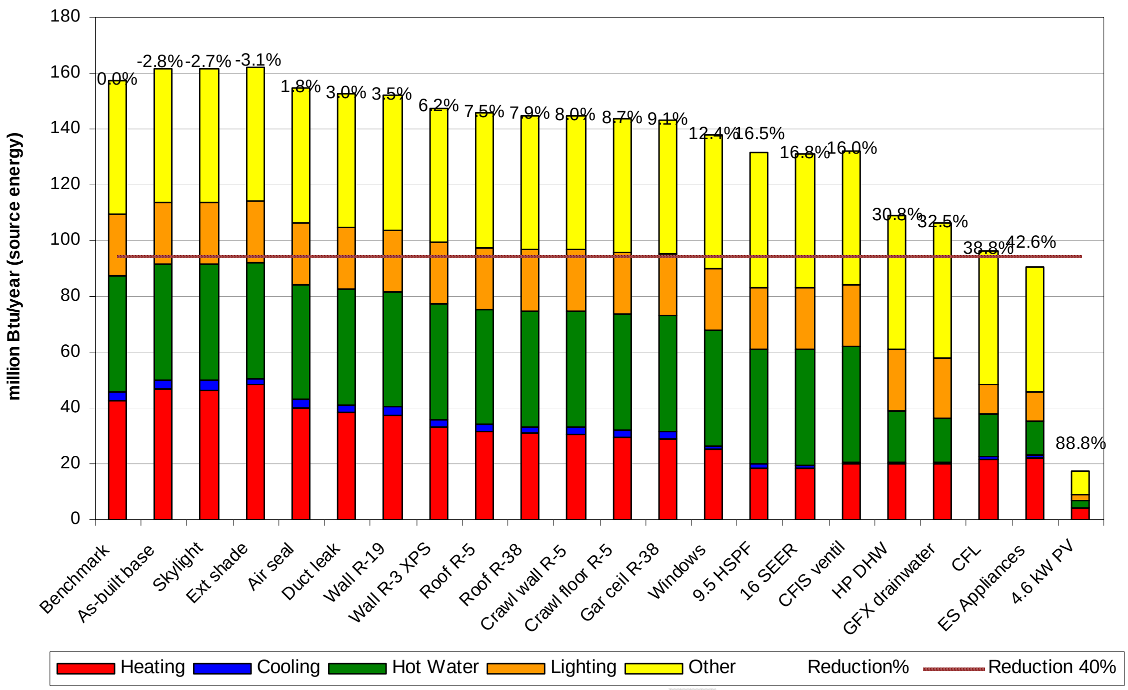


Figure 4: Parametrics simulations for Zeta Prototype

One thing that is immediately obvious from the graph is that the heating and cooling loads are not a very large fraction of the total—roughly 30% of the total source energy consumption (for the Benchmark). This means that many of the improvements directed towards the building enclosure (shell) have a much smaller payback than in hotter or colder climates. As noted by the average monthly temperatures (Figure 1), the small temperature differences mean that increasing insulation levels have a smaller effect.

Second, it should be noted that the energy simulation software has several limitations, and many of the more innovative techniques planned could not be explicitly modeled. They are noted below, but it cannot model the use of the crawl space as a "thermal flywheel" (heat/cold thermal storage), the insulation of the slab at the floor of the crawl space, and the slatted exterior window shades.

An item-by-item discussion of the upgrades is give below; the numbers correspond to the Parametric Run ID shown in Table 1 below.

1. **Windows as-designed:** this change puts the windows into their actual configuration, as opposed to the Benchmark assumption. It resulted in an increase in energy use (-2.8% penalty): the Benchmark assumes a glazing ratio of 18% of floor area, while the prototype is closer to 25%. Note that the Benchmark distributes the windows as per the existing orientation, so this penalty fails to reflect the benefits of the glazing orientation as done in this plan (high south glazing, low north glazing).
2. **Add skylight (south-facing; hallway):** results in a slight penalty on cooling, but a larger benefit on heating, resulting in an overall benefit (+0.1%)
3. **Add overhangs (brise soleil shades):** this item could not be explicitly modeled in this simulation; it only allows the use of solid overhangs. At the recommendation of the simulation developers, an overhang of 2/3 of the actual length was used to approximate the results. This change results in a slight overall **penalty**, with the benefits to cooling being outweighed by heating penalties. However, this is a very small difference (-0.3% or

$6/year), and should not be considered a definitive answer by any means. In addition, non-energy considerations (glare reduction) might be worthwhile reasons as well.

4. **Air seal (2.5 sq in/100 sf):** increasing airtightness resulted in improvements in both heating and cooling performance (4.9% total).
5. **Ducts 5% leakage (in conditioned space):** the ducts were already located within the conditioned building envelope (in the sealed crawl space); therefore, the benefit to reducing duct leakage was only moderate (1.2%)
6. **R-19 OVE Walls 24" o.c. from R-13$^+$:** this change was reduced by the fact that the Benchmark's "code" wall is relatively well insulated (R-13 batt plus R-1.1 insulating sheathing), resulting in an improvement of only 0.5%. This was only an upgrade from U=0.076 to U=0.063 (R-13.1 nominal to R-15.9 nominal), taking the thermal bridging at the wall framing into account.

   Note that the walls to the garage are drawn as 2x4 walls; 2x6 walls should be used at this location instead.
7. **Add wall sheathing 1" XPS R-5:** A 2.7% improvement; it eliminates thermal bridging through the stud framing. The plans appear to be currently drawn with ½" or ¾"insulating sheathing outside of the structural sheathing; this should be clarified.
8. **Roof add R-5 at roof deck:** 1.3% improvement
9. **Roof R-38 cavity insulation from R-25:** 0.4% improvement. This shows the effect of diminishing returns: the roofdeck is already insulated at a nominal R-30; adding R-13 on top of that only provides a small return.
10. **Crawl space walls to R-10 (2" XPS) from R-7:** 0.1% improvement. Note that this starts with the Benchmark (R-7.3) crawlspace wall to R-10; not the R-5 (1" XPS) shown on the current section.
11. **Crawl space floor to R-5 (1" XPS):** Unfortunately, the simulation does not provide a way to show insulation on the floor of the conditioned crawl space. To get an estimate, this step added R-5 at the floor framing; we would not recommend this in practice, but it partially captures the "decoupling" of the conditioned space from the cooler ground, which would also be accomplished by the sub-slab insulation. 0.7% improvement.
12. **Over garage to R-38 from R-15:** 0.4% improvement
13. **All windows Low-E (U=0.35, SHGC=0.30):** 3.3% improvement, which is fairly substantial.
14. **9.5 HSPF (heating season performance factor) heat pump:** 4.2% improvement, another significant jump. This climate is well-suited to the use of a heat pump for space conditioning; details are in the following sections.
15. **16 SEER (seasonal energy efficiency ratio) air conditioner:** a small (0.3%) improvement, which is understandable given the small proportion of the cooling load
16. **CFIS ventilation system:** a central fan integrated ventilation system is recommended to provide outside air ventilation when the house is sealed up during the heating season. There is an energy expense associated with this change (-0.8%), due to fan operating power (the Benchmark case is set up to eliminate the penalty for the heating/cooling cost associated with ventilation). Details of this system are in a section below.

17. **2.0 EF heat pump water heater:** a prototype heat pump water heater is specified; an energy factor (EF) rating of 2.0 was assumed. Given the small heating and cooling loads, the domestic hot water loads are a very large "piece of the pie"—as a result, this upgrade had a very large effect (14.9%). This upgrade more than doubles the efficiency of heating hot water (0.86 EF electric tank base case).
18. **GFX drainwater heat recovery:** a hot water savings of 15% was associated with the addition of a drainwater heat recovery system. This is based on an assumption of showers being 43% of hot water consumption, and a heat recovery rate of 35-42% (based on "Heat Recovery from Wastewater Using a Gravity-Film Heat Exchanger," DOE/EE-0247 Revised); the more conservative side was taken. Note that this system is only effective for concurrent draws and drains (i.e., showers, but **not** baths). Calculated overall savings were 1.7%.
19. **CFL Lighting Package:** changing to compact fluorescent lighting also provided fairly substantial savings (6.2%), once again, due to the size of the heating and cooling loads relative to plug/lighting/miscellaneous loads.
20. **Energy Star Appliances:** a 3.9% savings was estimated, based on the use of Energy Star rated refrigerator, dishwasher, and washing machine. Note that this savings includes the reduction in hot water use, due to the Energy Star appliances.
21. **4.6 kW PV system:** this system, placed at the roof slope, covers most (but not all) of the remaining annual electrical use. It results in a per-item savings of 46%, and a total savings for the entire package of 89% over the Benchmark.

Table 1: Parametric simulations for Zeta Prototype

Parametric Run ID	Description of change	over BA Benchmark[1]	Incremental Over Bmrk	Annual energy cost	Item Savings
0	Benchmark	n/a	n/a	$1,917	n/a
1	0 + Windows as-designed	-2.8%	-2.8%	$1,972	n/a
2	1 + Add skylight (south-facing; hallway)	-2.7%	0.1%	$1,970	$2
3	2 + Add overhangs (brise soleil shades)	-3.1%	-0.3%	$1,976	($6)
4	3 + Air seal (2.5 sq in/100 sf)	1.8%	4.9%	$1,882	$94
5	4 + Ducts 5% leakage (in conditioned space)	3.0%	1.2%	$1,861	$21
6	5 + R-19 OVE Walls 24" o.c. from R-13+	3.5%	0.5%	$1,851	$10
7	6 + Add wall sheathing 1" XPS R-5	6.2%	2.7%	$1,798	$53
8	7 + Roof add R-5 at roof deck	7.5%	1.3%	$1,774	$24
9	8 + Roof R-38 cavity insulation from R-25	7.9%	0.4%	$1,767	$7
10	9 + Crawl space walls to R-10 (2" XPS) from R-7	8.0%	0.1%	$1,764	$3
11	10 + Crawl space floor to R-5 (1" XPS)	8.7%	0.7%	$1,751	$13
12	11 + Over garage to R-38 from R-15	9.1%	0.4%	$1,744	$7
13	12 + All windows Low-E (U=0.35, SHGC=0.30)	12.4%	3.3%	$1,680	$64
14	13 + 9.5 HSPF heat pump	16.5%	4.2%	$1,600	$80
15	14 + 16 SEER air conditioner	16.8%	0.3%	$1,595	$5
16	15 + CFIS ventilation system	16.0%	-0.8%	$1,611	($16)
17	16 + 2.0 EF heat pump water heater	30.8%	14.9%	$1,326	$285
18	17 + GFX drainwater heat recovery	32.5%	1.7%	$1,294	$32
19	18 + CFL Lighting Package	38.8%	6.2%	$1,174	$120
20	19 + ES Appliances	42.6%	3.9%	$1,100	$74
21	20 + 4.6 kW PV system	88.8%	46.2%	$214	$886

Some secondary simulations were run to try to start to capture the effect of the crawl space thermal storage system. The included the addition of thermal mass (modeled as 2" of concrete, for the surface area of the crawl space), and moving the ductwork to the interior (instead of the crawl space, with the insulation at the floor framing level). These simulations are shown relative to run 20 (before adding the PV array). These changes are shown below; they should be added together (1.4%) for their combined effect.

A1	20 + Option: run with "mass" (2" concrete)	43.1%	0.5%	$1,090	$10
A4	20 + Move ducts inside after crawl insulation	43.6%	0.9%	$1,082	$18

However, note that these are simulations of using the thermal mass in a **passive** manner, **not** the active manner with the proposed control and air handler system.

HERS Index and Equipment Sizing

The HERS Index for this plan was calculated using these simulations; a HERS Index of 68 resulted without the photovoltaic system; with the system, it has an Index of 18. It should be noted that the HERS Index does not include the effect of the drainwater heat recovery system; it was simulated in our work by reducing the total daily hot water draw, which is a fixed number in the HERS Index simulations.

In addition, this simulation provides heating and cooling loads (useful for equipment sizing); the calculated loads were 14.2 kBtu/hour heating, and 8.2 kBtu/hour cooling. The smallest available size for the Goodman 16 SEER/9.5 HSPF heat pump (SSZ16 series) is 2 tons (24 kBtu/hour nominal output); this size will easily meet these loads.

Simulations in Alternate (Sacramento) Climate

In conversations with Dan Smith of DSA, he noted that Pittsburg CA had a climate more similar to Sacramento than to San Francisco. Despite initial doubts, the monthly average temperatures were compared between the three locations, as shown below in Figure 5. Based on this information, it appears that Sacramento is a closer match to Concord Airport/Pittsburg CA. However, the summers and winters are both milder in Concord, compared to Sacramento. The difference between San Francisco and Sacramento is also shown in terms of heating degree days, cooling degree days, and design conditions. Only limited data was available for Concord airport.

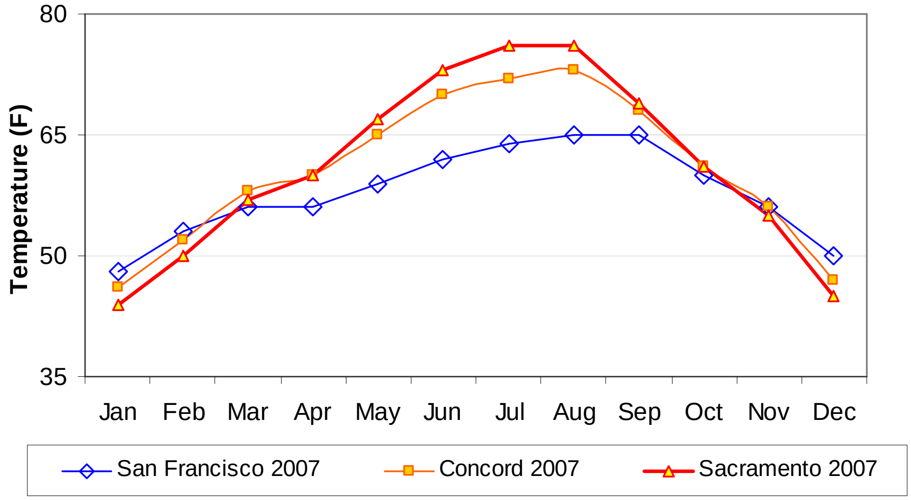


Figure 5: Monthly average temperature comparison (San Francisco, Concord airport, Sacramento)

Location	**HDD Base 65° F**	**CDH Base 74° F**	**Heating T (99.6%)**	**Cooling T (0.4%)**
San Francisco WSO	3164	265	37.8° F	83.0° F
SF Federal Bldg WS	3078	216	-	-
Sacramento WSO	2775	10464	31.3° F	100.4° F
Sacramento City WSO	2404	12556	31.1° F	100.0° F
Concord Airport (2007)	2987	-	-	-

Therefore, a selection of the previous simulations was run in the Sacramento climate, in order to observe the difference in behavior, as shown in Figure 6

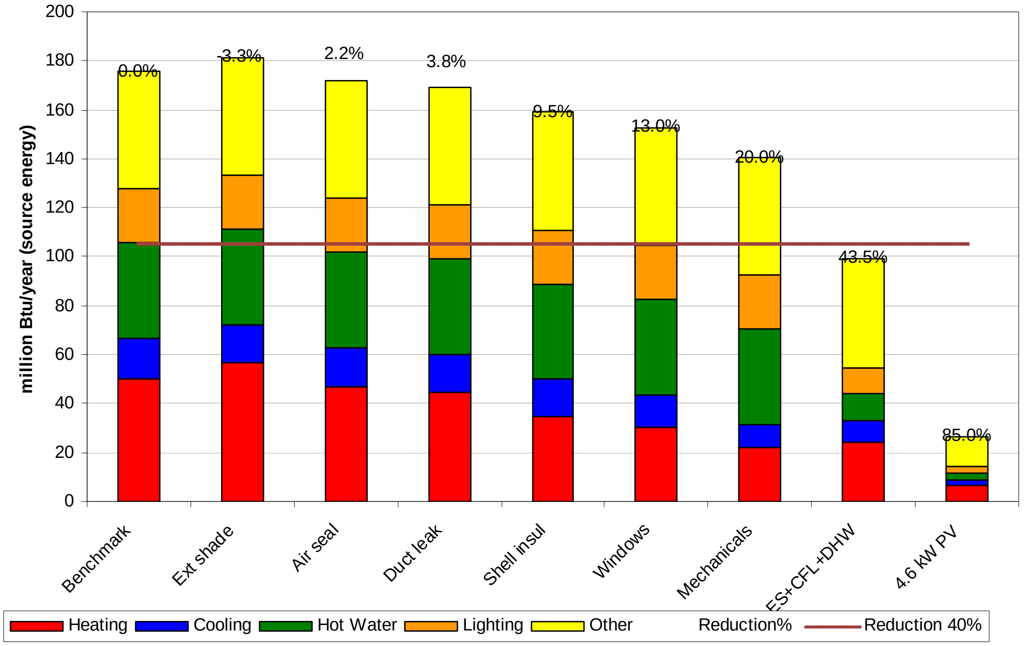


Figure 6: Selected parametric simulations for Prototype in Sacramento

There was a mixture of surprising and non-surprising results:

- As would be expected, the heating and cooling loads both increased for the Sacramento location. For the final Building America model, heating was 2055 kWh/year (San Francisco) and 2266 kWh/year (Sacramento); cooling was 73 kWh/year (SF) and 802 kWh/year (Sacramento).
- Domestic hot water, appliance, lighting, and miscellaneous loads stayed largely the same (domestic hot water was slightly lower in Sacramento, due to lower average annual temperature, resulting in higher temperature mains water).
- The reduction vs. Building America Benchmark was relatively similar between the two locations: for the final version without photovoltaic panels, 42.6% for

San Francisco; 43.5% for Sacramento. These results make sense, given that enclosure (heating/cooling) loads are higher in Sacramento, so the insulation measures specified will have a greater effect.

- With the addition of a 4.6 kW photovoltaic array, the San Francisco house was at an 89% reduction relative to the Benchmark, while the Sacramento house was at an 85% reduction relative to the Benchmark. This was slightly surprising: although heating and cooling loads were higher in Sacramento, it was expected that the greater PV production would make up for the difference, given the cloud cover in San Francisco. Therefore, the PV output was examined more closely.
- The PV output from the EgUSA simulation was 6745 kWh/year for San Francisco, and 6765 kWh/year for Sacramento. This small difference was quite surprising; therefore, another set of simulations were run using NREL's online PV simulator, PVWatts (http://rredc.nrel.gov/solar/codes_algs/PVWATTS/)
- The results of PVWatts were also surprising: the array (at a 9 degree tilt) produced 6224 kWh/year in San Francisco, but less—6118 kWh/year—in Sacramento. The results were examined several times: based on the simulation output, Sacramento receives 3% more solar radiation on panels at that tilt and azimuth. Some quick calculations were run to compare the efficiencies between the two sites; the results (for both the PV output and the efficiency) are shown in Figure 7 below.

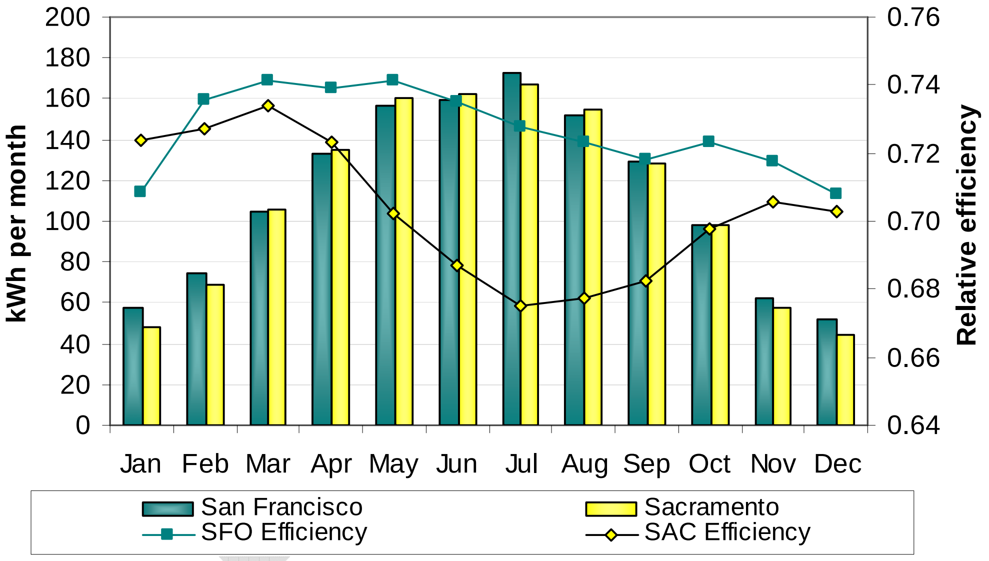


Figure 7: PV output for 1 kW array in San Francisco & Sacramento, with relative efficiency

That plot shows that the relative efficiency of the array in Sacramento suffers strongly in the summer months. This is caused by the higher summertime temperatures, which reduce the efficiency of PV cells.

Note that this "relative efficiency" is not **actual** panel efficiency—"conversion efficiency" is in the 6-12% range, typically (amorphous or crystalline modules). Instead, it is a metric (kWh/month irradiance divided by kWh/m^2·month PV production) used to compare the two panels.

The accuracy of the NREL weather file is unknown (i.e., the 3% difference in annual solar radiation), but is beyond the analysis being done at this time.

3. Mechanical System Items

Central Fan Integrated Ventilation

We would recommend the use of a controlled mechanical ventilation system that brings in a controlled and consistent amount of outside air throughout the year. Ventilation is especially important in small units with high occupant density (persons per square foot).

The recommended ventilation system is a central fan integrated supply ventilation system; the basics are covered in the document “Central Fan Integrated Supply Ventilation – The Basics” (http://www.buildingscienceconsulting.com/resources/mechanical/fancycling/CFIS_Basics.pdf) and at http://www.fancycler.com/.

The system is shown in Figure 8: it consists of an outside air duct connected to the return side of the air handler; when the system runs, it draws in outside air and distributes it throughout the house.

Continuous running of the air handler in order to draw ventilation air is not recommended. An Aprilaire VCS 8126 controller or equal (see http://www.fancycler.com/products/default.htm for options) is suggested, to run air handler periodically; it provides fan operation when there is no call for cooling or heating during the swing seasons, thus supplying ventilation. Furthermore, this system reduces stagnation and temperature stratification in the unit by providing mixing of house air. The system also controls a motorized damper in the outside air duct, which closes the duct after ventilation demand has been met. This prevents overventilation during peak heating and cooling times. The Aprilaire VCS 8126 fan cycler and motorized damper (see Figure 9) are available on www.aprilaire.com.

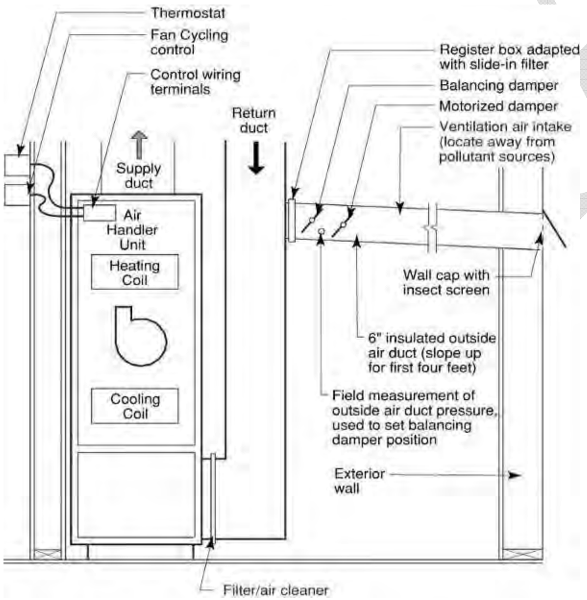


Figure 8: Central fan integrated supply system (shown with vertical AHU/furnace unit)

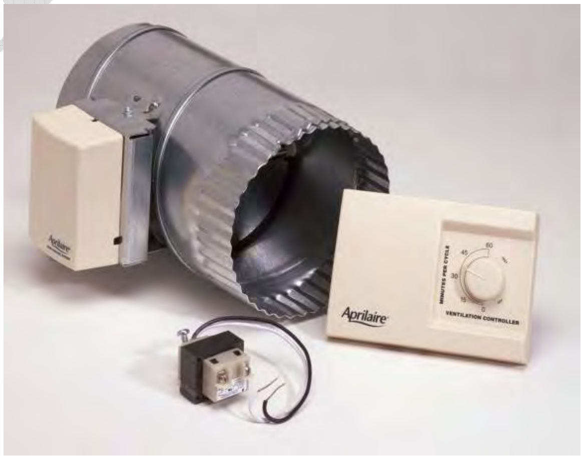


Figure 9: Aprilaire VCS 8126 controller and electrically operated damper

For this building, the ASHRAE 62.2 Standard rate would calculate out to a ventilation rate of 45 CFM, or roughly 0.2 air changes per hour. We would recommend operating the system at a **lower rate** (e.g., 40-50 CFM at a 33% duty cycle, resulting in 13-17 CFM average), except when dealing with large interior pollutant loads. Localized pollutant sources should be dealt with using exhaust fans, such as bathroom exhausts and a kitchen range hood vented to the exterior.

Is it very important to note that this system should be inactive when large house air changes are being done (e.g., night flushing). Otherwise, the fan operation will simply be energy expenditure for no purpose. Also, the ventilation system provides little benefit during periods when windows are open. Given the mild climate, this operating condition might be a large portion of the year.

Air Source Heat Pump Performance

The mild climate of the San Francisco Bay Area lends itself well to the use of an air source heat pump for heating. As outdoor temperatures fall, the efficiency of the equipment decreases, due to the increased work required to extract heat from outdoor air. In addition, when temperatures hit the mid to low 30s, the efficiency falls further, due to the requirement to add defrost energy, to melt frost that accumulates on the outdoor unit.

The ASHRAE design temperature (99.6% condition; 35 hours per year colder than that temperature) for San Francisco is 37.8° F; therefore, the equipment operates at high efficiency levels for most of the season.

This is shown in Figure 10 below. It plots the efficiency (COP, or coefficient of performance) for several heat pumps against the outdoor temperature, including the 16 SEER/9.5 HSPF Goodman unit specified (2 and 3 ton sizes). As mentioned above, the efficiency falls with decreasing outdoor temperature. In addition, the COP value of 2.8 is plotted on the graph: this is the efficiency level which is equivalent to a furnace burning at an efficiency of 90% AFUE (taking source and site energy considerations into account).

The design temperature (37.8° F) is also plotted, showing that in all expected conditions, the system will be operating at a higher efficiency level than burning of fossil fuels on site, as shown by the shaded grey box. A 13 SEER/7.7 HSPF Goodman unit is also plotted for comparison.

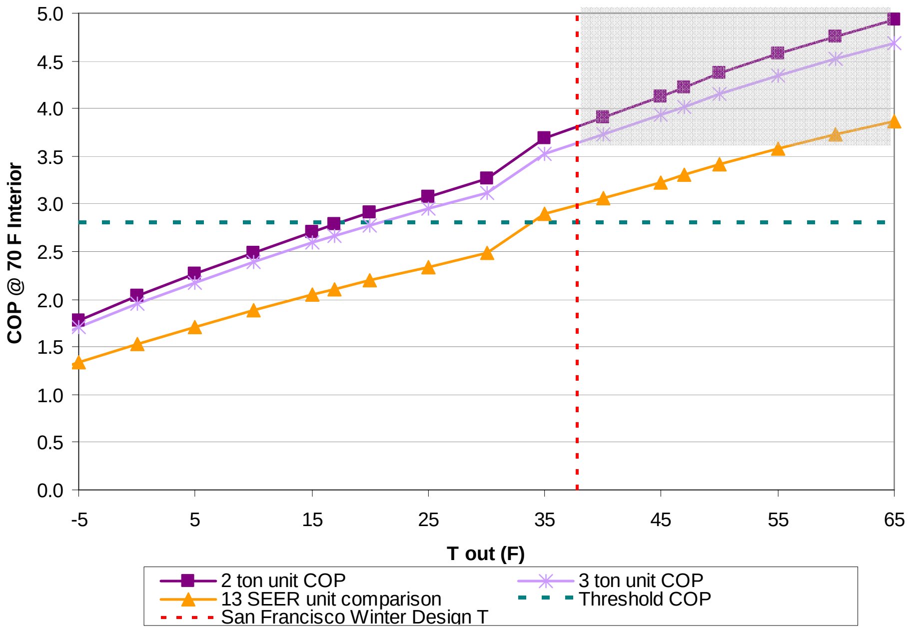


Figure 10: Goodman 16 SEER/9.5 HSPF heat pump performance

More importantly, it appears that it will not be difficult to design a system that will not spent any time running on electric strip resistance (backup) heat, which is far less efficient than heat pump operation (COP = 1.0). This can be determined by a comparison between the heating output of the unit at design conditions, and the calculated heat loss of the house.

The exceptional performance of heat pumps in the Bay Area is shown in the map below (Figure 11), taken from “Climate Impacts on Heating Seasonal Performance Factor (HSPF) and Seasonal Energy Efficiency Ratio (SEER) for Air Source Heat Pumps” (Fairey et al. 2004).

Figure 11: Effect of climate on HSPF and SEER (Fairey et al. 2004)

An ARI-rated 7.8 HSPF heat pump has an actual performance closer to 9.5 HSPF when located in San Francisco due to the mild winter climate. This paper can be found at http://www.fsec.ucf.edu/en/publications/html/FSEC-PF-413-04/.

4. Comparison with Energy-10 Modeling

There was substantial previous energy modeling done by Dan Smith & Associates using the SBIC simulation Energy-10; the results from those simulations were compared with BSC’s EnergyGauge USA simulations. Admittedly, this is a poor comparison, as we are comparing two different plans—one a single-family house, and the other a townhouse. In addition, in our experience, there are different assumptions and algorithms in different computer simulations; achieving correspondence is typically difficult if not impossible. However, it might be illuminating to compare this performance with earlier simulations, and see if there are extremely different assumptions between these modeling exercises.

The simulation was described as follows (as per Dietmar Lorenz):

> *The "ZETA townhouse" has R-25 walls, R-38 roof, double lo-e windows. The massing has offsets that allow some South fenestration. The indirect mass effect of the crawl space plenum has been approximated by adding thermal mass, which E-10 does by adding CMU partitions. Exhaust air heat recovery is approximated by lowering the infiltration from ELA=268 to ELA=50, less than the 27% default (ELA=72) for tight construction in E-10. The DHW savings have been approximated by lowering the demand to account for higher efficiencies*

(from 0.66 W/sf to 0.18 W/sf; assuming 30 savings by GFX heat recovery and 2.5 efficiency gain with a HP instead of ER).

Some key aspects that will make these simulations differ are:

- DSA ran the 1416 sf townhouse (either Plan 1A or 1B); BSC ran the 1553 sf single family prototype (all sides exposed, vs. party walls)
- Setpoints were different between the two simulations. In the DSA simulations, a heating setpoint of 70° F (with 65° F setback) and a cooling setpoint of 78° F (with 83° F setback) were used. In BSC's simulations, setpoints of 71° F and 76° F for heating and cooling are required for the Benchmark analysis.
- The DSA analysis had heating and cooling equipment with performance of COP=2.9,EER=8.9; the BSC analysis used HSFP and SEER numbers, but they are roughly equivalent to COP≈4 and EER≈11 or 12.
- Infiltration numbers were relatively similar: DSA used ELA=50; BSC used ELA=62.
- The BSC simulation used minimal mass elements, while the DSA simulation used some interior mass
- It is possible that there are differences in the weather files, even though the nominal climate is identical (San Francisco).

The results are shown below in Table 2 and Figure 12.

Table 2: Comparison of Energy-10 and Energy Gauge USA modeling reuslts

	DSA Energy-10	BSC EgUSA	BSC/DSA Ratio
Heating	550	2055	374%
Cooling	253	73	29%
DHW	1107	1161	105%
Lighting	609	960	158%
Other	3373	4129	122%
Total	**5892**	**8378**	**142%**

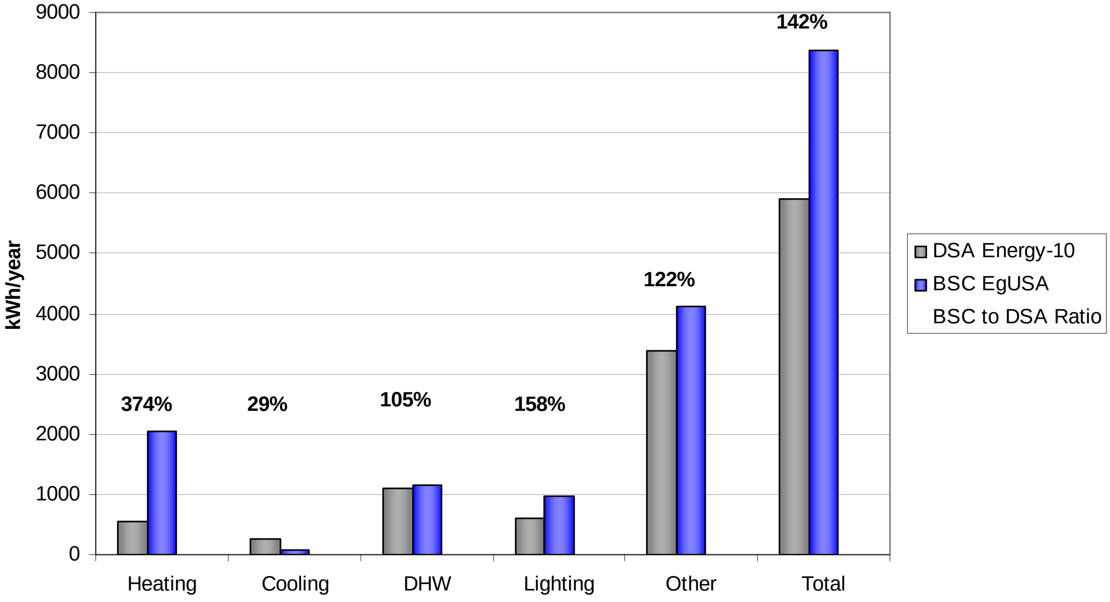


Figure 12: Performance of annual electrical consumption (kWh) for DSA and BSC simulations

Clearly, the majority of the difference is in the predicted heating load; much of this might be due to the difference between townhome and single-family construction (less exposed surface area). A version of the BSC simulation with the north wall under adiabatic (neighboring) conditions was run, dropping heating load from 2055 kWh/year to 1694 kWh/year, an 18% reduction.

The setpoint is another potential reason: changing the Energy Gauge setpoints to those used in the Energy-10 runs resulted in a drop in heating load from 2055 kWh/year to 1622 kWh/year; it assumed wintertime setbacks both during the day on weekdays, and during evenings on all days. This is a reduction of 20% of the heating consumption.

Combining these two previous measures results in a heating consumption of 1326 kWh/year, or a reduction of 35%. However, it is still much higher than the 550 kWh/year for the Energy-10 simulations). Adding thermal mass (in the form of a 2” slab the area of the crawl space) resulted in a further reduction to 1287 kWh/year. The large difference between the two simulations might be ascribed to the assumptions used in the software algorithms.

The cooling loads were also fairly different, but both were small loads. The lighting and “other” loads were higher in the BSC simulation (+60% and +20%), as per Benchmark requirements. Domestic hot water energy use showed reasonable correspondence.

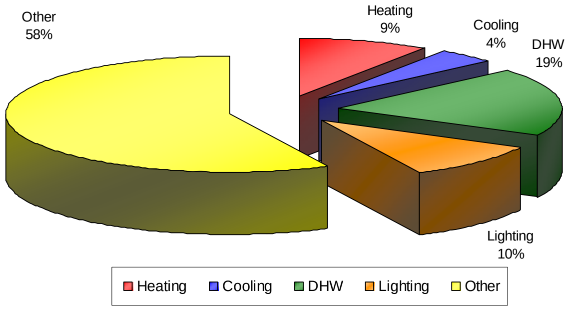


Figure 13: Energy-10 (DSA) results for 1416 sf Zeta Townhouse

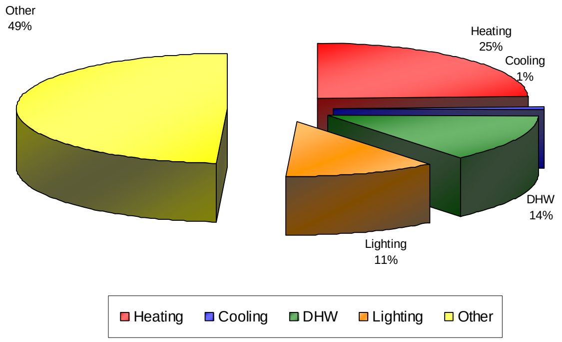


Figure 14: Energy Gauge USA (BSC) results for 1553 sf Zeta Prototype (single family house)

Of course, the question that everyone would like to know is which simulation is "right." This cannot be answered here; BSC has seen EgUSA simulations with close correspondence to a house population's utility bills, but has also seen many with very poor correspondence. It appears that DSA has found good correspondence between Energy-10 simulations and measured utility bills, which is quite convincing for accuracy of the simulation in this climate.

5. Improvement Items

In our simulations, several items were noted that were not quite optimized for best energy performance, as noted below.

Photovoltaic Array

The photovoltaic array is shown in the rendering matching the roof slope, which is at a 2:12 pitch. Best practices for this region are a higher slope of roughly 30°, as described in *Building America Best Practices Series: High-Performance Home Technologies: Solar Thermal & Photovoltaic Systems* (NREL 2007); it can be downloaded at http://www.eere.energy.gov/buildings/building_america/pdfs/41085.pdf

Assuming a 180° azimuth (south-facing) array, a 1 kW system with a 0.77 derate factor, the penalty for lowering the angle of the array to the roof slope (2:12 or 9 degrees) is 7 percent. For a 4.6 kW system, this would be a difference of 446 kWh, or $59/year at the electrical rate stated earlier. This is shown on a monthly basis in Figure 15 below; the results are from the NREL PVWatts simulation ("A Performance Calculator for Grid-Connected PV Systems").

However, lowering the angle of the array increases electricity output during the summer months (at the penalty of winter months); if there is time-of-use or seasonal metering that would change the value of the power based on generation time, this could be a worthwhile strategy. Of course, the cost of the rack to angle the rack at a latitude-appropriate tilt can be compared with a payback of $59/year, to determine the economics of this modification.

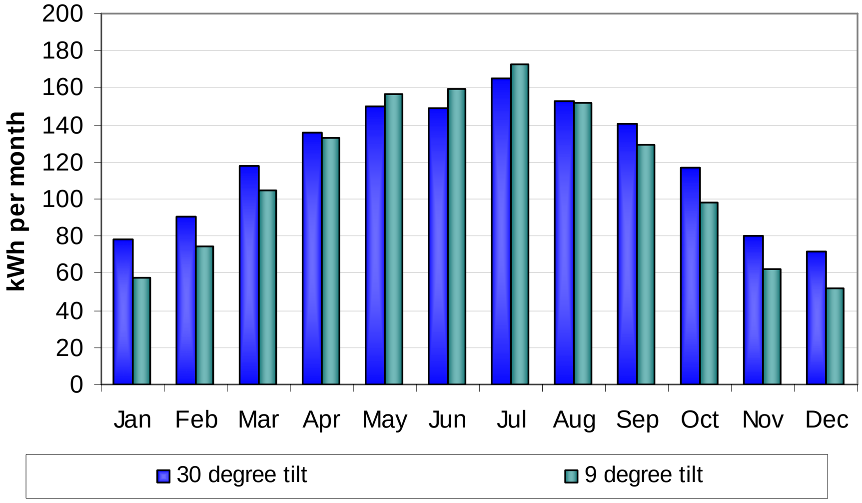


Figure 15: Comparison of monthly output of 30 & 9 degree PV array tilts

Exterior Sunshades

As mentioned above, the slatted brise-soleil style sunshades could not be modeled in simulation used here. Despite the lack of explicit modeling, one possible improvement to the system would be tilting the slats in order to maximize winter solar gain, and minimize summer solar gain. Ideally, the slats would be designed so that they shade at least 75% of the sun between March 21 and September 21.

It appears that it might be difficult to do have tilted slats without adding complications to construction details; for instance, if wooden slats are used (as shown), the boards would need to be ripped down at an angle from larger pieces, with resulting waste. Alternately, a frame could be set up that would allow the tilting of the slats.

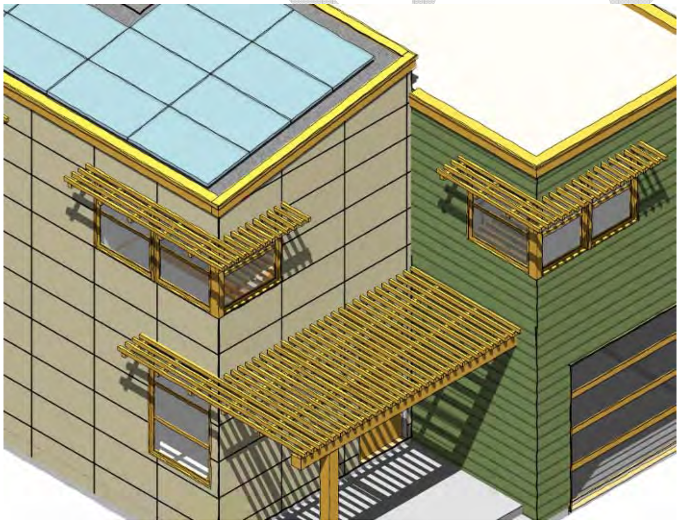


Figure 16: Exterior sunshades on front/side (east/south) orientations

Mechanical Room

The mechanical room adjacent to the garage is shown as an exterior space (connected to the garage). However, this results in some odd configurations of the thermal boundary (air barrier/thermal barrier), as noted below in Figure 17.

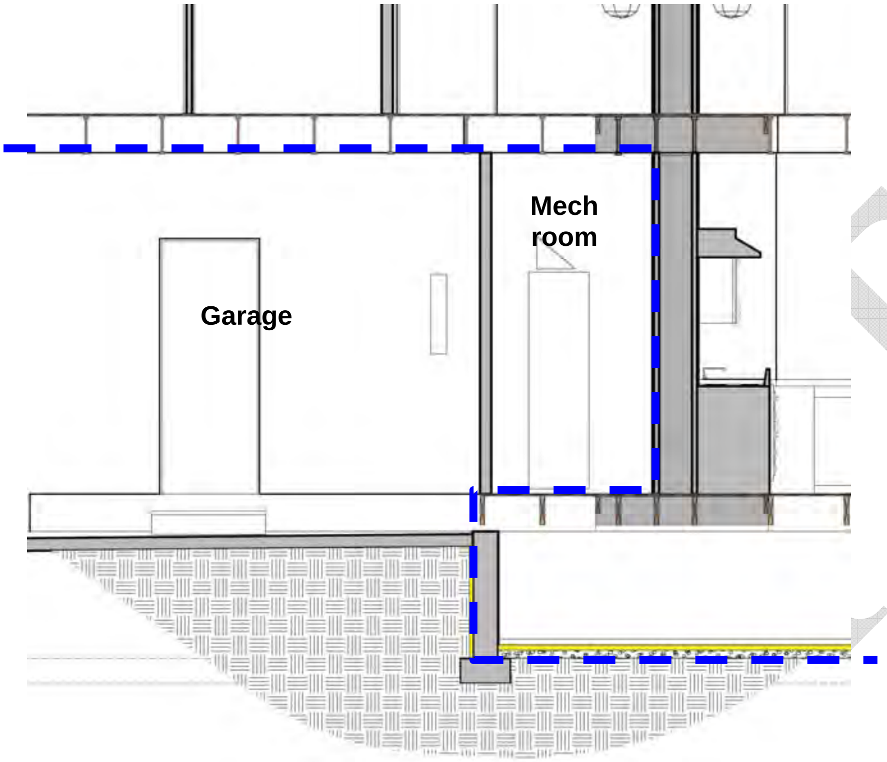


Figure 17: Garage and mechanical room (from Section B A4.2)

If the heat pump water heater is located in this space, it would need to be connected to the outside. Otherwise, if it were inside, given the dominance of heating over cooling, it would result in pulling heat out of the air during the heating season, and increased energy use.

That being said, the mechanical room forms a "pocket" that will require air sealing and insulation at the wall to the interior space, and at the floor and ceiling. The adjacent wall is the prefabricated mechanical/plumbing core which runs two stories. This provides an exceptionally vulnerable point for air leakage: any leak at the mechanical room would be well connected to the rest of the building.

The floor might be particularly difficult to insulate: it will require penetrations for mechanical equipment, making loose-fill insulation very inconvenient. It might be site insulated, but this will require access and inspection from inside the crawl space. The mechanical penetrations through the floor will connect to the crawl space, which is conditioned space (as well as the "thermal plenum," which will be pressurized or depressurized as needed).

The ceiling insulation will require insulation to continue from the floor over the garage.

6. Impact of Attached Housing

The actual production Zeta Communities houses are to be attached townhomes, located in San Francisco (Bayview neighborhood). Going from single-family housing to attached buildings will have an impact on the energy performance. Due to the reduction in the exposed surface area, the heating and cooling loads are a smaller proportion of total energy use in townhomes. Therefore, the improvements shown due to enclosure (shell) and mechanical upgrades will have a smaller effect. However, the enclosure upgrades will be a somewhat lower cost as well, due to the reduced surface area, again. Unfortunately, the Benchmark comparison is against a house of a similar configuration (i.e., townhome with similar exposure), so even though energy consumption (per square foot, or per occupant) is being reduced with this construction, the benefits are not seen in this Benchmark analysis.

This raises the question of whether it might be a worthwhile measure to look at greater control of the miscellaneous electrical loads (MELs); as seen in Figure 4, they are the single largest remaining load. The only reductions shown in the simulations were due to the addition of Energy Star appliances.

The problem is that MELs are controlled (and consumption is driven) completely by homeowner behavior. In our analysis of utility bills, we have found houses with the identical plan and orientation that had electrical consumption that varied by a factor of three or more.

There are many potential technologies to manage MELs, with varying levels of complexity and expense. One possible approach is to use a feedback system, which shows instantaneous electrical use in the occupied space, to give homeowners to modify their behavior, if they are so inclined. Examples include the TED (The Energy Detective/TED) monitoring system (Figure 18) as a very basic step (http://www.theenergydetective.com/ index.html); a more involved and higher resolution system, with a better (web-based) user interface, would be the Greenbox system (sample output in Figure 19 (http://www.getgreenbox.com/company/for-consumers/).

Figure 18: TED (The Energy Detective) electrical feedback monitor

312 Bachman
Los Gatos, CA

Electricity

Current Power 5.97 kW

Electricity Used Today 15.44 kWh
6.49 kwh less than average

Annual cost $ 3,378

Annual Carbon Emissions 9.05 tons

Heating and Cooling

Heat Run Time 97 min

Cost $2.31

Gas

Usage 0 therms

Cost $2.30

Weather

Wind SW 15 mph

UV Index 2

Humidity 28%

Temperature 73F

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You could save $100 a month with a solar system

Green Savings bank will loan you money to weatherize your house

Figure 19: Sample forms of output display for Greenbox system

An evaluation of this type of equipment was written in “Pilot Evaluation of Energy Savings from Residential Energy Demand Feedback Devices” (Parker 2008), which can be downloaded at http://www.fsec.ucf.edu/en/publications/pdf/FSEC-CR-1742-08.pdf. The authors found “an average 7% reduction in energy use from feedback homes in the second year of monitoring after controlling for weather-related influences.” Of course, all of this requires homeowners to modify their behavior; if they are uninterested in making such a change, little or no savings will result.

7. Building Simulation Characteristics

Building enclosure	**As-Built/Building America Version**	**Benchmark Version**
Ceiling	R-38 cellulose (2x12 ceiling joists) + 1" XPS rigid insulation	U=0.036 (R-25 cavity insulation)
Walls	2x6 OVE R-19 cavity insulation + 1" XPS rigid insulation	U=0.076 (R-13 cavity insulation + R-1.1 sheathing)
Frame Floors	R-38 cellulose (12" TJI floors)	U=0.052 (R-15.3 cavity insulation)
Crawl space	Sealed insulated crawl as thermal storage plenum	Sealed insulated crawl (wall U=0.110/R-7.3)
Windows	Vinyl frame low-emissivity units	Benchmark windows per Table 3 (3,000–3,999 HDD)
	Average U=~0.35, SHGC=~0.30	U=0.58, SHGC=0.58
Infiltration	2.5 sq in leakage area per 100 sf of envelope area	0.00057 specific leakage area (SLA)
	1130 CFM 50 / 5.18 ACH 50	2322 CFM 50 / 10.6 ACH 50
Mechanical systems		
Heating & Cooling	Goodman 16 SEER/9.5 HSPF air source heat pump (SSZ16)	Air source heat pump, 6.8 HSPF
	located in conditioned space (crawl space)	Air source heat pump, 10 SEER
	with Goodman/Amana MBE ECM modular blower interior	
DHW	Prototype heat pump water heater (2.0 EF)	Electric tank water heater, 0.86 EF
Ducts	Located in conditioned space (crawl space)	Located in conditioned space (crawl space)
	leak free to outside (5% or less)	15% total leakage (9.75% to outside)
Ventilation	Aprilaire VCS 8126 Supply-only system integrated with AHU	17 CFM ventilation neutralization @0.5 W/CFM
	33% Duty Cycle: 10 minutes on; 20 minutes off	-
	17 CFM continuous average flow	-
Return Pathways	Transfer grilles/jump ducts at bedrooms	n/a
Lighting	100% Compact Fluorescent Lighting	Conventional lighting
Appliances	Energy Star Appliances	Conventional appliances

2008-12 Zeta Lancaster Lofts Energy Analysis

From:	Kohta Ueno, Building Science Corporation	Date:	December 2, 2008
To:	Dan Smith DSA Architects	Re:	Zeta Lancaster Lofts Energy Analysis

Hello Dan:

I have run the Lancaster Lofts Duplex plan in Oakland through a similar energy analysis as the previous models, including some estimates of PV array sizing that will result in net zero energy performance. If you have any questions, you can reach me as per the contact information below, or at kohta@buildingscience.com.

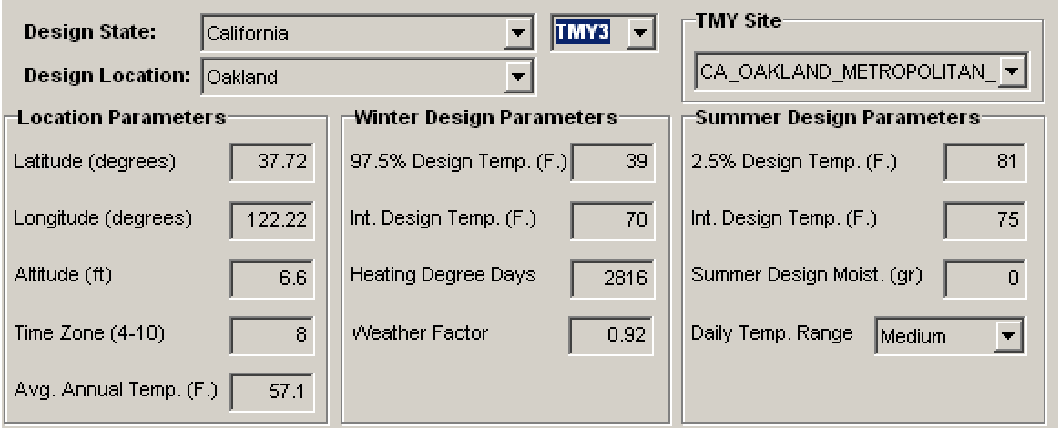
Best regards,

Kohta Ueno

Cc: John Straube, Ph.D., P.Eng.

Modeling Inputs

The simulation software that we use has been updated to include the TMY3 (Typical Meteorological Year) data set, which has data for 1020 locations, compared with 239 for the TMY2 data set. One of the included sites is Oakland, CA, which was used here (see Figure 1).



Design State: California
TMY3
TMY Site: CA_OAKLAND_METROPOLITAN_
Design Location: Oakland

Location Parameters
Latitude (degrees): 37.72
Longitude (degrees): 122.22
Altitude (ft): 6.6
Time Zone (4-10): 8
Avg. Annual Temp. (F.): 57.1

Winter Design Parameters
97.5% Design Temp. (F.): 39
Int. Design Temp. (F.): 70
Heating Degree Days: 2816
Weather Factor: 0.92

Summer Design Parameters
2.5% Design Temp. (F.): 81
Int. Design Temp. (F.): 75
Summer Design Moist. (gr): 0
Daily Temp. Range: Medium

Figure 1: Oakland CA TMY3 data summary

For reference, the ASHRAE *Handbook of Fundamentals* weather conditions are shown

Table 1: Oakland Airport Weather Station Data WMO # 724930 (ASHRAE)

Heating 99.6% T	37.5°F
Cooling 0.4% T	81.8°F
Coincident wet bulb T	65.0°F
Elevation	3 ft
HDD Base 65 F	2880
CDH Base 65 F	435

The building enclosure and mechanical system characteristics shown in Table 2 were used for the initial parametric simulations. The majority of these are identical to characteristics used in previous simulations; the one exception is the window characteristics.

Table 2: Building enclosure and mechanical characteristics

Building enclosure	**As-Built/Building America Version**
Ceiling	R-38 cellulose (2x12 ceiling joists) + 1" XPS rigid insulation
Walls	2x6 OVE R-19 cavity insulation + 1" XPS rigid insulation
Frame Floors	R-38 cellulose (12" TJI floors)
Crawl space	Sealed insulated crawl as thermal storage plenum R-10 exterior wall insulation; R-5 under slab
Windows	Serious Materials/ThermaProof Windows Series 500 Typical: U=0.22 SHGC=0.20
Infiltration	2.5 sq in leakage area per 100 sf of envelope area 1150 CFM 50 / 4.4 ACH 50
Mechanical systems	
Heating & Cooling	Goodman 16 SEER/9.5 HSPF air source heat pump (SSZ16) located in conditioned space (crawl space) with Goodman/Amana MBE ECM modular blower interior
DHW	AirTap heat pump water heater (2.11 EF)
Ducts	Located in conditioned space (crawl space) leak free to outside (5% or less)
Ventilation	Aprilaire VCS 8126 Supply-only system integrated with AHU 33% Duty Cycle: 10 minutes on; 20 minutes off 17 CFM continuous average flow
Return Pathways	Transfer grilles/jump ducts at bedrooms
Lighting	100% Compact Fluorescent Lighting
Appliances	Energy Star Appliances

Since Serious Materials ThermaProof windows are planned for this project, they were used in these simulations. For these initial runs, a 500 Series Dual Pane, 1 Low SHG Film, Krypton-filled unit was selected, with numbers as per above. Some alternate simulations are shown later, examining the effect of window choices (Alternate Measure Simulations (Windows)).

One unit of the duplex was modeled, in the orientation as shown on the drawings (front facing roughly northwest; rear facing southeast). Since windows are only present on the front and back elevations, both units should have close to identical performance.

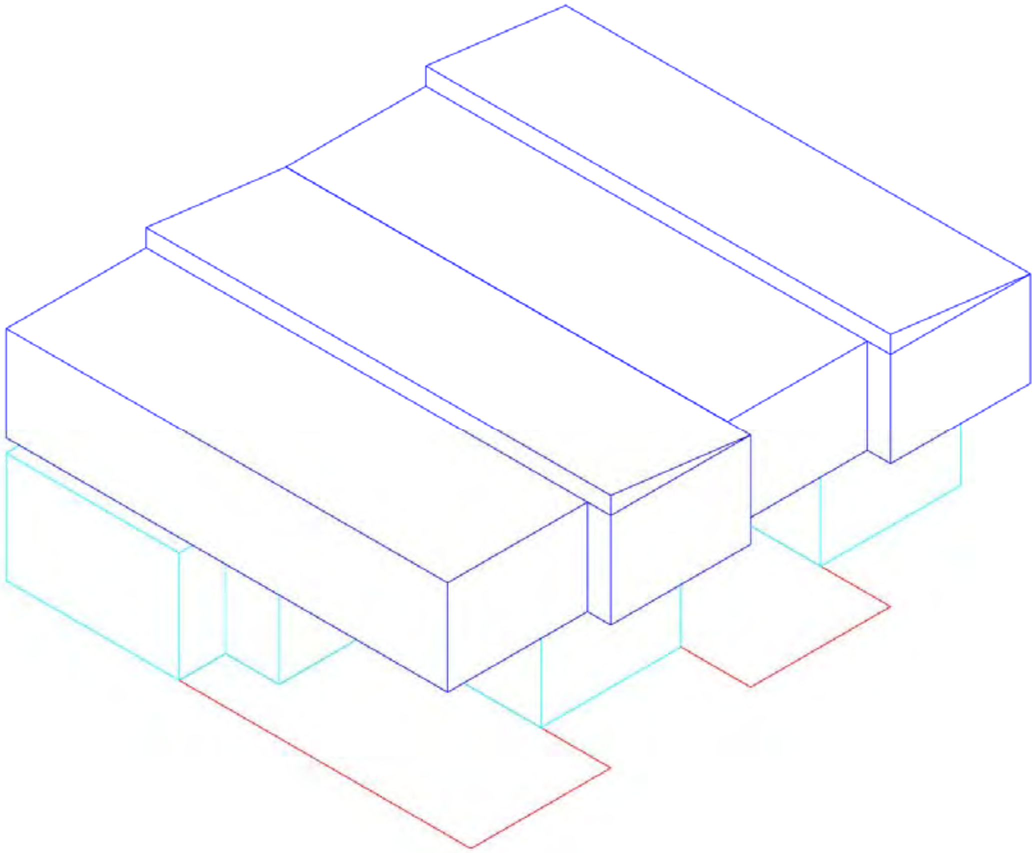


Figure 2: Isometric block model used for area takeoffs

Figure 3: Lancaster Lofts front view (c/o DSA)

Simulation Results

Using the inputs given above, a parametric analysis (incrementally changing from the Building America Benchmark simulation to the as-built prototype) was performed; the results are shown in Figure 4 and Table 3 below. Some points of interest are as follows:

- Similar to previous simulations, the heating and cooling load are a relatively small proportion of the total building's load: in the Benchmark, it is only 30% of the total. This will tend to reduce the effectiveness of enclosure measures (increased insulation, airtightness, duct tightness).
- The cooling load is close to insignificant; therefore, measures that tend to penalize the heating performance to improve cooling performance are unlikely to be effective.
- If Building America Benchmark operating assumptions are used, a 4.6 kW photovoltaic system does not provide net zero energy. However, the size of the PV system is examined in more detail below (see Photovoltaic System Sizing).
- With the measures specified, the unit meets the 40% improvement over Benchmark target, without the use of photovoltaics. It reaches 44.4%, which is slightly better than the Pittsburg single family prototype located in the Concord, CA climate (43.4% improvement). Although better windows are used in the Oakland simulations, we also face the penalty of proportionately reduced heating/cooling loads in duplex construction.

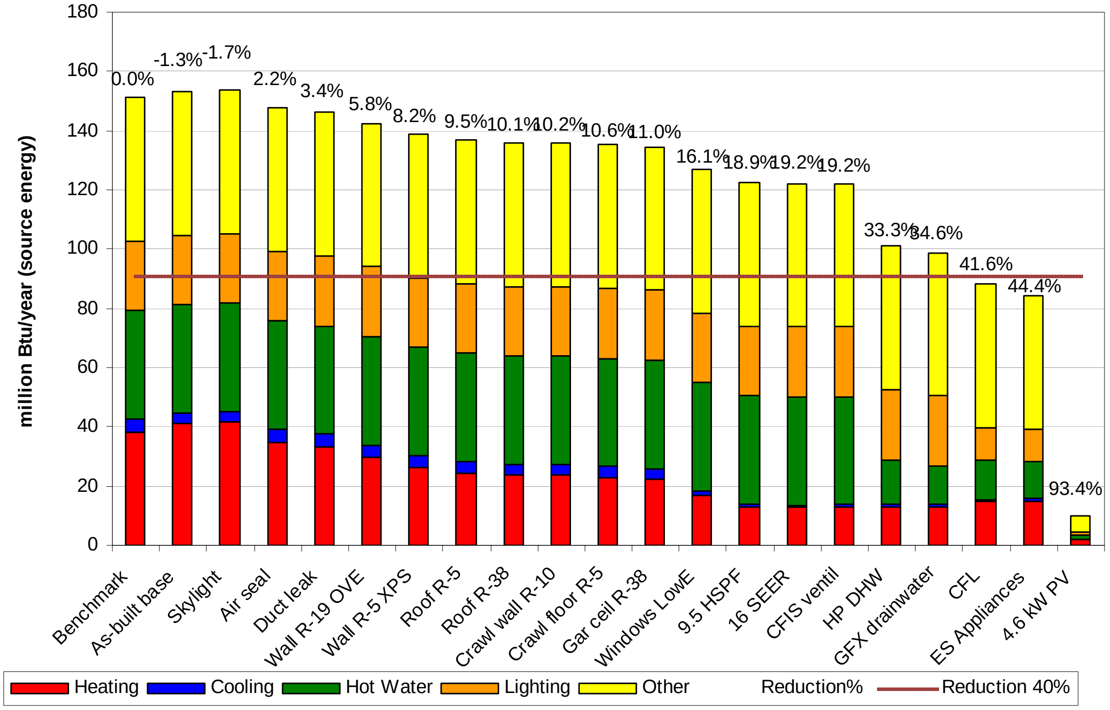


Figure 4: Parametric simulation results for Lancaster Lofts (Oakland)

Table 3: Parametric simulation results for Lancaster Lofts (Oakland)

Parametric Run ID	Description of change	over BA Benchmark[1]	Incremental Over Bmrk	Annual energy cost	Item Savings
0	Benchmark	n/a	n/a	$1,723	n/a
1	0 + Windows as-designed & overhangs	-1.3%	-1.3%	$1,753	($30)

Parametric Run ID	Description of change	over BA Benchmark[1]	Incremental Over Bmrk	Annual energy cost	Item Savings
2	1 + Add skylight (stairwell; 1.5:12)	-1.7%	-0.4%	$1,762	($9)
3	2 + Air seal (2.5 sq in/100 sf)	2.2%	3.9%	$1,692	$70
4	3 + Ducts 5% leakage (still in crawlspace)	3.4%	1.2%	$1,672	$20
5	4 + R-19 OVE Walls 24" o.c. from R-13+	5.8%	2.4%	$1,631	$41
6	5 + Add wall sheathing 1" XPS R-5	8.2%	2.4%	$1,590	$41
7	6 + Roof add R-5 at roof deck	9.5%	1.4%	$1,566	$24
8	7 + Roof R-38 cavity insulation from R-25	10.1%	0.5%	$1,556	$10
9	8 + Crawl space walls to R-10 (2" XPS) from R-6	10.2%	0.1%	$1,555	$1
10	9 + Crawl space "floor" to R-5 (1" XPS)	10.6%	0.4%	$1,547	$8
11	10 + Over garage & hang to R-38 from R-16	11.0%	0.4%	$1,540	$7
12	11 + All windows ThemaProof 500 Series Lo SG	16.1%	5.1%	$1,454	$86
13	12 + 9.5 HSPF heat pump	18.9%	2.8%	$1,404	$50
14	13 + 16 SEER air conditioner	19.2%	0.3%	$1,399	$5
15	14 + CFIS ventilation system	19.2%	0.0%	$1,399	$0
16	15 + 2.11 EF heat pump water heater	33.3%	14.1%	$1,155	$244
17	16 + GFX drainwater heat recovery	34.6%	1.3%	$1,132	$23
18	17 + CFL Lighting Package	41.6%	7.0%	$1,012	$120
19	18 + ES Appliances	44.4%	2.7%	$962	$50
20	19 + 4.6 kW PV system; 7 tilt, 210 azimuth	93.4%	49.0%	$62	$900

Some detailed points on the simulation results are as follows:

- The windows in as-designed locations and the addition of the skylight both resulted in energy penalties; the Benchmark assumes even lower glazing (224 sf) than that used in the plan (300 sf). This penalty does not include any counterbalancing benefit from reduced lighting loads in the stairwell/hallway.
- Air sealing is one of the more substantial upgrades at 4%.
- Duct sealing/location in conditioned space has a relatively small benefit, given that the ducts are in a relatively “benign” location of a sealed and semi-conditioned crawl space
- The opaque enclosure insulation upgrades all have relatively small effects (0.1% to 2.4%); greater benefits are seen in the wall upgrades. This result makes sense given diminishing returns issues (Benchmark roof starts at R-25 insulation, vs. R-9.3 walls).
- The windows are a significant upgrade (5%), which is expected given their exceptional performance (ThemaProof 500 Series Lo SG U=0.22 SHGC=0.20).
- Upgrading the mechanical system also had a noticeable effect (3%), mostly on the (dominant) heating side.
- The addition of the heat pump water heater had the single largest upgrade effect (14%), due to the relatively large proportion of the domestic hot water load. This assumes that it will be operating at its stated efficiency (2.11 EF) throughout the year; it is unknown what the actual field operating efficiency will be.
- Compact fluorescent lighting and Energy Star appliances also caused significant reductions (7% and 3%, respectively).

As can be seen in Figure 5, the "other" (miscellaneous end use loads and appliance loads) are a significant fraction of the total energy use.

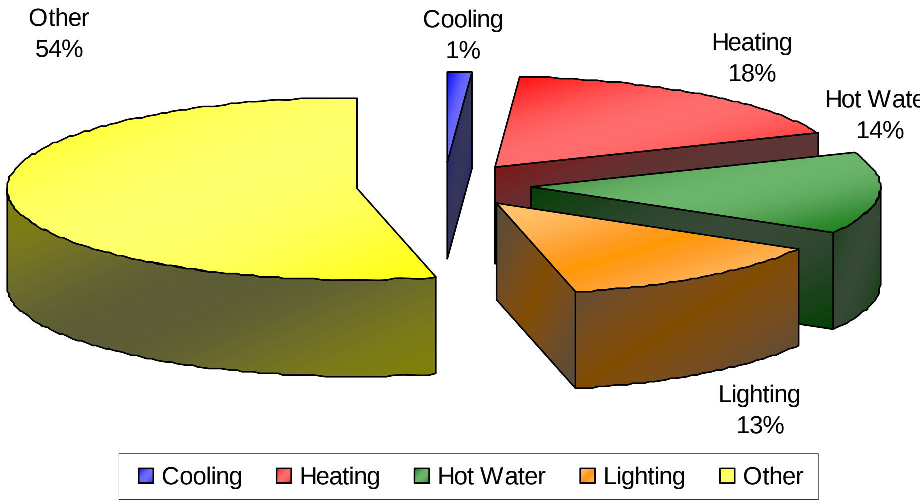


Figure 5: Load breakdown of Zeta Lancaster Duplex

The heating load is 18% of the total (see Figure 5), which is a significant fraction. The heating load is further broken down in Figure 6; note that infiltration is the single largest piece, at 36%; this reflects that further reductions in air leakage could have some benefit.

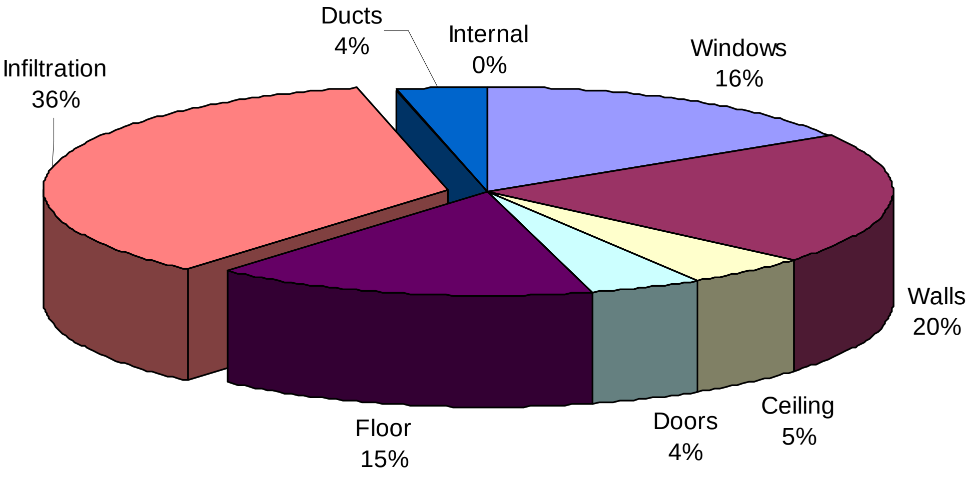


Figure 6: Heating load breakdown for Lancaster Duplex

Photovoltaic System Sizing

As noted above, the 4.6 kW system run in simulations did not result in net zero energy performance using Benchmark operating condition assumptions. Similar to the previous report (2008-09-24 Zeta PV Sizing), the loads were reduced assuming the use of more prudent operation, such as a setback thermostat schedule, turning off heating for a portion of the year, the use of an energy feedback system, and several items to try to conservatively simulate the effect of the zTherm system. **The overall reductions show that 4.6 kW is likely a reasonably-sized system for net-zero energy performance, with conservative operation of the building.**

	kWh/year	Reduction kWh/year	PV Required (kW)	% Reduction
Starting Condition	7324	-	5.2	-
Setback thermostat	7045	279	5.0	3.8%
Moving ducts into conditioned space	6871	174	4.9	2.4%
Added thermal mass (4" concrete slab)	6835	36	4.9	0.5%
Heating off June-September, cooling off	6805	30	4.9	0.4%
Energy feedback system (5% overall)	6465	340	4.6	4.6%

Alternate Measure Simulations (Windows)

Some additional simulations were run to explore some potential alternate measures. Note that all measurements are shown relative to Run 19 (the last option before the addition of PVs).

Parametric Run ID	Description of change	over BA Benchmark[1]	Incremental Over Bmrk
19	18 + ES Appliances	44.4%	2.7%
31	19 + Heat recovery ventilation	45.0%	0.6%
32	19 + ThermaProof Hi SG 500: U=0.26 SHGC=0.39	44.8%	0.4%
33	19 + ThermaProof Lo SG 925: U=0.16 SHGC=0.17	45.2%	0.8%

- A heat recovery ventilator (HRV) was simulated at the same ventilation rate as the central fan integrated system (50 CFM/33% duty cycle), but with a 68% efficiency heat recovery. It showed some savings (0.6% or $10/year); this figure is low enough that it would not appear that this measure is cost effective (upgrade cost for HRV is roughly $800).

- A high solar gain window (ThermaProof 500 Series U=0.26 SHGC=0.39) was swapped in as an option; it has a slightly worse U value, and an SHGC double the window previously used in simulations. It shows a slight improvement (0.4% or $6/year); if it can be determined whether there is a risk of overheating, this may result in a slight performance improvement.

- A higher performance option (ThermaProof 925 Series Dual Pane, 2 Low SHG Films, Krypton fill gas, U=0.16 SHGC=0.17) was also simulated. It showed an improvement of 0.8%. However, given that the associated utility bill savings is $14/year, it is unlikely that this is a cost-effective measure.

Memo of Record

From:	Kohta Ueno, Building Science Corporation	Date:	September 24, 2008
To:	Dietmar Lorenz, Dan Smith DSA Architects	Re:	Zeta Pittsburg Prototype PV Array Sizing

Dietmar and Dan:

I have written up some of my findings on recommended sizing of the photovoltaic array, based on our previous email discussions and further modeling. In addition, I have taken a look at some of the disparities seen in the energy use predictions of the Energy-10 and Energy Gauge USA models that we have both worked on.

If you have any questions, you can reach me as per the contact information below, or at kohta@buildingscience.com.

Thank you,

Kohta Ueno

Cc: John Straube, Ph.D., P.Eng.

Modeling Comparison Continued

The previous report from 9/24 (“2008-09-11 Zeta Preliminary Energy Performance”) included analysis on the difference between DSA’s Energy-10 model and BSC’s Energy Gauge USA model. The comparison is shown in Figure 1 below: note that one number was corrected (the cooling load), which went from 29% to 8% relative fractions. However, all other numbers remained the same.

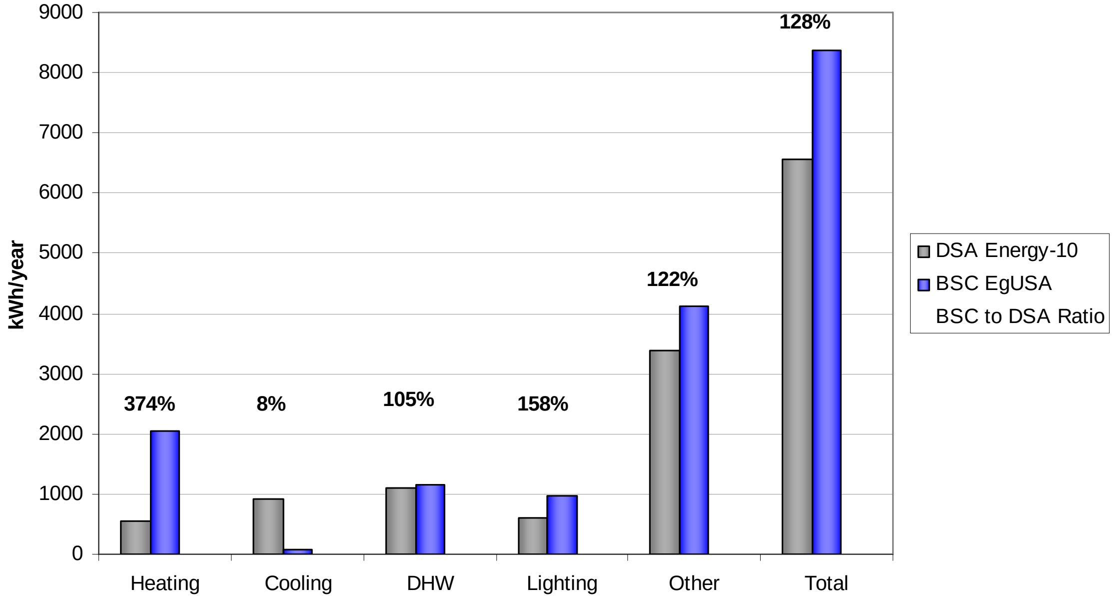


Figure 1: Annual electrical consumption (kWh) for DSA and BSC simulations (revised)

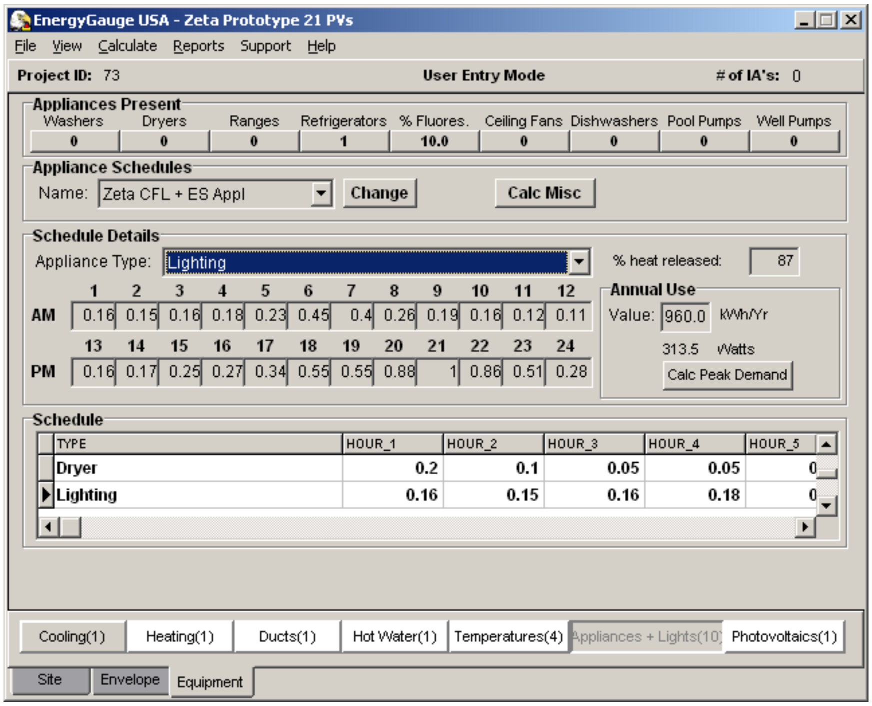
Some of the factors causing heating load differences are noted in the previous report (see page 16 of 24). They included townhouse vs. single family enclosure configuration, setpoints, and thermal mass. However, these changes only dropped the difference from 374% to 234%.

DSA noted that the difference might be due to internal gains: which Dietmar noted as follows: “I think the heating contribution of internal loads might also be higher in our simulation, which used 0.51 W/SF (0.15 lights + 0.36 others). The occupancy schedule is set for permanent occupancy, 7 days a week; so most of the time the heat of the equivalent of seven 100W light bulbs is emitted into the space, plus the occupants radiating like three more light bulbs.”

The BSC model used appliance, lighting, and miscellaneous loads as per daily default schedules, explicitly setting the fraction of the appliance or end use heat that is released to the interior, as shown below in Table 1 and Figure 2. The internal gains due to occupancy are ignored in this examination; it is assumed they are roughly equivalent.

Table 1: Appliance, lighting, and miscellaneous internal gains

	kWh/year consumed	% to interior	kWh/year interior load
Clothes Washer	64	80%	51
Dishwasher	87	75%	65
Dryer	835	20%	167
Lighting	960	87%	835
Miscellaneous	2038	100%	2038
Range	605	70%	424
Refrigerator	500	100%	500
Total			**4080**



Project ID: 73 **User Entry Mode** **# of IA's:** 0

Appliances Present

Washers	Dryers	Ranges	Refrigerators	% Fluores.	Ceiling Fans	Dishwashers	Pool Pumps	Well Pumps
0	0	0	1	10.0	0	0	0	0

Appliance Schedules

Name: Zeta CFL + ES Appl

Schedule Details

Appliance Type: Lighting

% heat released: 87

	1	2	3	4	5	6	7	8	9	10	11	12
AM	0.16	0.15	0.16	0.18	0.23	0.45	0.4	0.26	0.19	0.16	0.12	0.11
	13	14	15	16	17	18	19	20	21	22	23	24
PM	0.16	0.17	0.25	0.27	0.34	0.55	0.55	0.88	1	0.86	0.51	0.28

Annual Use

Value: 960.0 kWh/Yr

313.5 Watts

Schedule

TYPE	HOUR_1	HOUR_2	HOUR_3	HOUR_4	HOUR_5
Dryer	0.2	0.1	0.05	0.05	0
Lighting	0.16	0.15	0.16	0.18	0

Figure 2: Appliance/lighting screen in EgUSA, showing schedule

These two sets of assumptions are compared in Table 2 below. BSC's internal loads are roughly 60% of DSA's internal loads.

Table 2: Internal load comparison (DSA vs. BSC)

Metric	DSA	BSC
Watts/sf	0.51	0.30
Square feet	1416	1553
Watts	722	466
kWh/year	6326	4080

These results appear to partially explain the remaining disparity between models. However, there is one inconsistency noted. Based on the internal load of 0.5 W/sf running continuously in the DSA model, this would result in 6326 kWh/year annual consumption at a minimum (i.e., those internal gains need to be generated from some electrical load). However, if the electrical consumption in Figure 1 is checked, it is only 3982 kWh/year. The reason for this disparity is unknown; however, if internal loads in the simulation are set **separately** from electrical consumption, these results make sense.

Photovoltaic Array Sizing Overview

Sizing the photovoltaic array is a difficult question, since it is an expensive decision to make based on limited information—and in this case, conflicting models. The ideal solution, as noted in my previous email, would be to have actual utility bills for a similar previous project. Since this option is not available, a modified version of Benchmark assumptions might get us closer to “realistic” numbers. This approach is described in the following section.

But first, it is necessary to define the goal for this project. It appears that we need to strike a balance between, “It will be an embarrassment if we fail to achieve zero energy,” and “We do not want to overspend by specifying too large of a PV array, not to mention the fact that it is not very economically advantageous to sell overproduction back to the grid.” DSA noted some options below:

- 4.6 kW - fits on the sloped roof, net-zero potential for "conservation-minded" people, or people that don't spend much time at home
- 6 kW - net-zero potential for "average" people, but potential cost penalty for people who underutilize the expensive system without getting a refund (under current law)
- ~8 kW - cover all available roof area, economy of scale, hope for regulatory changes to get overproduction refund, potential to power plug-in hybrid or electric car

Based on previous Benchmark-based models and assumptions, we found that:

- In the San Francisco climate, we would achieve annual net zero energy with a 5.7 kW array
- In the Sacramento climate, we would achieve annual net zero energy with a 6.3 kW array

I am assuming that the zero energy requirement is a “soft” goal (as described above), as opposed to a “hard” goal (i.e., investors will withdraw if we fail to exactly hit net zero).

Overall, our general approach is to tell the homeowner that this “can be a zero energy house”, if operated conscientiously--but a great deal depends on how the house is "driven."

PV Sizing: BSC Approach

Based on previous examination of utility bills, Building Science Corporation considers the Benchmark assumptions for appliance, lighting, and miscellaneous loads to be within the reasonable range. However, that is with the caveat that the data varies over a **very** wide range. The loads can vary hugely depending on occupant type (e.g., professional couple vs. family with children and stay at home parent vs. retirees). The numbers vary over a wide range; as shown in that research: the **identical** house plan (Ideal Homes) had an electrical base load that varied by a factor of 3.

However, it is a worthwhile exercise to try to re-estimate consumption with some changes in modeling assumptions—i.e., trying to make model more realistic. Remember that Benchmark runs are necessary as a "goalpost" to make sure we are reaching our DOE program goals, but if we are trying to get a more accurate projection of actual operating energy, we should modify operating conditions accordingly. From these estimates, we can project a PV array size for net zero energy. The following items were modified:

1. Heating and cooling setpoints with setbacks (78/83 cooling; 65/70 heating)
2. Addition of thermal mass (2” of concrete, same area as crawl space slab)
3. Locate ducts and air hander in “interior space”

4. Changing the operating seasons of heating/cooling equipment (heating off June-September)—the Benchmark assumes both systems are active year round. This also partially represents the reductions in heating and cooling due to the “thermal flywheel” system.
5. A reduction in plug load, based on literature estimates of what can typically be achieved with energy feedback systems (see “Plug Load Reduction from Feedback System”)

Exterior window screens were not used in these runs, as they made performance worse.

The results of these simulations are shown in Table 3 below; some of these items were run in simulations in the previous report (see pages 8-9 of 21).

Table 3: Energy load reduction estimates for PV sizing

	kWh/year	Reduction kWh/year	PV Required (kW)
Starting Condition	8378		5.7
Setback thermostat	7908	470	5.4
Moving ducts into conditioned space	7773	135	5.3
Added thermal mass (2" concrete slab)	7726	47	5.3
Heating off June-September, cooling off	7649	77	5.2
Energy feedback system	7279	370	5.0

These results show that given these assumptions, we might be close to zero net annual energy with a 5 kW photovoltaic system. Of course, as discussed earlier, this requires a conscientious homeowner who would use the energy efficiency features of the house.

The final simulation was also run in Sacramento; it showed that a 5.3 kW PV system would be required. However, these might be less realistic operating conditions, as the cooling season is longer in Sacramento (and Pittsburg) than in San Francisco.

Plug Load Reduction from Feedback System

A Greenbox home energy feedback system will be installed at the Zeta Communities units; these types of systems have been shown reduce energy consumption. A recent paper (“Pilot Evaluation of Energy Savings from Residential Energy Demand Feedback Devices” Parker et al. 2008) looked at these types of systems. The authors did a literature survey back to the 1970s, noting typical reductions in the 5-15% range. However, it is important to remember that this includes the entire power bill—so it reflects reductions in heating, cooling, appliances, and lighting due to changes in occupant behavior.

Their research involved the installation of an energy monitoring system in 17 houses, and measuring the effect on energy use before and after this change. The researchers found savings of 5-15%, with an average savings of 7% over the year. The greatest reduction was seen in two houses that were initially the highest energy use in the sample set; as the authors explain:

> *Based on exit interviews with the occupants, these two household paid close attention to the monitors and used what they learned to make overt changes in household appliances as well as scheduling for some equipment. This included large changes to household lighting, reduction of pool-pump hours and replacement of an aging AC system in one. This may mean that energy feedback monitors would have special value for utilities in homes with high bill complaints. It also may indicate that the economics of feedback will be most persuasive, for interested, but high energy consumers.*

This demonstrates that the largest effects in this sample were not on normal plug loads, but instead on cooling, major appliances, and lighting.

Also note that the 5-15% savings comes from houses that are significantly more influenced by heating and cooling loads than typical Building America homes, so a BA home will have lower savings.

These results make it difficult to assume a substantial reduction in isolated miscellaneous end use loads. However, Benchmark assumptions are made for operating conditions (heating, cooling, appliance use). Therefore, as a conservative estimate was made by using the lowest end of the estimated savings, at 5% of total consumption. This was done by reducing the miscellaneous load (24% of the total in the final Benchmark-based run) by 20%, or an equivalent of a 4.8% reduction in overall electrical use. This is meant to cover not only actual reductions in plug loads, but possible reductions in heating, cooling, and/or appliance use due to homeowner awareness.

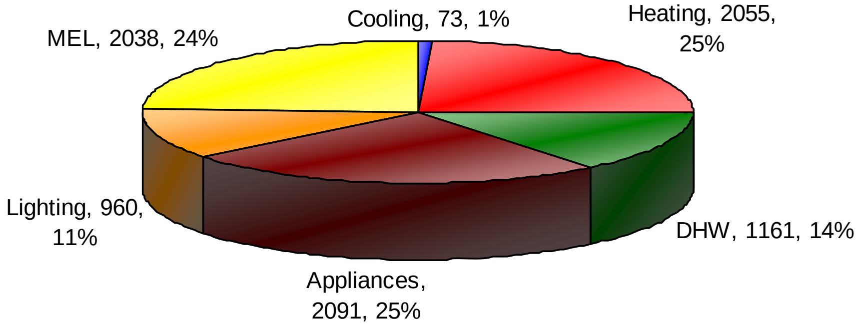


Figure 3: Load distribution by component (load type, kWh/year, % of total)

HOURLY SUMMARY REPORT

Zeta Communities

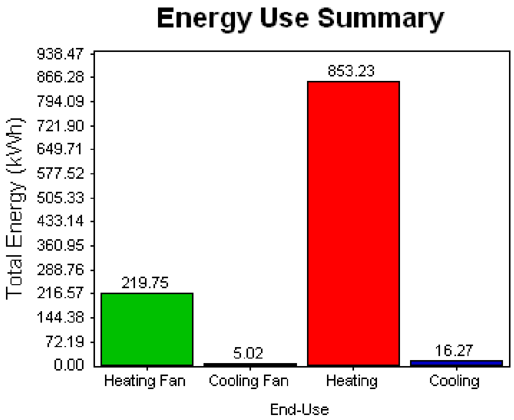
,

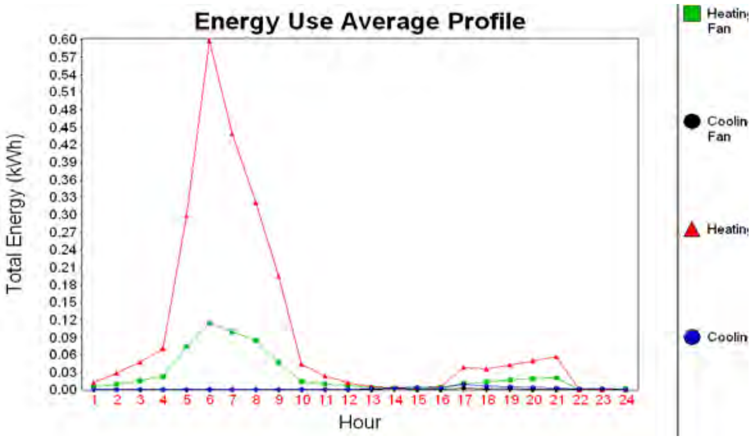
Project Title:
Zeta Prototype 20 + H-C Off Seasons
Building Type: User

TMY City: CA_SANFRANCISCO
Elec Util: PG&E Electric E-1
Gas Util: PG&E Gas G-1
Run Date: 09/24/2008 13:43:27

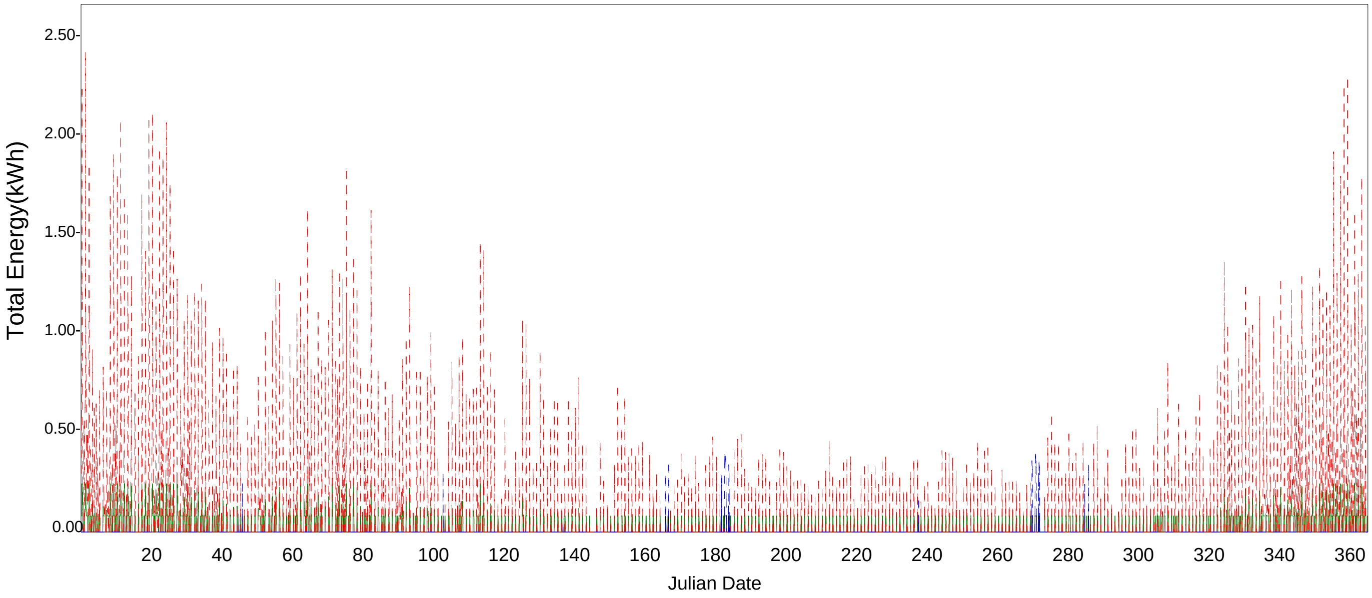
Start Date: January 1 End Date: December 31

End-Use	Units	Average	Minimum	Maximum	Total
Heating Fan	kWh	0.0251	0.0000	0.2450	219.7
Cooling Fan	kWh	0.0006	0.0000	0.0810	5.0
Heating	kWh	0.0974	0.0000	2.4350	853.2
Cooling	kWh	0.0019	0.0000	0.3950	16.3


Energy Use Summary


Energy Use Average Profile

Energy Use Time Series

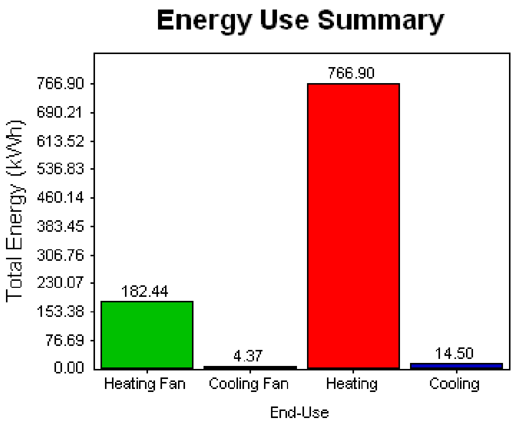


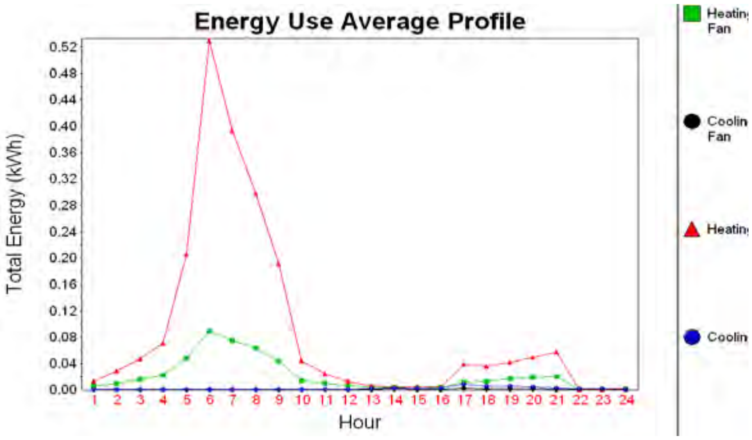
HOURLY SUMMARY REPORT

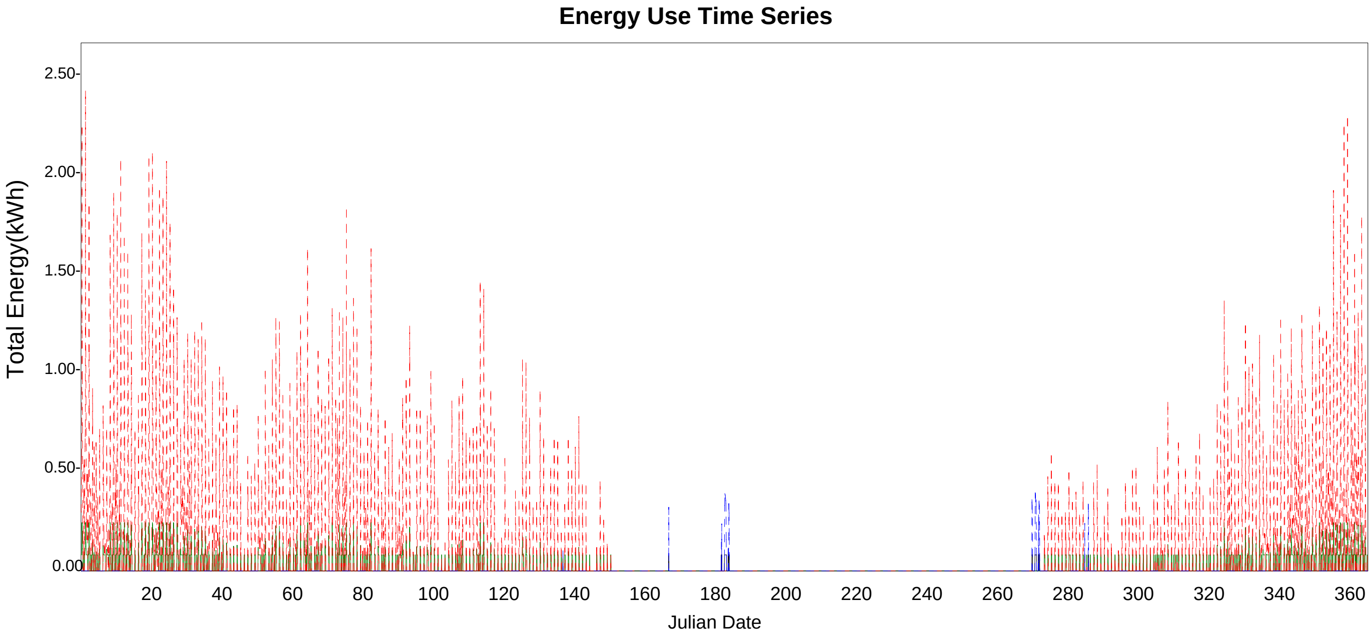
Zeta Communities ,	Project Title: Zeta Prototype 20 + H-C Off Seasons Building Type: User	TMY City: CA_SANFRANCISCO Elec Util: PG&E Electric E-1 Gas Util: PG&E Gas G-1 Run Date: 09/24/2008 13:51:06

Start Date: January 1 End Date: December 31

End-Use	Units	Average	Minimum	Maximum	Total
Heating Fan	kWh	0.0208	0.0000	0.2450	182.4
Cooling Fan	kWh	0.0005	0.0000	0.0810	4.4
Heating	kWh	0.0875	0.0000	2.4350	766.9
Cooling	kWh	0.0017	0.0000	0.3960	14.5







ZETA Space Conditioning EgUSA Simulations

From:	Kohta Ueno, Building Science Corporation	Date:	July 15, 2009
To:	John Straube, Ph.D., P.Eng., Aaron Grin, Gregory Leskien	Re:	Space Conditioning Issues in the San Francisco Bay Area

John, Aaron, and Greg:

I have drafted this report to explain some of the research and modeling that I have done looking at the space conditioning problem in the Bay Area. First, there is the issue of "how little space conditioning is there in the Bay Area"? Second, I took a look at how the simulation handles thermal mass, to see if those results seemed reasonable, given everyone's background. I then looked at heating load behavior throughout the year, and ventilation cooling and economizer use in the Bay Area. Some conclusions I gained from this work:

- If the simulations are correct, interior setpoint has a huge effect on overall heating energy use in the Bay Area, due to the narrow temperature band of exterior conditions (i.e., many hours not very far from interior setpoint temperature).
- For instance, dropping setpoint from 71° F (BA Benchmark) to 65° F resulted in heating use being cut to less than half of the original use.
- Note that dropping the heating setpoint is the same thing as "expansion of comfort range," which is reputed to be common in the Bay Area. This is a reasonable behavior, given the reasonable dewpoints throughout the year, which allows comfort at a wide temperature range.
- The EgUSA simulation (and Benchmark conditions) assumes the use of ventilation cooling when conditions are favorable. Turning off this ventilation cooling (i.e., operation of windows at the correct time) result in a substantial amount of overheating throughout the year. To me, this implies that economizer makes a huge amount of sense when we cannot rely on correct operation of windows for cross-ventilation.
- The famous Mark Twain quote about San Francisco weather ("The coldest winter I ever spent was a summer in San Francisco.") appears to be apocryphal. However, weather data indicates that this is a reasonable statement.

If you have any questions, you can reach me as per the contact information below, or at kohta@buildingscience.com.

Thank you,

Kohta Ueno

Cc: Dan Smith, Dietmar Lorentz (DSA Architecture)

Background: Real Data Example

I believe that all of us are worried that simulations might be significantly in error in predicting heating and cooling use in the Bay Area. However, I realized that I had the resource of a friend who lived in a 1200 sf apartment in Oakland, CA (Piedmont neighborhood). He was living there as a single occupant. The oven/range was electric, refrigerator was not Energy Star, and he did not use the dishwasher very much. Laundry (washing and drying) and hot water were provided through the building.


Figure 1: Apartment location in Oakland; at west corner of building


Figure 2: Street view of apartment building, indicating location

Space heating was provided by small wall-mounted electric resistance space heaters. He reported that they were "fairly ineffectual," so he rarely used them, unless it got very cold—he would typically just put on another layer of clothing instead. No cooling was installed.

I am guessing that the apartment building might be 1970's or earlier construction; windows are single glazed, aluminum frame. The apartment is exposed on two sides (southwest and northwest); it was unit between two conditioned floors (no ceiling or floor to exterior conditions).

I ran a quick model in EgUSA 2.8.02; I did not bother generating full MEL usage numbers, instead using a generic ~900 sf apartment usage (from Uxbridge). I assumed R-99 floor and ceiling. I did not have actual wall or window areas, but I did a ballpark estimate based on memory. This simulation zeroed out the clothes washer and dryer usage. The results are shown below in terms of kWh/year of electric resistance heat, at three different interior setpoints:

Table 1: EgUSA 2.8.02 simulation results for 1200 sf apartment

	Heating	Reduction	Total
Base simulation	2169 kWh		6864 kWh
Setpoint 65° F	560 kWh	74%	5255 kWh
Setpoint 60° F	64 kWh	97%	4759 kWh

These results show the tremendous effect that setpoint can have in this climate. In addition, this implies that if the model is inaccurate in predicting the balance point (e.g., calculating actual solar gain), it could have a major effect on predicted space conditioning energy use.

The electricity consumption for the apartment during 2005-2006 is shown in Figure 3. The monthly billing periods do not coincide exactly with the calendar months. The first month ("January 2005") is for 12/21/04 through 1/19/05. February 2006 (final month) falls outside of the expected heating vs. baseline pattern due to increased time at home after leaving a job.

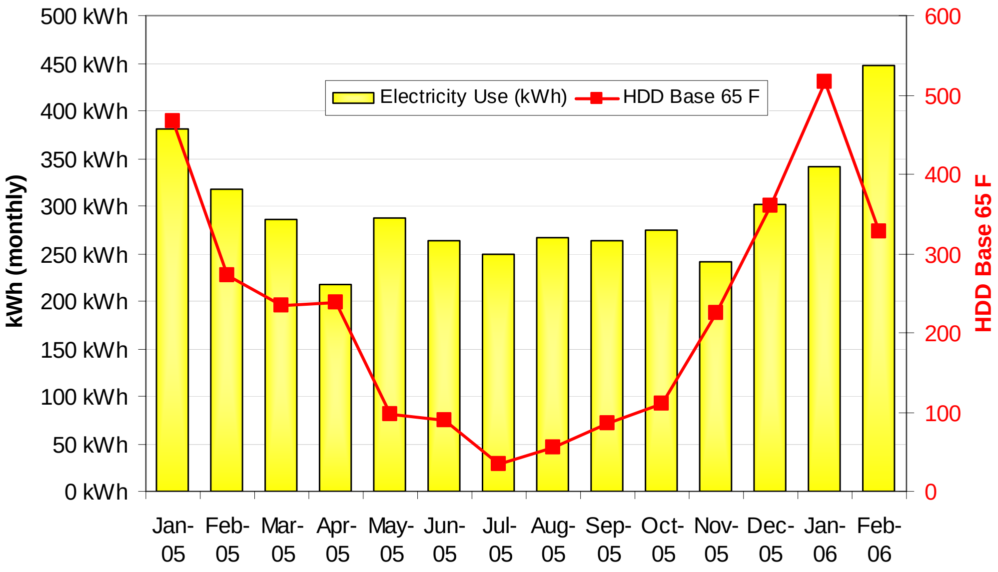


Figure 3: Apartment electricity use 2005-2006

The annual totals for heating energy use—even with electric resistance heat—are in the range of 268 to 359 kWh/year, which at $0.13/kWh, comes out to $35 to $47. This level of consumption makes it incredibly difficult to financially justify any upgrades to the space conditioning side, either enclosure or mechanical. I guess we could state that a more effective space conditioning system would result in upgraded comfort—but then real-world energy savings would probably then be smaller than predicted in any model. The actual heating consumption falls between levels predicted for the 65° F and 60° F setpoints.

Incidentally, based on my friend's energy use, his base load is roughly 3170 kWh/year. Using Benchmark assumptions for 2 bedrooms, 1560 sf (ZETA Lancaster) is 4700 kWh/year, after subtracting out the washing machine and dryer. Basically, actual baseline consumption was 2/3 of the Benchmark assumption.

Andy Äsk Advice

Andy Äsk and I corresponded about various San Francisco projects (I believe Turk Street was the one we were looking at, then). I believe I have forwarded them on, but some key points were:

- He shares this observation that people basically use no energy for thermal comfort.
- Added insulation might shift things over into a cooling load situation. However, I would observe that those loads could probably be removed via ventilation (see "

Ventilation Cooling Experiments” below).

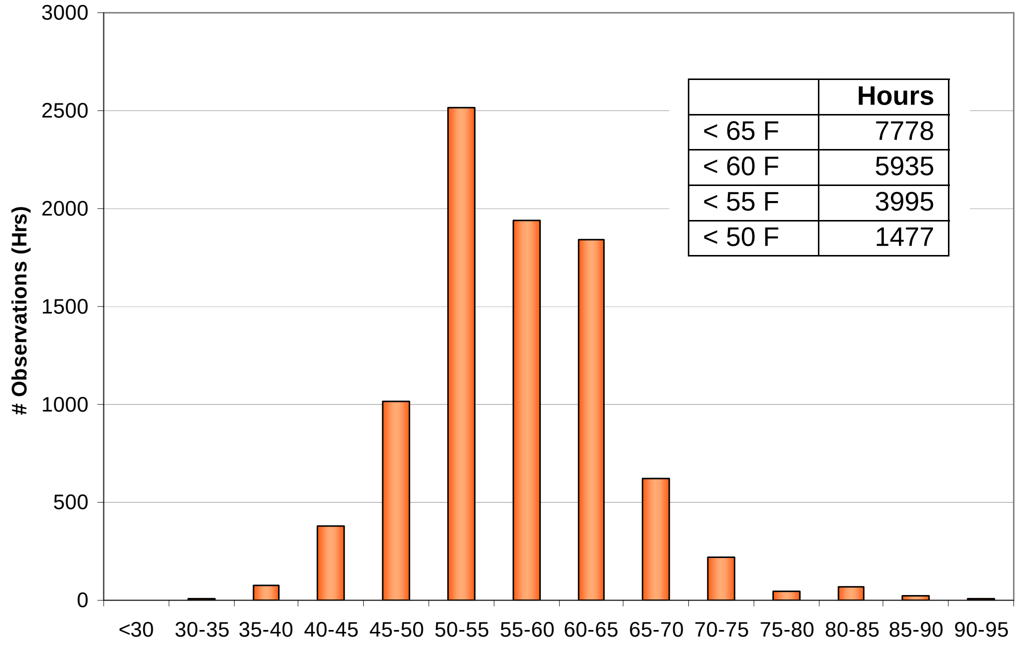
- He would probably just run electric resistance space heaters, in specific locations where sedentary activity occurs.
- If anything, it would be reasonable to invest in upgrading the domestic hot water equipment.

This concurs with some of the preliminary observations that we are coming up with at Nano Lofts/SmartSpace. His comments are as follows.

> *I am familiar with the San Francisco climate--my daughter lives there. They don't use heating or cooling so your starting point for comparing solutions is zero energy use for comfort. Any insulation you add will create an artificial air conditioning load--no matter how cold it gets outside, internal gain from people and electrical energy use will overheat the dwelling. It's always overcast so PV wouldn't work. It looks to me like an easy place to get to net-not-very-much energy (they're already there) but impossible to achieve net zero. Orthodox building science practice will make cavities cool and damp; but no heat available for drying, therefore encourage mold and rot. Life in San Francisco is pretty good in leaky R = next to nothing homes and can only get worse if we "do our thing;" so daunting for the building scientist.*
>
> *If I lived in San Francisco I would consider using enough open cell foam to create an air barrier and then have no HVAC of any description except a portable electric heater when I shower and where I sit and watch TV (what I do in Florida during the winter--I have never connected my electric strip heat.)*
>
> *I would challenge one statement you made: San Francisco is an awesome climate for heat pumps in general--a 99.6% design T of 38 F. No, it's an awful climate for heat pumps because you don't need heat. Waterloo is an awesome heat pump climate because you do need heat.*
>
> *Related story from recent personal experience: I spent Christmas in MN at my son's home--new 6,500 SF house, appears to be well-constructed, 10 people there for the holidays. I'm used to freezing my butt off when I go north in the winter but I was uncomfortably warm this trip, presumably because they were keeping it warm for the baby. Not true: thermostat was set at 68 F., furnaces not running. At approximately 35F outside (it thawed while I was there), the house was overheating from internal loads. Our old degree day models assumed heating fuel being consumed below 65 F OAT; with modern construction you don't need to add heat to a home until it freezes outside and any model assuming otherwise would be defective.*
>
> *It looks to me like domestic water heating is the only energy-consuming activity worth reducing. Again, if I lived there, I'd consider a tiny water-to-air heat pump water heater in the apartment (cooling the space, heating water).*
>
> *Finally, one truly off-the-wall idea: install a little dehumidifier (Thermastor 65 pint) but control it with a room heating thermostat. San Francisco may not have heat, but it does have humidity. The DH would convert the latent heat of vaporization in available moisture (including that in OA introduced for ventilation and aspirated by occupants) to sensible heat. The 300 watts it consumes even when running dry would be a good start on token heating. You may not need any other HVAC.*

Balance Point Analysis

After these initial exercises, I became curious how the simulation was behaving, and its patterns in calling for heating. This analysis used Energy Gauge USA (DOE-2 based simulation): although it is a common energy model, there are still many open questions on how well it reflects reality. First, I did a histogram of exterior dry bulb temperatures for the Oakland weather file:



	Hours
< 65 F	7778
< 60 F	5935
< 55 F	3995
< 50 F	1477

Figure 4: Oakland CA TMY3 dry bulb temperatures

It is clear that if we use a common balance point used for most climate reporting (HDD Base 65° F), there is a significant number of hours (7778 hours) that would “require heating.” However, relatively small shifts in balance point could result in significant reductions in hours requiring heating. For reference, annual monthly temperatures and dewpoints are shown below.

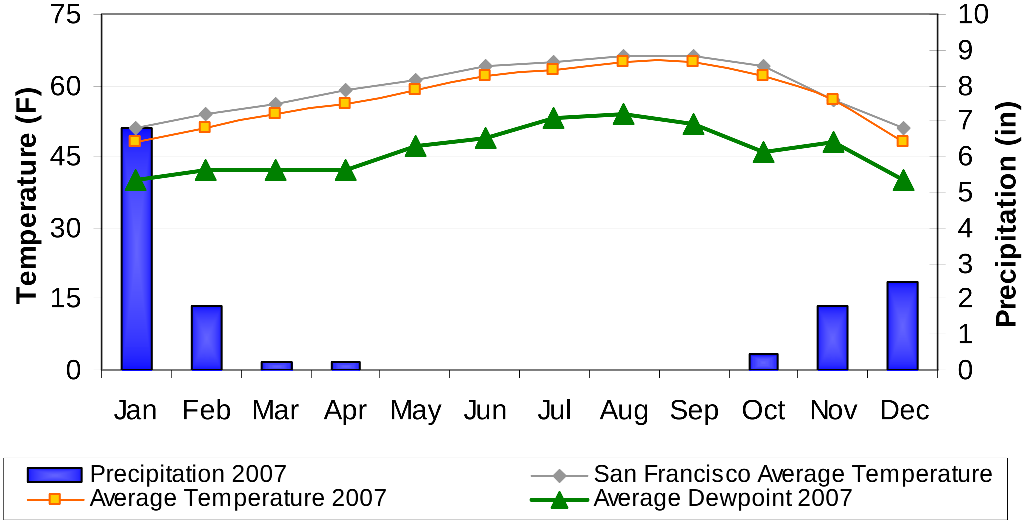


Figure 5: 2007 Oakland weather data (rainfall, temperature, dewpoint)

Therefore, simulations were run using the Lancaster Lofts model, assuming 71° F (Benchmark), 65° F, and 60° F setpoints. The heating load was then plotted against outdoor temperature, in order to obtain balance point plots, as shown below. The interior setpoints are shown in matching colors, for reference.

It is interesting to note that even with a simulation, and a constant setpoint, and a repeating occupant schedule, there is still significant scatter in the balance point (R^2 values).

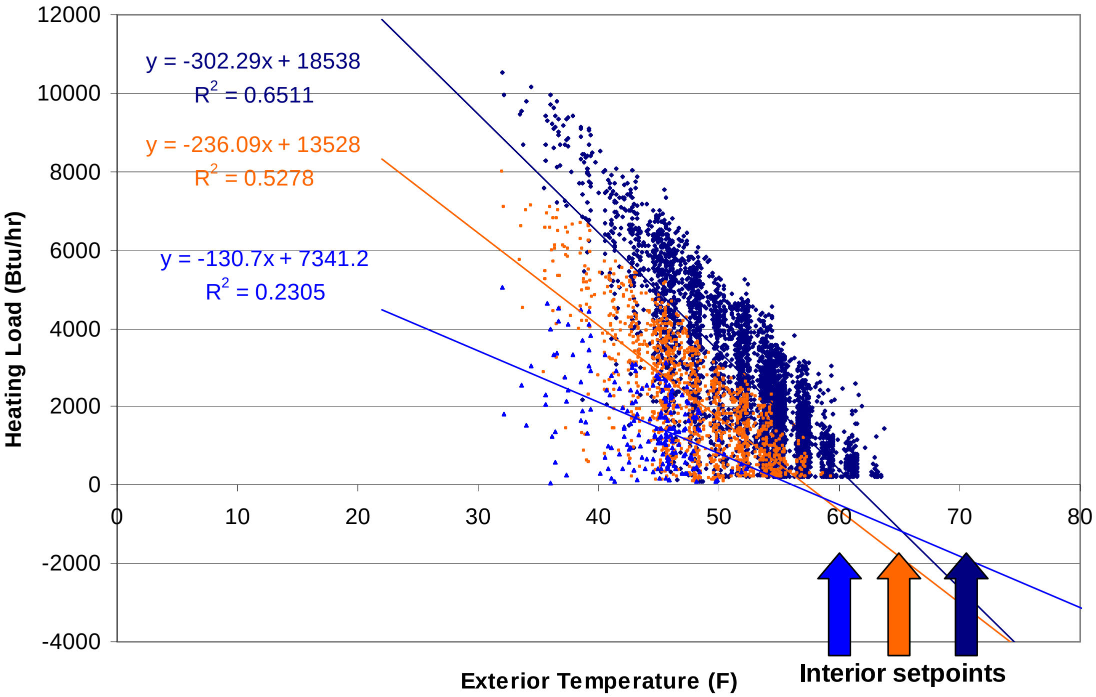


Figure 6: Balance point analysis for Oakland Lancaster simulations

If the linear curve fits are used to approximate the balance point (x-intercept), we obtain the following balance point temperatures:

Table 2: Simulated balance points at various setpoints for Oakland Lancaster

Setpoint	Balance Point	Hours < Balance
71	61.3	6736
65	57.3	5301
60	56.4	2303

Comparing these results with the exterior temperature histogram, we can see once again that these setpoint changes have a large effect on the number of hours requiring heating. These results are summarized in one more form, showing annual heating load (kBtu/year) for the various setpoints, along with heating energy cost (@ $0.13/kWh).

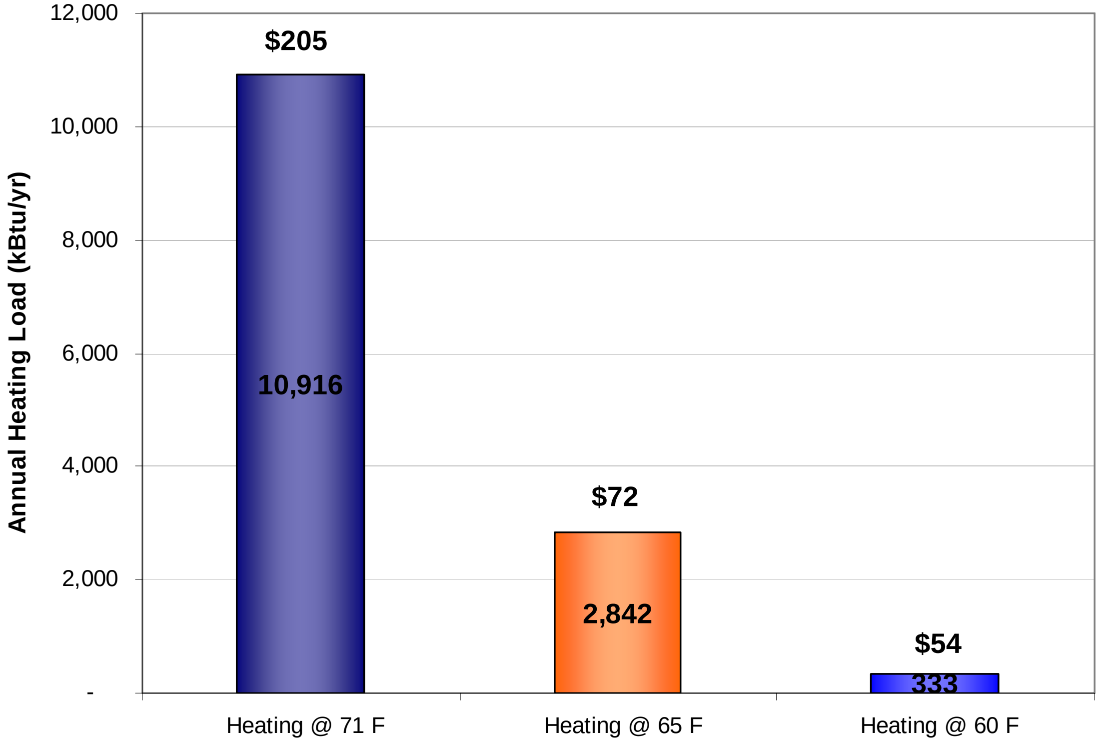


Figure 7: Heating load (kBtu/yr) and energy cost

Note that although total heating **loads** fell by ~95% (going from 71° F to 60° F), costs (and **energy use**) only fell 75%--probably due to heat pump temperature effects.

Thermal Mass Analysis

These simulations resulted in some curiosity on how the simulation would respond to the additional of thermal mass, given previous discussions on Bay Area diurnal swings. The results are summarized in the table below. The initial model (71° F setpoint) was compared to those adding the full crawl space footprint, as well as double that amount, of 2" concrete slab.

Table 3: Thermal mass simulation results (Lancaster Oakland)

	Heating Load (kBtu/year)	Heating Use (kWh/year)	Heating Cost
Heating @ 71 F	10,916	1560	$205
Add 644 sf mass	10,326	1523	$200
Add 1288 sf mass	9,917	1497	$197

The EgUSA results imply little benefit to thermal mass in this climate. I am not sure we might pursue further simulations changing more variables, if there might be some problems with the DOE-2/EgUSA engine.

On the other hand, it seems quite possible that these results might reflect reality. For instance, the glazing is not at all optimized for passive solar gain: the windows on Lancaster Lofts are on the northwest and southeast sides; there is no directly south-facing glazing. Since thermal mass truly shines when it can store excess daytime solar gain to offset later heating loads, this would probably have a strong effect. Also, it is possible that cross-ventilation is assumed to shed excess heat during the day (instead of storing it in the 'thermal plenum,' as per Lancaster), thus leaving no stored heat for release at night (see "

Ventilation Cooling Experiments” below).

Heating Usage Patterns

This previous exercise made me curious how the heating system actually behaved, so I graphed outdoor temperature against hourly heating load below:

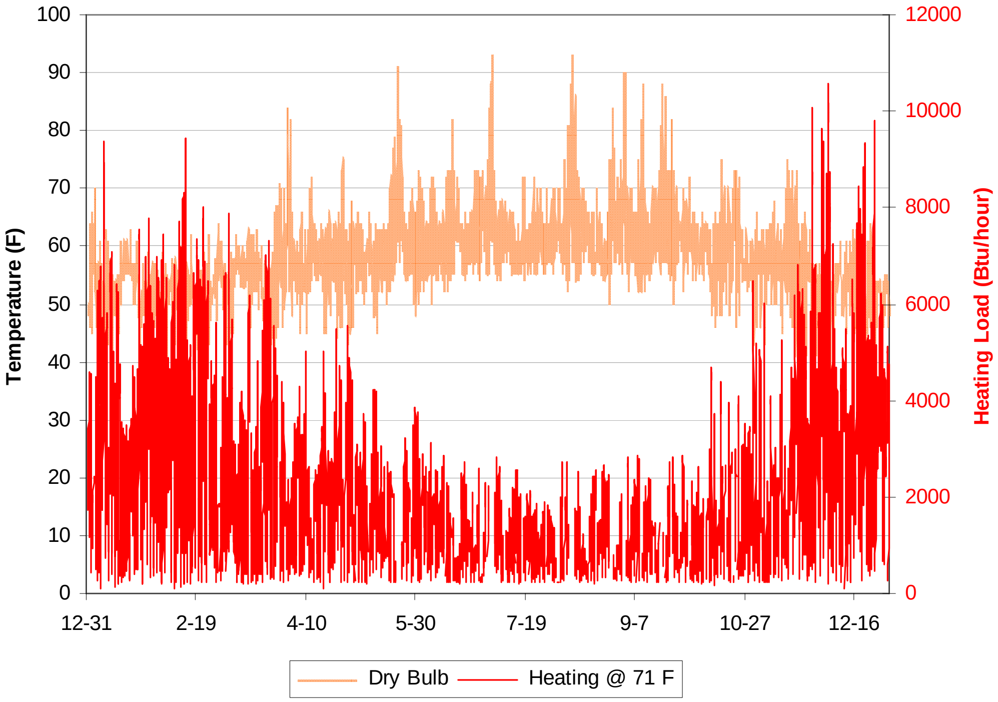


Figure 8: Hourly outdoor temperature and heating loads, Oakland Lancaster 71° F setpoint

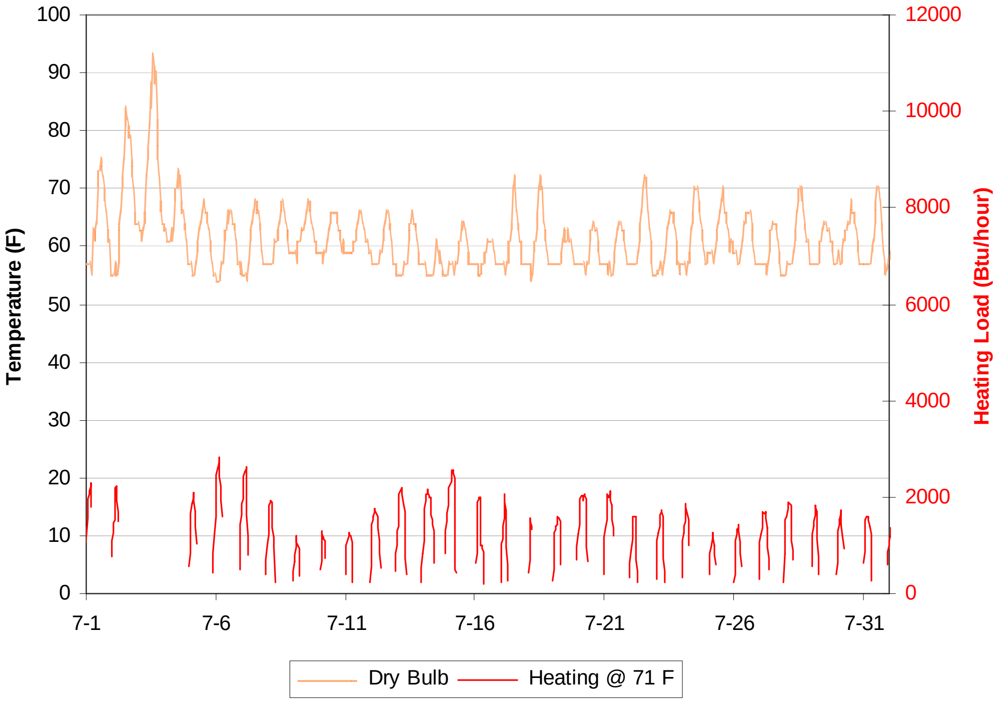


Figure 9: Hourly outdoor temperature and heating loads, July detail

I was very surprised to see consistent heating loads throughout the year—all the way through the entire summer. Apparently, the purported Mark Twain quote is not actually attributed to him ("The coldest winter I ever spent was a summer in San Francisco.")—see http://www.snopes.com/quotes/twain.asp. However, this data set would indicate the truth to this statement.

This is also consistent with Straube's observation that he often sees Bay Area heating systems firing up late at night or in the morning during the summer, to "take the edge off." Also, this supports the idea that thermal mass **ought** to help—i.e., a small amount of heating during summertime mornings. For instance, 1500-2000 Btu/hour (typical range of July loads) is 440-590 W–not quite at the level of typical electric standby loads, but not too far off either. As mentioned above, it is quite possible that thermal mass is showing no benefit here because ventilation cooling is turned on, which ventilates away excess daytime heat to remain at setpoint, instead of storing it (as per the zTherm controller).

Also, this behavior is consistent with Greg's observations at Nano/SmartSpace—the occupant density is so high (and associated internal gains), and the exposed surface areas are so low, that it seems likely that these summertime heating bumps might be eliminated. We might try to decide if the existing "pod" model might give reasonable results for this type of balance point research.

As another example, here is a similar plot, but for the 65° F setpoint: at that condition, almost the entire summertime heating load is eliminated:

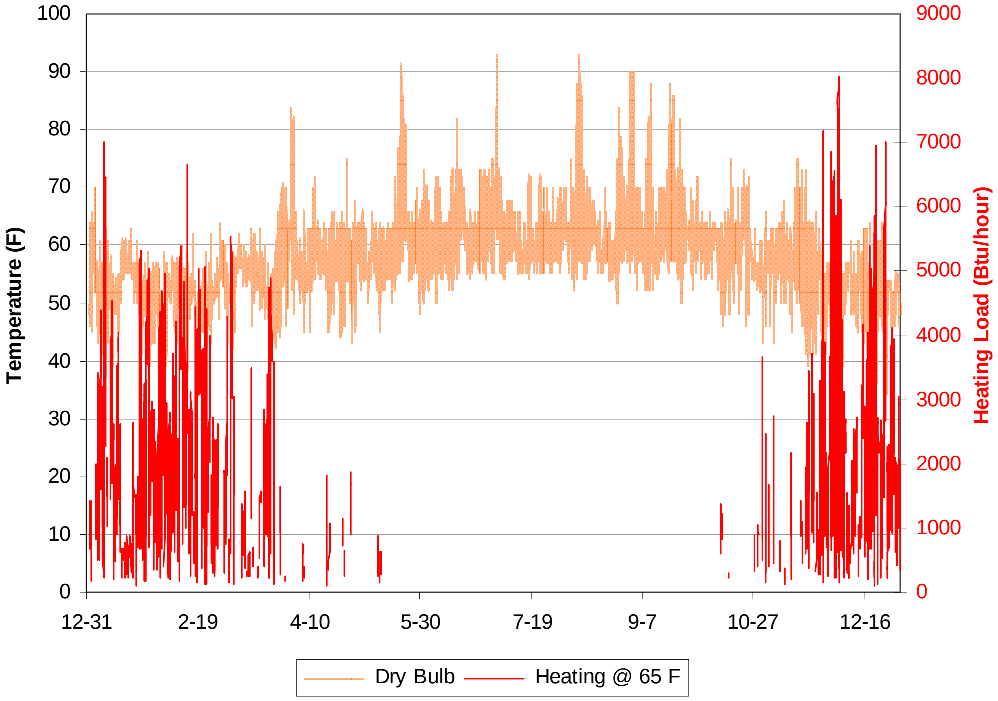
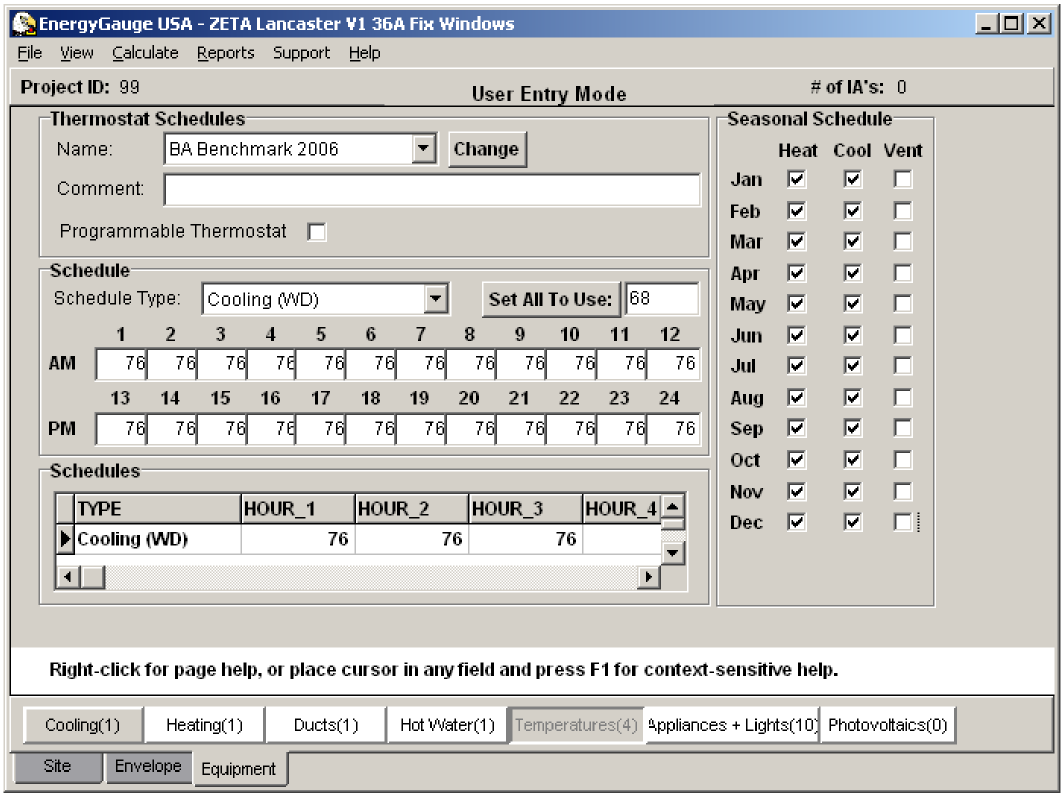


Figure 10: Hourly outdoor temperature and heating loads, Oakland Lancaster 65° F setpoint

Ventilation Cooling Experiments

Given the emphasis we are placing on the economizer or “free cooling,” I wanted to examine the model’s behavior. I initially wanted to get a feel for the number of hours when it would be useful in this climate—i.e., the house would be over cooling setpoint, but exterior temperatures were low enough to cause cooling effectively.

One first thing that I realized was that a critical setting is the heating/cooling/ventilation operation in EnergyGauge USA: turning this on and off basically controls whether windows are opened at the correct times to allow for ventilation cooling.



EnergyGauge USA - ZETA Lancaster V1 36A Fix Windows

Project ID: 99

User Entry Mode

# of IA's: 0

Thermostat Schedules

Name: BA Benchmark 2006

Comment:

Programmable Thermostat ☐

Schedule

Schedule Type: Cooling (WD)

Set All To Use: 68

	1	2	3	4	5	6	7	8	9	10	11	12
AM	76	76	76	76	76	76	76	76	76	76	76	76

	13	14	15	16	17	18	19	20	21	22	23	24
PM	76	76	76	76	76	76	76	76	76	76	76	76

Schedules

TYPE	HOUR_1	HOUR_2	HOUR_3	HOUR_4
Cooling (WD)	76	76	76	

Seasonal Schedule

	Heat	Cool	Vent
Jan	☑	☑	☐
Feb	☑	☑	☐
Mar	☑	☑	☐
Apr	☑	☑	☐
May	☑	☑	☐
Jun	☑	☑	☐
Jul	☑	☑	☐
Aug	☑	☑	☐
Sep	☑	☑	☐
Oct	☑	☑	☐
Nov	☑	☑	☐
Dec	☑	☑	☐

Right-click for page help, or place cursor in any field and press F1 for context-sensitive help.

Figure 11: Energy Gauge USA screenshot, showing heating/cooling/ventilation operation

There is a huge difference in interior temperatures when this is turned on and off, as shown in Figure 12 and Figure 13 below.

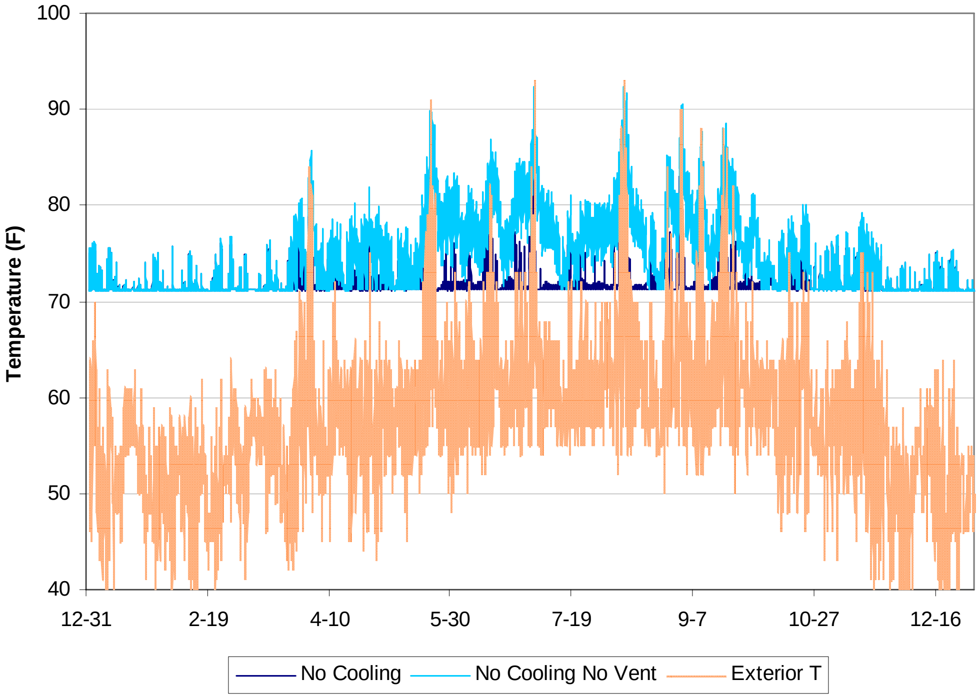


Figure 12: Lancaster Oakland interior temperatures, with and without ventilation cooling

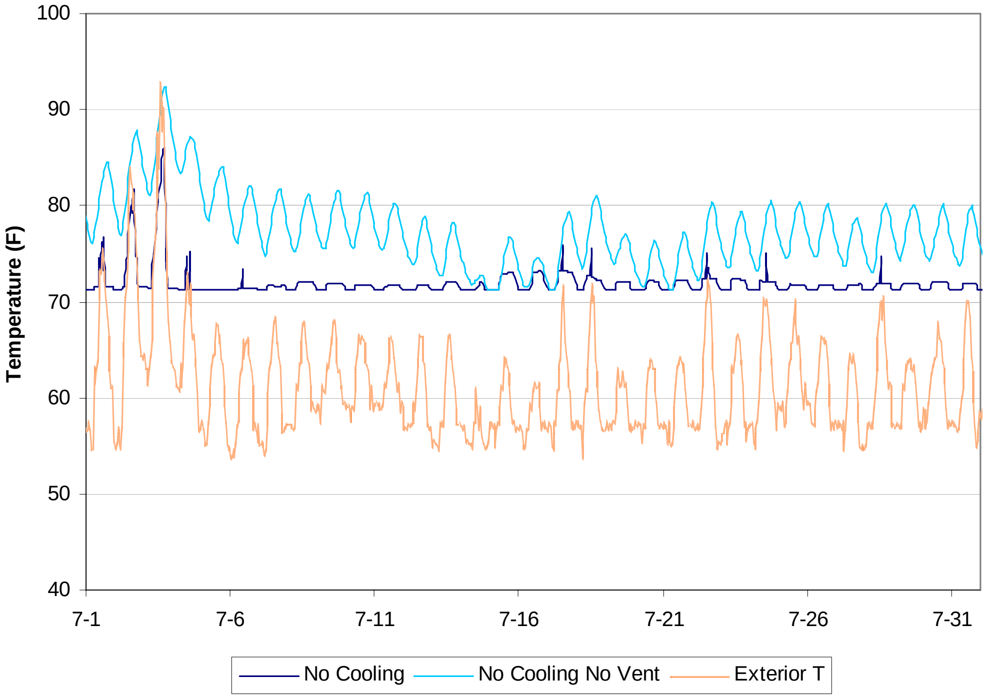


Figure 13: Lancaster Oakland ventilation cooling, July detail

Basically, there are huge fractions of the year where ventilation cooling or economizer cycle makes sense, and would maintain summertime interior setpoint without a problem. EgUSA assumes that windows are being operated completely rationally when the “ventilation” checkboxes are activated. However, this is a strong assumption—there are some neighborhoods where opening windows is a security risk; also, it assumes that homeowners would be at home to operate the windows correctly. What this implies to me is that an economizer might have very little use if window operation is done correctly. However, if this correct operation cannot be guaranteed, an economizer could be very beneficial, assuming that the effective cooling efficiency (EER; see 2009-07-03 ZETA Lancaster Testing Report) is better than compressor-based cooling.

The July temperatures spikes with windows closed also back up the earlier comment about thermal mass not being successfully modeled in the current EgUSA simulations; there is definitely "excess storable heat" available that could offset late night/early morning heating loads, if a 71° F setpoint is used.

Appendix D.10.7.3
Mechanical System Design

ZETA Thermal Basement/Crawl Space Information

March 4, 2009

Building Science Corporation is a consultant to ZETA Communities on the topics of energy efficiency and building durability, through the Department of Energy's Building America Program. Building America is an industry-driven research program designed to accelerate the development and adoption of advanced building energy technologies in new and existing homes.

Building Science Corporation is a building science consulting firm with offices in Boston, Massachusetts and Waterloo, Ontario and clients throughout North America. Our focus is preventing and resolving problems related to building design, construction and operation; we are internationally recognized for our expertise in moisture dynamics, indoor air quality, and forensic (building failure) investigations. We are also on the leading edge of the design of sustainable communities and buildings. We believe in promoting energy efficiency and environmental responsibility within the constraints of marketable and affordable building technology.

Building Science Corporation has prepared the following document to answer questions on how moisture risks are controlled with the "Thermal Basement" being implemented by ZETA Communities.

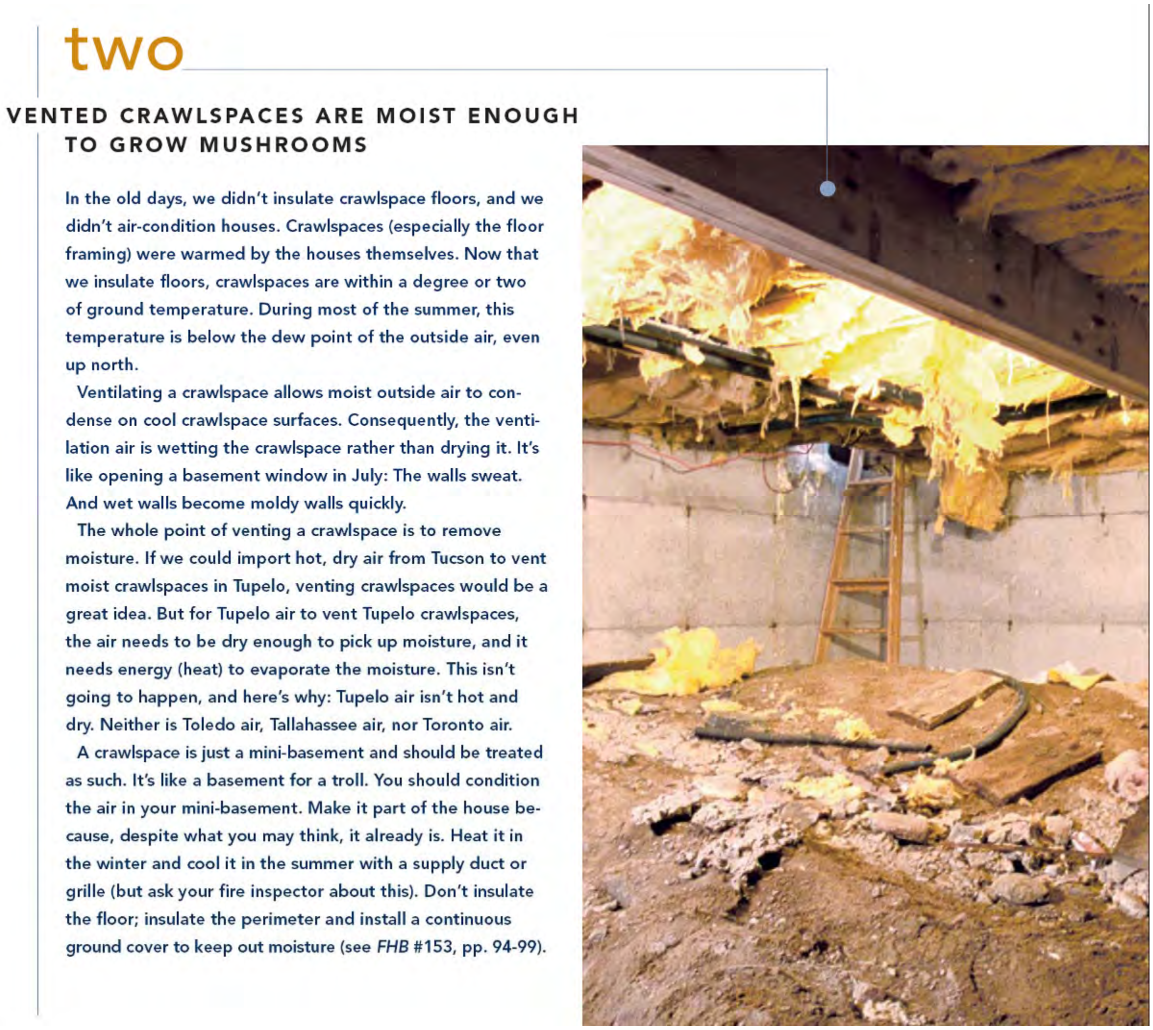
Isn't sending house air through the crawl space risky?

It is common, if not natural, to think of crawl spaces as dank, moisture-filled spaces, with a high risk of mold growth. Given a perceived risk of mold growth, it is reasonable to have concerns when connecting the house air to the crawl space, as this would spread the problems throughout the house. Given the history of crawl spaces, this is a very rational concern.

However, the foundation that we are building at ZETA Communities is a sealed and insulated space with a concrete slab over the soil—it can be thought of as a "short conditioned basement," or "conditioned crawl space." This method prevents the typical problems associated with this construction by ensuring that the temperature and humidity are controlled by the mechanical systems. The conditions in the thermal basement will be similar to that in a closet on an exterior wall.

What are the causes of crawl space moisture problems?

Conventional vented crawl space construction in the many parts of the United States has become associated with moisture problems, including mold growth on the wood floor framing members and even decay. This issue is described in an article by Joseph Lstiburek (one of BSC's principals) from *Fine Homebuilding Magazine* (April/May 2004): "Built Wrong from the Start: Top 10 blunders that rot your house, waste your money, and make you sick." The number two problem was vented crawl spaces:



two

VENTED CRAWLSPACES ARE MOIST ENOUGH TO GROW MUSHROOMS

In the old days, we didn't insulate crawlspace floors, and we didn't air-condition houses. Crawlspaces (especially the floor framing) were warmed by the houses themselves. Now that we insulate floors, crawlspaces are within a degree or two of ground temperature. During most of the summer, this temperature is below the dew point of the outside air, even up north.

Ventilating a crawlspace allows moist outside air to condense on cool crawlspace surfaces. Consequently, the ventilation air is wetting the crawlspace rather than drying it. It's like opening a basement window in July: The walls sweat. And wet walls become moldy walls quickly.

The whole point of venting a crawlspace is to remove moisture. If we could import hot, dry air from Tucson to vent moist crawlspaces in Tupelo, venting crawlspaces would be a great idea. But for Tupelo air to vent Tupelo crawlspaces, the air needs to be dry enough to pick up moisture, and it needs energy (heat) to evaporate the moisture. This isn't going to happen, and here's why: Tupelo air isn't hot and dry. Neither is Toledo air, Tallahassee air, nor Toronto air.

A crawlspace is just a mini-basement and should be treated as such. It's like a basement for a troll. You should condition the air in your mini-basement. Make it part of the house because, despite what you may think, it already is. Heat it in the winter and cool it in the summer with a supply duct or grille (but ask your fire inspector about this). Don't insulate the floor; insulate the perimeter and install a continuous ground cover to keep out moisture (see *FHB* #153, pp. 94-99).

Figure 1: Fine Homebuilding article excerpt (Joseph W. Lstiburek, Fine Homebuilding Magazine)

So what is the current state of insulated and sealed crawls?

There is a wealth of research that conclusively demonstrates that sealed and insulated crawl spaces with a properly installed vapor barrier on the ground have superior moisture performance. A full background is covered in BSC's web document "Research Report-0401: Conditioned Crawl Space Construction, Performance and Codes" (http://www.buildingscience.com/documents/reports/rr-0401-conditioned-crawl-space-construction-performance-and-codes) Also, Advanced Energy Corporation (of NC) has published much of their data on a website, www.crawlspaces.org. BSC was involved in conducting some of this field research as well.

These types of foundations are commonly constructed throughout the Southeast now, and are used as a retrofit measure to eliminate moisture problems (as described in a *Journal of Light Construction* article "Fixing a Wet Crawlspace," by Jeff Tooley, August 2004).

What crawl space problems are relevant to ZETA?

Eliminating crawl space ventilation has benefits for moisture control and energy (by increasing house airtightness, and reducing ductwork losses). However, there are still risks to performance, listed below. All of these problems are dealt with by the explicit ZETA design details.

- The ground is still a moisture source. This is dealt with by using a vapor barrier layer (6-mil polyethylene film) between the ground and the conditioned space, which eliminates this moisture transmission.
- The ground has a good deal of thermal lag; the slab/ground surface and lower portion of the walls will remain relatively cool throughout the year. This could conceivably cause problems with condensation during the spring, when outdoor air moisture conditions start to rise. However, both the walls and crawl space floor are insulated on the exterior with insulation board. This material raises the interior surface temperatures, preventing any condensation problems (i.e., the crawlspace floors and walls are “thermally decoupled” from ground).
- When boxes or materials are stored in a “typical” basement or crawl space, they basically act as insulation on the floor, preventing heat loss. As a result, the surface between the box and the floor is cooler, and has a greater risk of condensation. The result of this phenomenon is that the bottom of boxes in basement often “rot out” or become waterlogged, mold-ridden, and weakened. However, in our case, there is a layer of insulation underneath the 2” thick slab. This “thermally decouples” the slab from the ground, eliminating this problem.

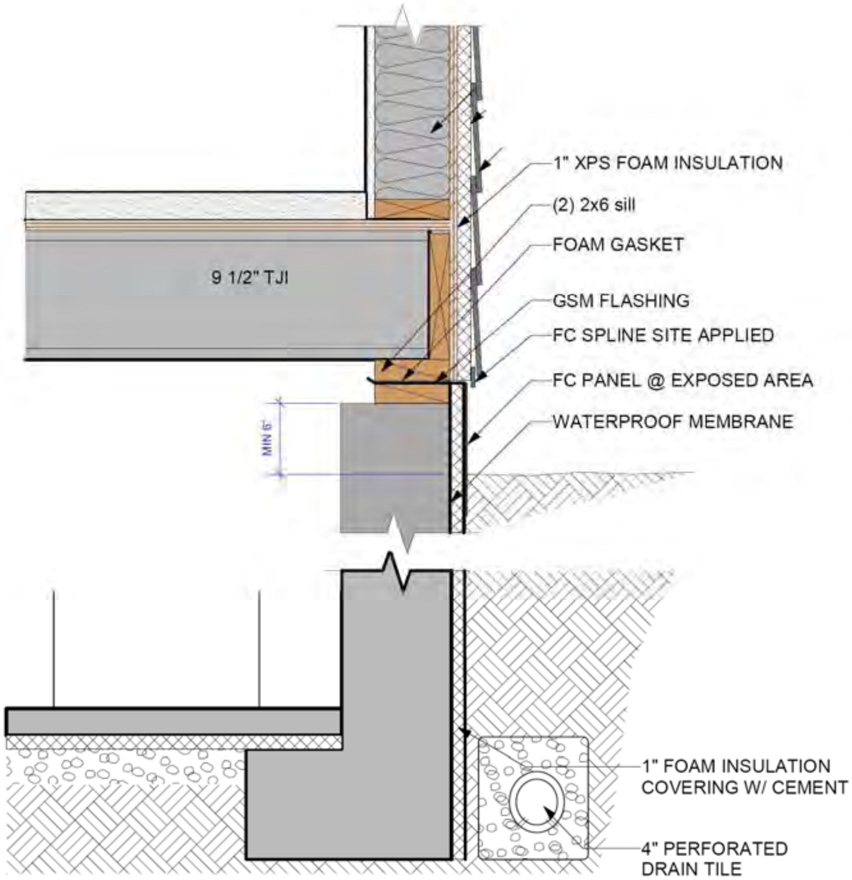


Figure 2: Thermal basement section (c/o DSA Architects)

- Ground water or major plumbing leaks could be an issue: if the foundation floods, moisture in this location is inside the conditioned space. First and obviously, a flood should be dealt with appropriately and pumped/vacuumed out. However, the ZETA design includes a detailed system for keeping surface water away from the foundation (perimeter drain and exterior sump), as well as an interior sump in a sump pit in the floor.

This sump has a tight-fitting cover, to prevent soil gases from coming into the house. In the event of a flood, this cover can be opened, and the water swept into the foundation drain. The use of a 2” thick “rat slab” on the floor of the space allows simple drainage and cleaning of this space.

Is this construction accepted by code?

The building code has caught up with research in this field showing that this is an excellent solution to crawl space moisture problems. Unvented crawl spaces have been accepted by the International Residential Code since the 2006 Edition, excerpted here:

1. R408.3 Unvented crawl space. Ventilation openings in under-floor spaces specified in Sections R408.1 and R408.2 shall not be required where:

2. Exposed earth is covered with a continuous vapor retarder. Joints of the vapor retarder shall overlap by 6 inches (152 mm) and shall be sealed or taped. The edges of the vapor retarder shall extend at least 6 inches (152 mm) up the stem wall and shall be attached and sealed to the stem wall; and One of the following is provided for the under-floor space:

2.1. Continuously operated mechanical exhaust ventilation at a rate equal to 1 cfm (0.47 L/s) for each 50 ft^2 *(*$4.7m^2$*) of crawlspace floor area, including an air pathway to the common area (such as a duct or transfer grille), and perimeter walls insulated in accordance with Section N1102.2.8;*

2.2. Conditioned air supply sized to deliver at a rate equal to 1 cfm (0.47 L/s) for each 50 ft^2 *(4.7* m^2*) of under-floor area, including a return air pathway to the common area (such as a duct or transfer grille), and perimeter walls insulated in accordance with Section N1102.2.8;*

2.3. Plenum complying with Section M1601.4, if under-floor space is used as a plenum.

California’s current building code is based on IBC 2006; there are analogous sections in the IBC (Chapter 12: Interior Environment). It provides exceptions to crawl space ventilation (1203.3.2 Exceptions) as follows:

3. Ventilation openings are not required where continuously operated mechanical ventilation is provided at a rate of 1.0 cubic foot per minute (cfm) for each 50 square feet (1.02 L/s for each 10 m^2*) of crawl-space floor area and the ground surface is covered with an approved vapor retarder.*

4. Ventilation openings are not required when the ground surface is covered with an approved vapor retarder, the perimeter walls are insulated and the space is conditioned in accordance with the ***International Energy Conservation Code****.*

The ZETA design goes above and beyond these minimum requirements: the air handling system in the thermal basement provides hundreds of cfm of mechanical ventilation, insulates the floor slab, and protects the vapor barrier with a 2” concrete slab.

June 15, 2009

ZETA Communities
3145 Geary Boulevard, #733
San Francisco, CA 94118
tel 415.753.1810
fax 415.564.6911
ATTN: Naomi Porat
nporat@zetacommunities.com

Re: Economic Analysis for Energy Optimization for ZETA Lancaster Lofts Plan

Dear Ms. Porat:

In preparation for Tuesday's discussion on cutting production costs without sacrificing overall quality and/or energy performance, I have prepared this document that tries to quantify some of the cost-benefit balances of various energy upgrade measures. This uses methods that Building Science Corporation has developed in the past to try to optimize and select for the highest-ranked performers. The overall strategy is as follows: since we are pursuing net zero performance, measures that are more cost effective than photovoltaics are to be kept, and those with worse performance might be discarded.

It is important to point out that much of what we recommend targets durability, air quality, and reliable installation—as opposed to energy paybacks. We should all try to keep this in mind as a guiding principle.

If you have any questions or comments about this report, please contact Kohta Ueno of Building Science Consulting (kohta@buildingscience.com), or as per contact information shown.

Sincerely,

Kohta Ueno

Cc: Shilpa Sankaran, Jeremy Fisher (ZETA Communities)
John Straube, Ph.D., P.Eng., Aaron Grin (Building Science Corporation)
Daniel Smith (Daniel Smith & Associates, Architects)

Insulating Sheathing Discussion

Our understanding is that some of the pushback is coming from the 1" of XPS rigid sheathing. As per John Paddock's email:

> *The 1" foam wrapping the structure is challenging & costly from the manufacturing end. If we leave it off, can we still achieve our zero energy goals, perhaps by adding more PV?*

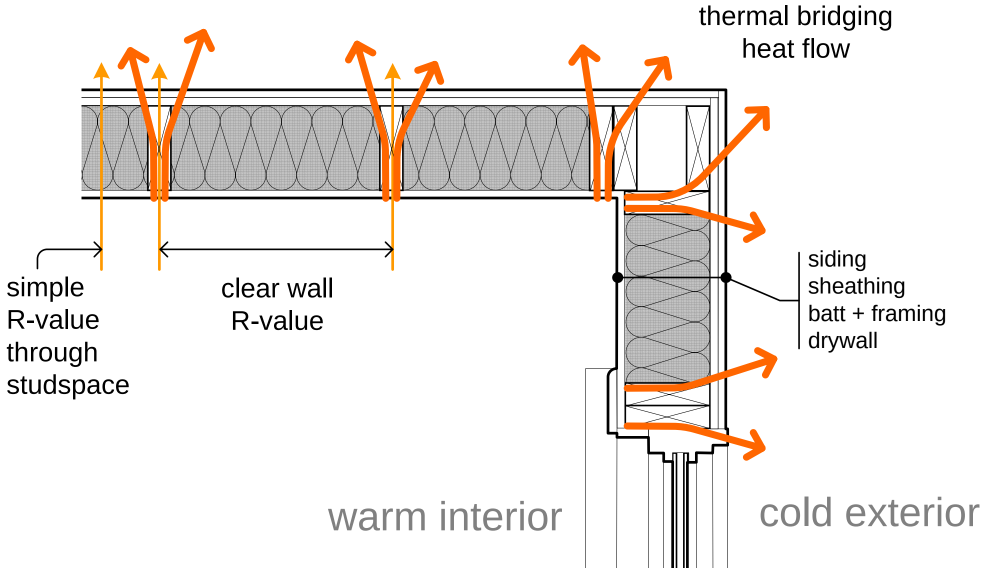
John Straube responded:

> *I am sure there are ways to remove the R5 sheathing from the walls and reach net zero. I am equally sure that the resulting product will be far inferior and I doubt it will be as economic.*
>
> *We apparently have not made it clear enough that the foam sheathing is an important part of ensuring durability, comfort and health. The R value is an added benefit we can achieve in other ways. Lots of other builders and designers have tried to build high performance framed walls without the foam sheathing with predictably poor results.*
>
> *So the short answer is "don't remove the insulting sheathing, it is a critical part of a high performance building".*

The economics of insulating sheathing will be discussed in the following section, along with other measures. However, there are several facts that I wanted to spell out briefly:

- Insulating foam sheathing deals with thermal bridging (heat flow through wood studs), as shown in Figure 1. As a result, adding just 1" of XPS foam improves wall actual R value from R-13.6 (of a **2x6 wall**, without insulating sheathing) to R-18.6. *This is an increase of 37% relative to the base case of a wall with only structural sheathing.* This occurs even though the cavity insulation is a nominal R-19, while the continuous (i.e., foam) is only R-5. As a point of reference, a **2x8** wall, with full cavity insulation, would only achieve an overall R value of R-18.1.
- Insulating sheathing deals with interstitial condensation issues in a highly effective, robust, and reliable manner.
- As a final note, the vast majority (if not all) of BSC's Building America builders have no problem incorporating insulating sheathing into their standard construction practices on a production level. This includes several Northeast builders who use 2" of XPS foam sheathing as their standard practice. At least 1" of XPS is considered basic run-of-the-mill construction in the majority of southern Canada. BSC worked with production builders changing their entire product over to 1" of XPS or polyisocyanurate exterior foam sheathing (**in lieu of** structural sheathing, except where bracing is required) going back to the 1990s.

2x6 Framed Wall



2x4 with Exterior Insulation

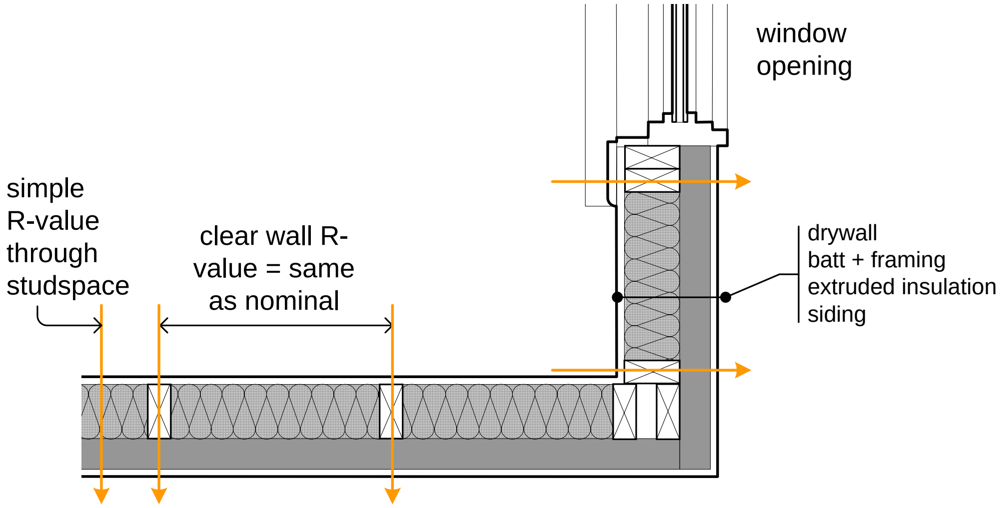


Figure 1: Thermal bridges and the role of insulated sheathing in light-weight framed structures

One discussion that is warranted, however, is to determine what costs—or perceived costs—are actually associated with the addition of insulating sheathing. I think that this should be broken down into specific components and problems.

- Foam sheathing material cost: This cost is on the order of 50 cents/sf, or on the order of $1000.
- Foam sheathing installation cost: It is unknown what the base installation cost is for this additional layer of sheathing. Previous work has let us trade off structural sheathing for

insulating sheathing, and only retain structural sheathing as required for shear bracing. However, this is not being done in this case.

- Rainscreen: I want to make sure that you are not blaming costs associated with rainscreen siding installation to the foam insulating sheathing. These two items are **separate measures**: the rainscreen siding installation is done as a best practice for durability and rain control. It appears that some of the costs of rainscreen siding are associated with the ¾” airspace; BSC does not have a problem with using the ¼” airspace detail throughout (as shown in Figure 2). A smaller dimension might be easier to detail, overall. This smaller gap will still provide acceptable drainage and some ventilation drying.
- Hardie rainscreen: All of us at BSC are quite flabbergasted that James Hardie will not allow any other furring product other than their own ¾” Hardie furring, which no doubt is adding significant cost. Any type of spacer should provide acceptable performance.
- Windows: Some costs for foam are probably ascribed to the required window details. The way ZETA is building the window openings definitely adds costs, by ripping down and installing 1” thick plywood as a nail base for the windows. BSC’s standard detail, which has been put into practice in a production setting countless times, is to simply fasten the nailing fin through the foam, in applications up to ~1-½” thick. Thicker foam applications (e.g., 4”) require some specialized details. If there are concerns of the dead weight bearing of the window, a rough opening sill extension can be provided using dimension lumber or plywood (see Figure 3).
- Interior window details: due to pushing the window outwards by 1”, the interior return dimension must be increased; but given drywall returns, this dimension change is trivial.
- Trim: the same 1” plywood detail is used for trim support; there are some geometries where this is necessary, but other geometries where it is not.

Figure 2: ZETA current 1/4" rainscreen practice using plastic corrugated sign board

Figure 3: Rough sill extension for window dead weight (interior view)

Economic Evaluation

Basic Analysis

The economic analysis presented here has several additional parameters beyond what is given in our typical analysis. Note that this is not intended to be a complete life-cycle analysis, or include the escalation of fuel rates. However, it does go into more detail than previous simple payback calculations.

Column headings shown on previous analysis included:

- Estimated individual cost: an estimate of the upgrade cost associated with this measure (dollars)
- Item savings: the annual energy saving resulting from this upgrade (dollars/year)
- Increment payback: simple payback; the number of years required (at fixed energy costs, and not accounting for inflation or loan costs) to pay back the cost of the energy improvement measure (years)

But this analysis includes these additional items:

- Savings: the source energy savings resulting from this upgrade (million Btu/year)
- $/$10^6$ Btu: dollars per million Btu saved per year. This column basically gives the “cost” a unit of energy savings—the lower the number, the more cost effective the measure is. Note that this is stated in terms of source energy (i.e., electricity at 3x energy cost metered at site) (dollars/million Btu/year)

Table 1: Parametric simulations: basic economic analysis

Parametric Run ID	Description of change	Estimated Individual Cost	Annual energy cost	Increment payback (yr)	Savings [10^6 Btu / yr]	$ per 10^6 Btu Saved (1 year)
0	Benchmark	n/a	$1,768	n/a	n/a	
1	Windows as-designed & overhangs	n/a	$1,837	n/a	(6.0)	
2	Add skylight (stairwell; 1.5:12)	n/a	$1,842	n/a	(0.4)	
3	Air seal (2.5 sq in/100 sf)	$500	$1,738	5	9.1	$55
4	Ducts 5% leakage (still in crawlspace)	$500	$1,721	*30*	1.4	*$346*
5	R-19 OVE Walls 24" o.c. from R-13+	$0	$1,683	0	3.3	$0
6	Add wall sheathing 1" XPS R-5	$1,500	$1,646	*41*	3.2	*$465*
7	Roof R-32 cavity insulation from R-25	$350	$1,636	*35*	0.9	*$401*
8	Crawl space walls to R-7.5 (1.5" XPS)	$100	$1,626	11	0.8	$121
9	Crawl space "floor" to R-5 (1" XPS)	$450	$1,617	*48*	0.8	*$552*
10	Over garage & overhang to R-22	$200	$1,612	*43*	0.4	*$498*
11	Serious 725 Series U=0.23 SHGC=0.42	$6,500	$1,514	*66*	8.6	*$754*
12	9.5 HSPF heat pump	$800	$1,451	13	5.5	$146
13	16 SEER air conditioner	$650	$1,443	*76*	0.7	*$871*
14	CFIS ventilation system	$250	$1,443	n/a	n/a	n/a
15	2.11 EF heat pump water heater	$1,400	$1,200	6	21.3	$66
16	GFX drainwater heat recovery	$1,000	$1,179	*48*	1.8	*$548*
17	CFL Lighting Package	$150	$1,056	1	10.7	$14
18	ES Appliances	$750	$1,008	16	4.2	$179
19	5.4 kW PV system; 7 tilt, 210 azimuth	$21,000	$105	*23*	77.6	$270
20	Optional: add HRV 100 W, 120 CFM	$1,000	$1,010	n/a	n/a	n/a

We have ascribed very rough numbers to the production costs; if you have more detailed information, this can easily be dropped in to our spreadsheets to see how they affect the ranking.

The main column we will be looking at here is the “dollars per million Btu saved per year”—as we stated above, it covers the cost of the “buying” a given unit of energy savings. Although it presents information similar to the simple payback, it eliminates energy costs as an additional variable. Energy costs, of course, can vary between locations and over time.

Note that some of the numbers in the latter columns are shown in orange. **These cells are highlighted to show that their financial advantage (simple payback or $/million Btu/year) is worse than the 5.4 kW of photovoltaic system (if the price is reduced by government subsidies to ~$4/watt, as opposed to its ~$8/watt purchase price).** Of course, all of the enclosure and mechanical measures will be proportionately better if the PVs were priced at market rates.

Measures 8 and 10 have oddly low costs and associated savings; this is because the change from Benchmark to Prototype R value was small: R-6 to R-7.5, and R-16 to R-22, respectively.

Furthermore it should be noted that spray foam insulation (Icynene) was not broken out as a separate line item. The insulating value per inch is comparable to any cavity fill insulation (~R-3.5/inch). Its main benefit comes from its air sealing properties, which is primarily covered under line item 3.

Measure-by-Measure Description

Instead of going through these measures exhaustively one-by-one, we have concentrated on the apparent “worst performers” in Table 1, as follows:

- HRV: When fan cycling (mixing) is added, in order to provide adequate distribution of ventilation air throughout the house, the net result is that the HRV does not save energy in this mild climate, relative to the base case of central fan integrated ventilation. This is a combination of the mild climate (small temperature differences) and the small ventilation flows required.

  If this mixing is not used (not a recommended step), the resulting energy performance is still poor: it has a 110 year incremental payback, or $63 dollars per million Btu saved per year—higher than any other measure on the page.
- 16 SEER air conditioner: The poor performance of this measure is due to the miniscule cooling load in the Oakland climate. As a result, there is little cooling “budget” to “save from,” which does not lend itself to spending on equipment. However, this equipment is part and parcel of the high performance heat pump, so it not truly relevant for the elimination/retention decision.
- Serious Materials Windows: although Serious Materials 725 windows have fantastic performance, their high cost combined with the mild climate makes them difficult to justify as an energy measure alone. Our previous analysis showed that conventional high performance (low E argon filled double glazed) windows ended up being closer to a reasonable upgrade measure. However, there are likely political ramifications for selecting or not selecting Serious Materials windows.
- Crawl “floor” to R-5: this measure was solely done to “trick” the simulation to recognize R-5 sub slab insulation; it is likely not even an accurate reflection of the true energy performance. Note that sub slab insulation is required if the zTherm (thermal mass) system is being implemented: the crawl space slab must be more closely coupled to the interior rather than the ground, otherwise huge heat losses will result.

Extended Analysis (Lifetime)

One way to increase the realism of this exercise is to extend this economic analysis to include the rough lifetime of these measures, to give their dollars per unit energy savings over their lifetimes. Table 2 below adds the following columns to the previous analysis:

- Estimated lifetime: rough lifetime of the measure, at least until replacement or a repair that is a substantial fraction of the installation cost (years)
- \$ per 10^6 Btu Saved (lifetime): this figure divides the "cost effectiveness" metric (\$/million Btu/year) by lifetime (years), in order to obtain **\$/million Btu saved over the lifetime of the item**. It is also equivalent to [the cost of the upgrade (\$)] ÷ [annual energy savings (million Btu/year) × the lifespan of the measure (years)].

We believe this analysis, by taking into account the lifetime of the measure, is a much more realistic economic assessment than the previous measures—especially when taken from a global perspective of optimizing energy use reduction.

Table 2 below shows two of the previous columns (in grey), with the new columns of lifetime (years), and \$ per 10^6 Btu Saved.

Table 2: Parametric simulations: extended economic analysis (grey columns repeated from previous)

Parametric Run ID	Description of change	Savings [10^6 Btu / yr]	\$ per 10^6 Btu Saved (1 year)	Estimated Lifetime [yr]	\$ per 10^6 Btu Saved (Lifetime)
0	Benchmark	n/a			
1	Windows as-designed & overhangs	(6.0)			
2	Add skylight (stairwell; 1.5:12)	(0.4)			
3	Air seal (2.5 sq in/100 sf)	9.1	\$55	75	\$0.73
4	Ducts 5% leakage (still in crawlspace)	1.4	*\$346*	75	\$4.61
5	R-19 OVE Walls 24" o.c. from R-13+	3.3	\$0	75	\$0.00
6	Add wall sheathing 1" XPS R-5	3.2	*\$465*	75	\$6.20
7	Roof R-32 cavity insulation from R-25	0.9	*\$401*	75	\$5.35
8	Crawl space walls to R-7.5 (1.5" XPS)	0.8	\$121	75	\$1.61
9	Crawl space "floor" to R-5 (1" XPS)	0.8	*\$552*	75	\$7.36
10	Over garage & overhang to R-22	0.4	*\$498*	75	\$6.64
11	Serious 725 Series U=0.23 SHGC=0.42	8.6	*\$754*	40	*\$18.85*
12	9.5 HSPF heat pump	5.5	\$146	20	\$7.30
13	16 SEER air conditioner	0.7	*\$871*	20	*\$43.55*
14	CFIS ventilation system	(0.0)	-n/a	20	n/a
15	2.11 EF heat pump water heater	21.3	\$66	20	\$3.29
16	GFX drainwater heat recovery	1.8	*\$548*	50	*\$10.96*
17	CFL Lighting Package	10.7	\$14	5	\$2.80
18	ES Appliances	4.2	\$179	20	\$8.97
19	5.4 kW PV system; 7 tilt, 210 azimuth	77.6	\$270	30	*\$9.02*
20	Optional: add HRV 100 W, 120 CFM	(0.1)	n/a	20	n/a

Most enclosure measures are shown with a 75 year lifetime, and mechanical systems with a 20 year lifetime. There are several items with "in between" levels (PV system, 30 years typically cited, and windows, 40 years used here).

Although the lifetimes can be argued and fine-tuned, they are a reasonable starting point for this discussion. When examined for the worst performers ("culling the herd"), the lowest items (shown in bold in the table above) are:

- HRV: negative savings; if mixing is removed, cost is ~\$63 per 10^6 Btu Saved (lifetime)
- 16 SEER air conditioner, \$44; as per above, part of the heat pump system
- Serious Materials windows: \$19
- Drainwater heat recovery: \$11

Note that all of the enclosure measures, due to their long lifetimes, as much better performers than any of the measure described above. This includes, for instance, the foam insulating sheathing. This is consistent with guidance given in Building Science Insight 14 (by John Straube), "Deciding on Energy Priorities When Building New." That document states that enclosure items are difficult, disruptive, and costly to change over the lifetime over the building, and that insulation technology is unlikely to undergo a dramatic technology-based improvement (e.g., as photovoltaics or mechanical equipment might). Therefore, enclosure upgrades should often be prioritized over mechanical system upgrades.

- http://www.buildingscience.com/documents/insights/bsi-014-deciding-on-energy-priorities-when-building-new

Net Zero Energy Homes

Dr John Straube

www.buildingscience.com

Building AMERICA
U.S. Department of Energy
Research Toward Zero Energy Homes

Definitions

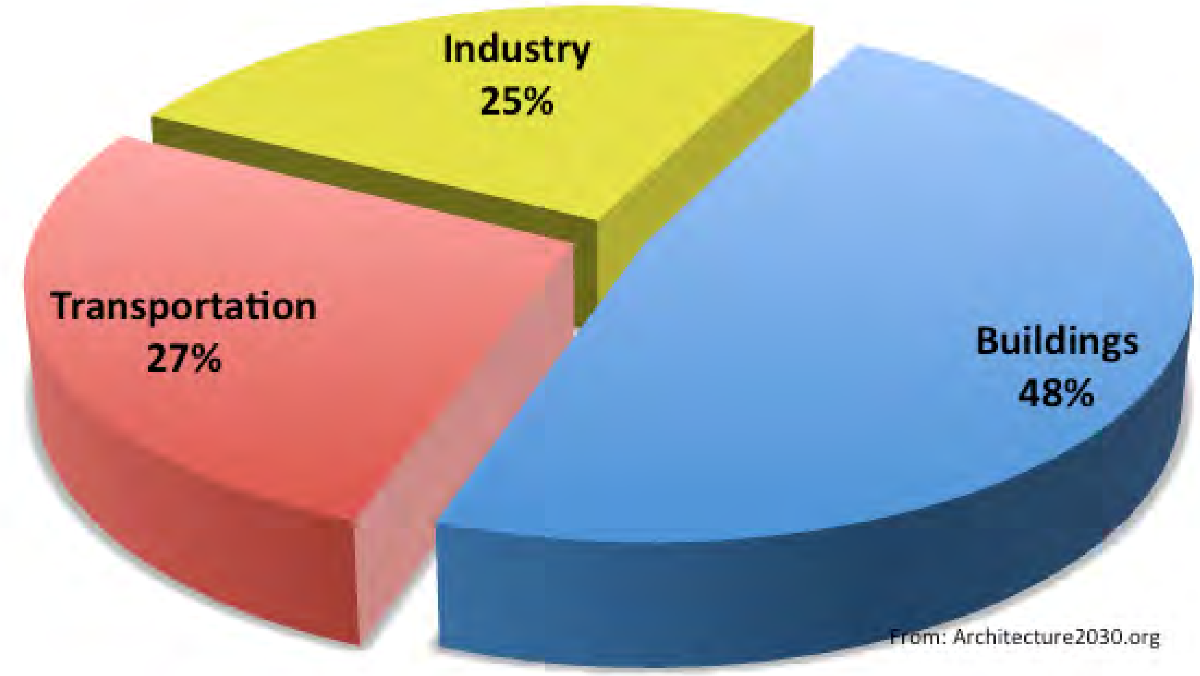
- NZE: A building that produces as much energy in a typical year as it consumes.
    - Consumes grid power when it needs it
    - Feed power to grid when it has extra
- ALL energy considered
    - Electric is not special.
- NOT Zero Carbon, or Zero GHG
- NOT off-grid
    - Much more difficult

Why Reduce Energy Use?

- Environment
  - GHG emissions and climate change
  - Other emissions, NOx, SOx, Hg, $PM_{2.5}$, etc.
- Energy Security
  - Peak oil (we are running out of oil)
  - national/local independence
  - International political implications
- Short answer: save energy to reduce environmental and human damage

Why Buildings

- Building Sector is largest energy consumer and GHG emitter



From: Architecture2030.org

Building Environmental Damage

- Resource Extraction
  - Cutting trees, mining, drilling oil, etc.
- Processing
  - Refining, melting, etc. Pollutants and energy
- Transportation
  - Mass and Mode (ship/truck) and Mileage
- Construction
  - Energy, worker transport
- Operational Energy

80-90% of Impact!

Low Energy

- Low Energy Buildings are therefore environmentally friendly
- Once low energy, then worry about material energy and pollution
- NZE are ZERO ENERGY
    - So materials matter

Energy

- Ability to do work
  - – Measured in Btu (IP) or J (SI) or kWh (SI)
    - MMBtu = 1 million Btu = 293 kWh
  - – One Btu = heat one pound $H_2 0$ 1F
  - – One kWh = 100 Watt lightbulb for ten hours
- Energy delivered at gas usually in therms
    - Therm = 100 000 Btu = 29.3 kWh
- Energy delivered as electricity usually in kWh
    - One kWh = 3400 Btu

NZE Design Targets

- Produce as much as we consume
- Production is usually MUCH more expensive than reducing waste (efficiency/conservation)
  - Hence the energy demanded by building should always be reduced, reduced, reduced before adding production
  - Check cost of reducing demand vs cost if supplying energy

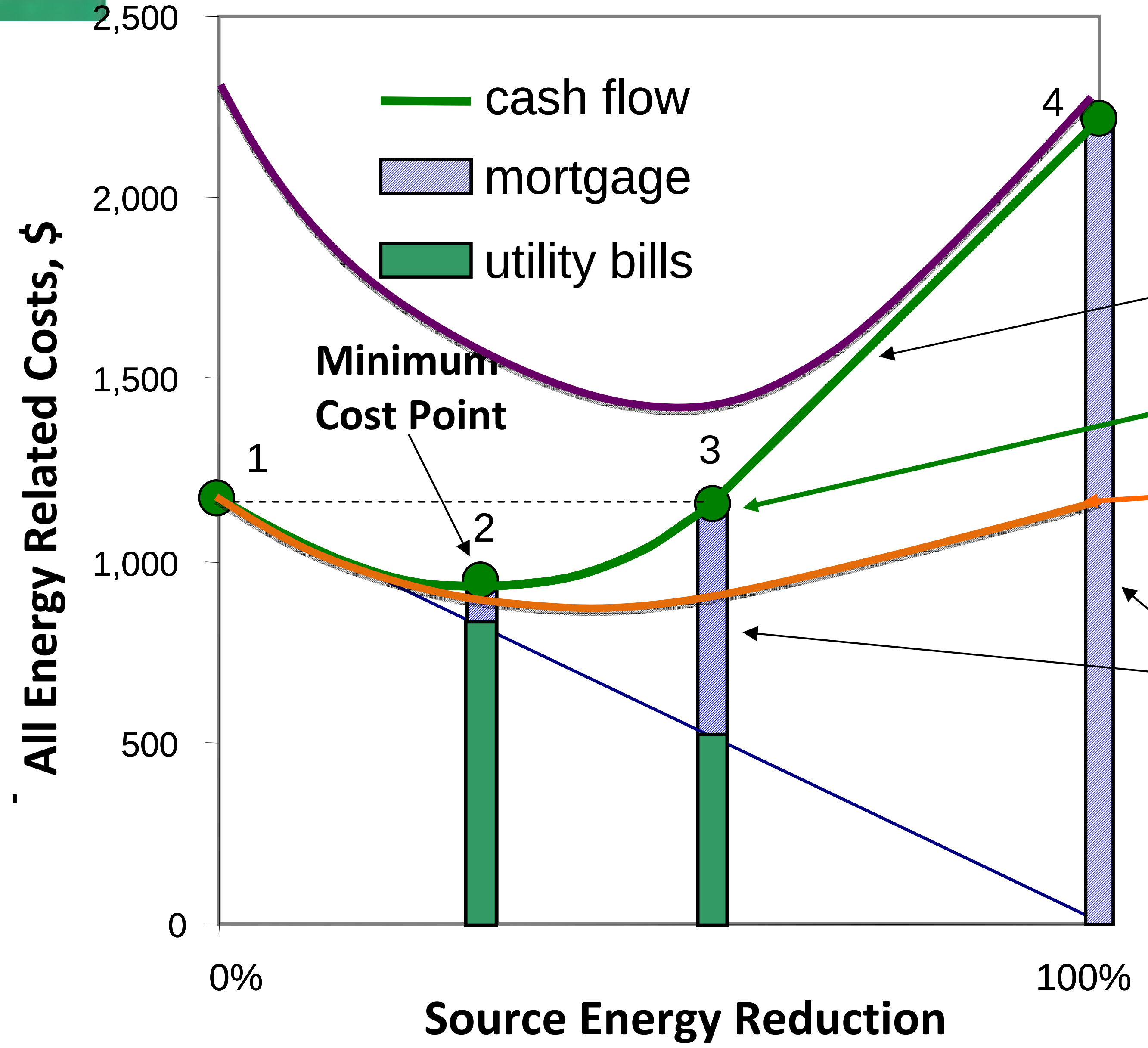
Efficiency

- Not very precise /often not useful term
- Efficiency = desired effect / effort in
    - Heating energy out / energy in (gas, electric, sun)
    - Cooling energy out / energy in (electric, open window)
    - – A small house needs less heating energy but a large house might use a “more efficient” furnace
- Efficiency = 1 happy person / Energy used?

Energy Intensity

- One measure of efficiency
- Energy use per area
  - kBtu/sf/yr or MMBtu/houshold/yr
  - $kWh_e/m^2/yr$ or MWh_e/houshold/yr
- Energy use per person
  - Person = bedrooms+1
  - Design occ. Vs actual occ.

Capital Investment vs Operating Cost



Higher Energy costs

“Least Cost” Curve

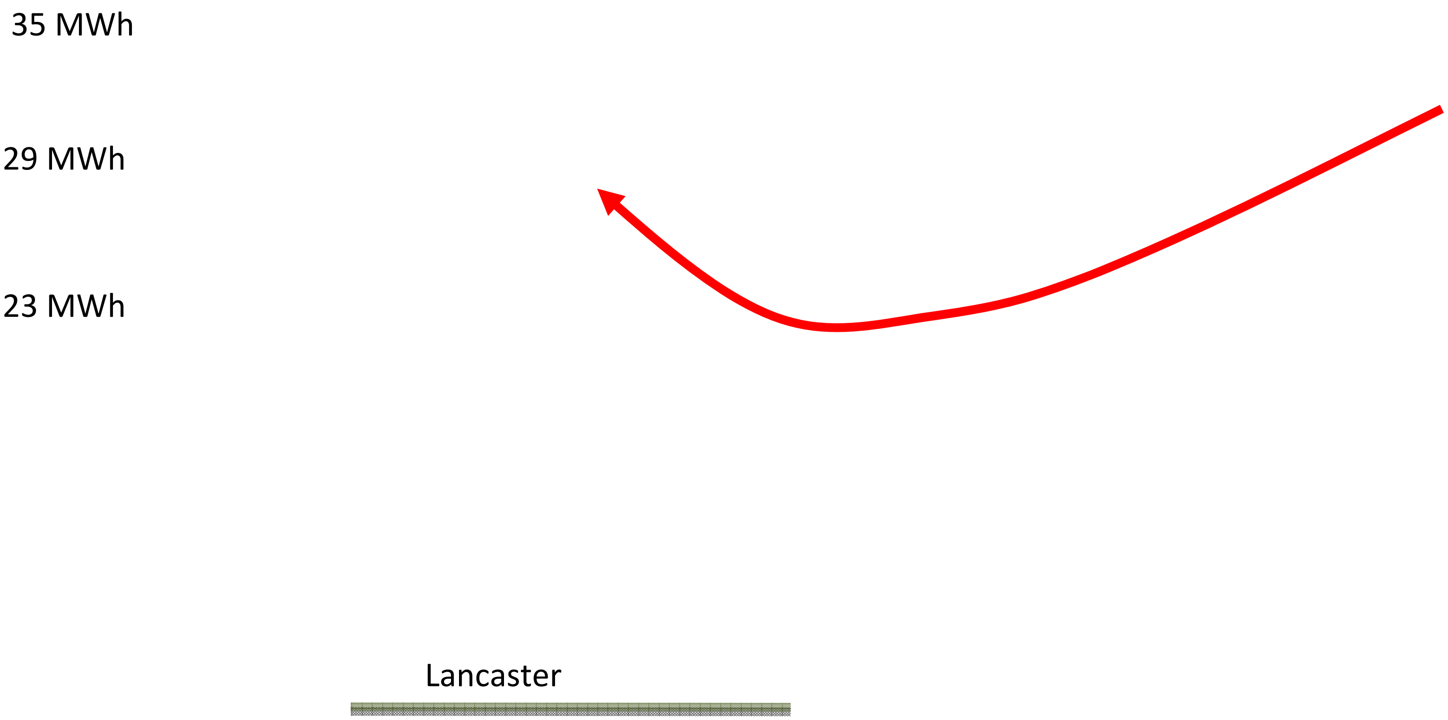
Neutral Cost Point

Lower cost conservation

Incremental, Energy Related Mortgage Costs

Underlying Source: Dr Ren Anderson, NREL

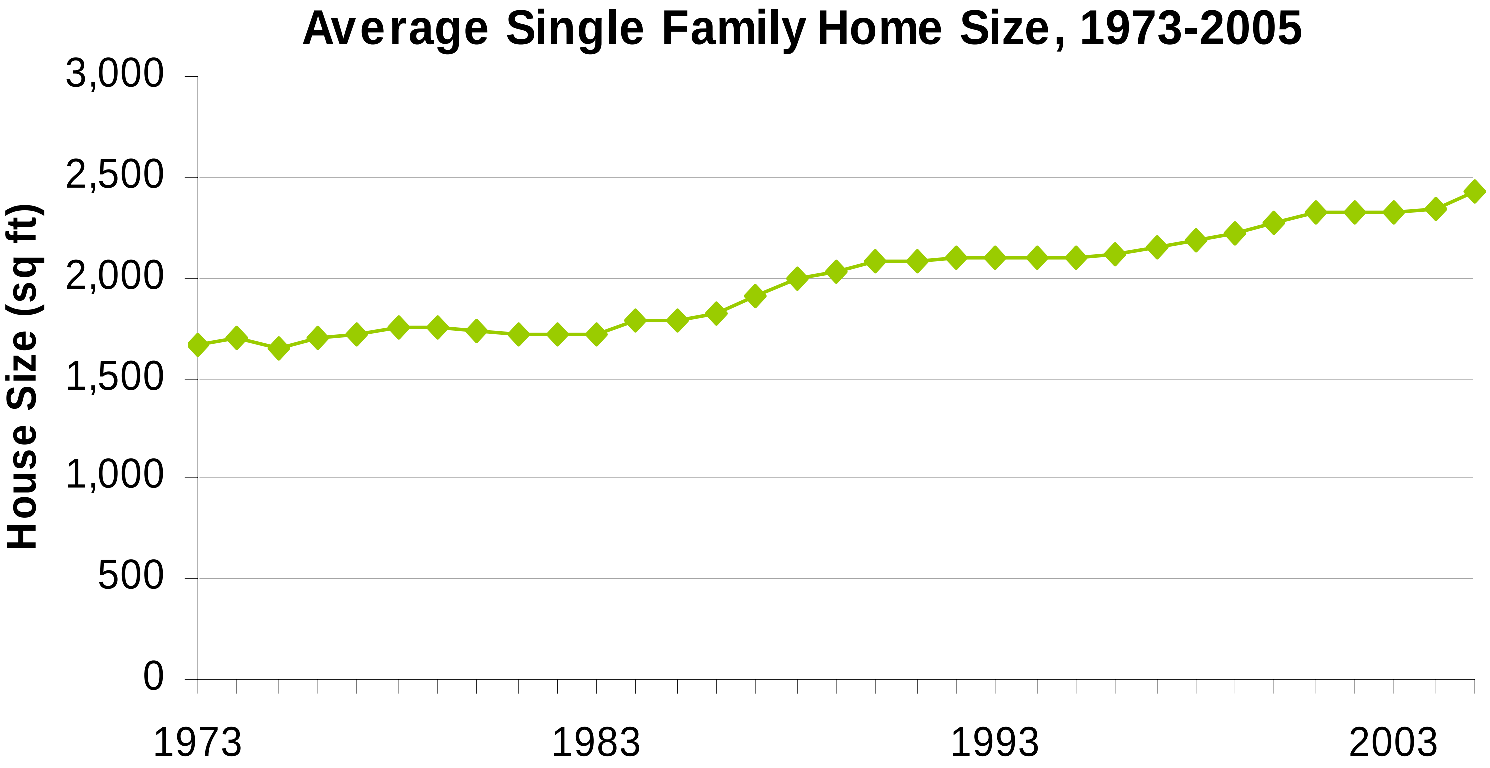
Old & New Houses Energy Use



Source: US Census Bureau, Annual Housing Survey: http://www.census.gov/hhes/www/housing/ahs/ahs.html

Getting Bigger as Time Goes On

- Average House Size in **1940: ~1100 sq ft**[1]
- Average House Size in **1973: 1660 sq ft**[2]

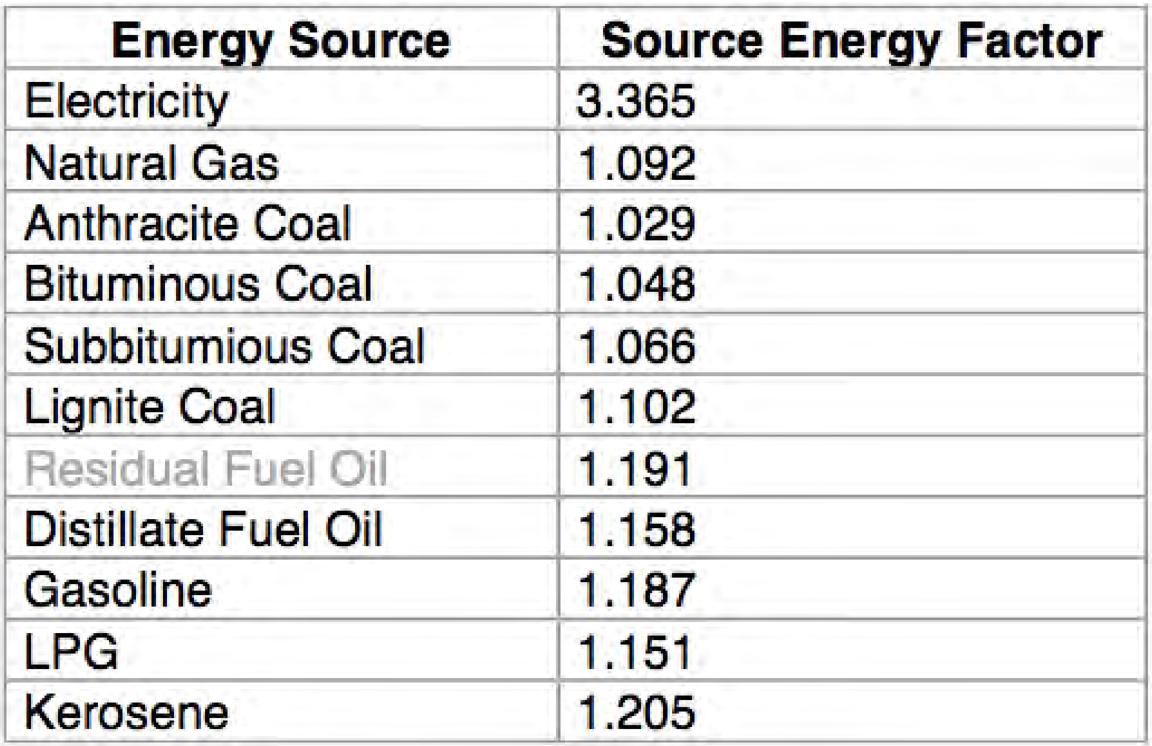


- Average House Size in **2005: 2434 sq ft**

1. Wilson, Alex and Jessica Boehland “Small is Beautiful” *Journal of Industrial Ecology*, Vol 9, No 1-2. 2005
2. EIA, Annual Energy Review, 2001 data: www.eia.doe.gov/emeu/aer

Source-to-Site Conversion

- January 2009, NREL figures for Building America
- Of course, varies with source of electricity supply
  - Most coal plants are 35% efficient, new NG plants 60%+
  - 5% transmission loss

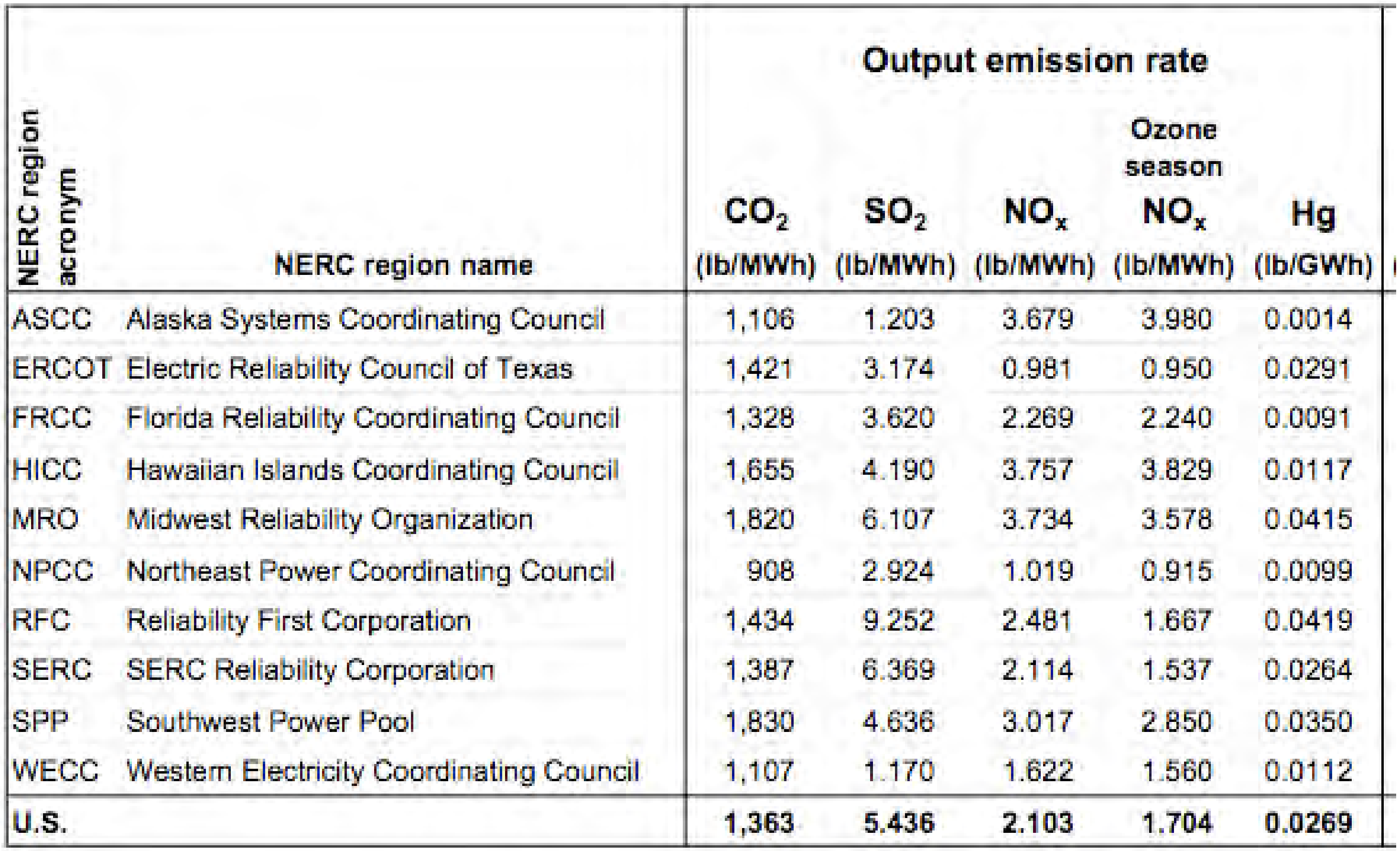


Energy Source	Source Energy Factor
Electricity	3.365
Natural Gas	1.092
Anthracite Coal	1.029
Bituminous Coal	1.048
Subbitumious Coal	1.066
Lignite Coal	1.102
Residual Fuel Oil	1.191
Distillate Fuel Oil	1.158
Gasoline	1.187
LPG	1.151
Kerosene	1.205

eGRID 2006 NERC Regional Interconnects

Electrical GHG Emissions

- April 2007, EPA eGRID files



NERC region acronym	NERC region name	Output emission rate				
		CO_2 (lb/MWh)	SO_2 (lb/MWh)	NO_x (lb/MWh)	Ozone season NO_x (lb/MWh)	Hg (lb/GWh)
ASCC	Alaska Systems Coordinating Council	1,106	1.203	3.679	3.980	0.0014
ERCOT	Electric Reliability Council of Texas	1,421	3.174	0.981	0.950	0.0291
FRCC	Florida Reliability Coordinating Council	1,328	3.620	2.269	2.240	0.0091
HICC	Hawaiian Islands Coordinating Council	1,655	4.190	3.757	3.829	0.0117
MRO	Midwest Reliability Organization	1,820	6.107	3.734	3.578	0.0415
NPCC	Northeast Power Coordinating Council	908	2.924	1.019	0.915	0.0099
RFC	Reliability First Corporation	1,434	9.252	2.481	1.667	0.0419
SERC	SERC Reliability Corporation	1,387	6.369	2.114	1.537	0.0264
SPP	Southwest Power Pool	1,830	4.636	3.017	2.850	0.0350
WECC	Western Electricity Coordinating Council	1,107	1.170	1.622	1.560	0.0112
U.S.		**1,363**	**5.436**	**2.103**	**1.704**	**0.0269**

National 1.36 lb CO_2/kWh (0.91 to 1.83)
WECCC 1.11 lb CO_2 / kWh

Fossil Fuel GHG Emissions

- Assuming combustion @ 100% efficiency
- Nat gas
  - 117 pds CO_2 / MMBtu = 0.40 /kWh
  - 92% eff. = 0.435 lb/kWh
  - Around 3 times less GHG emission vs electric
- Propane
  - 139 pds CO_2/MMBtu = 0.475 /kWh
- Heating oil No. 2
  - 161 pds CO_2/MMBtu = 0.54 /kWh

Source: DOE EIA Emissions Coefficients

Major Energy Use Categories

kWh/yr for a typical US 2200 sf 3 BDR home

- Space Heating
  - 5000 – 25 000 very climate dependent
- Space Cooling
  - 0 – 10 000 very climate dependent
- Domestic Hot Water
  - 4000-6000 small climate dependency
- Appliances
  - 1000 – 2000
- Misc Electrical Loads + plug
  - 1000-3000
- Lighting
  - 750- 2000
- Total: 20 000 – 35 000 kWh/yr

- Mileage Chart:

Estimated Whole House Energy Use Comparison

US Average Mileage Chart

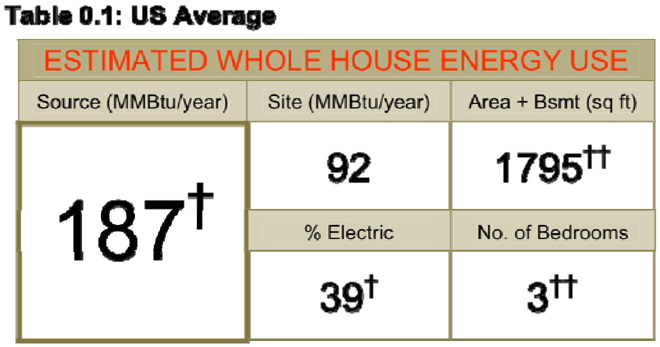
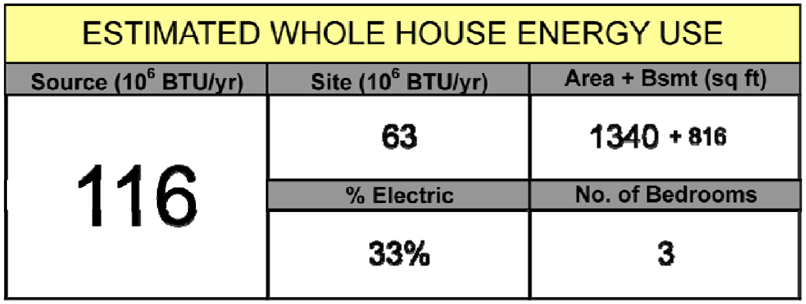


Table 0.1: US Average

ESTIMATED WHOLE HOUSE ENERGY USE		
Source (MMBtu/year)	Site (MMBtu/year)	Area + Bsmt (sq ft)
187†	92	1795††
	% Electric	No. of Bedrooms
	39†	3††

Source MWhr/yr	Site
54.8	27.0

Westford House Mileage Chart

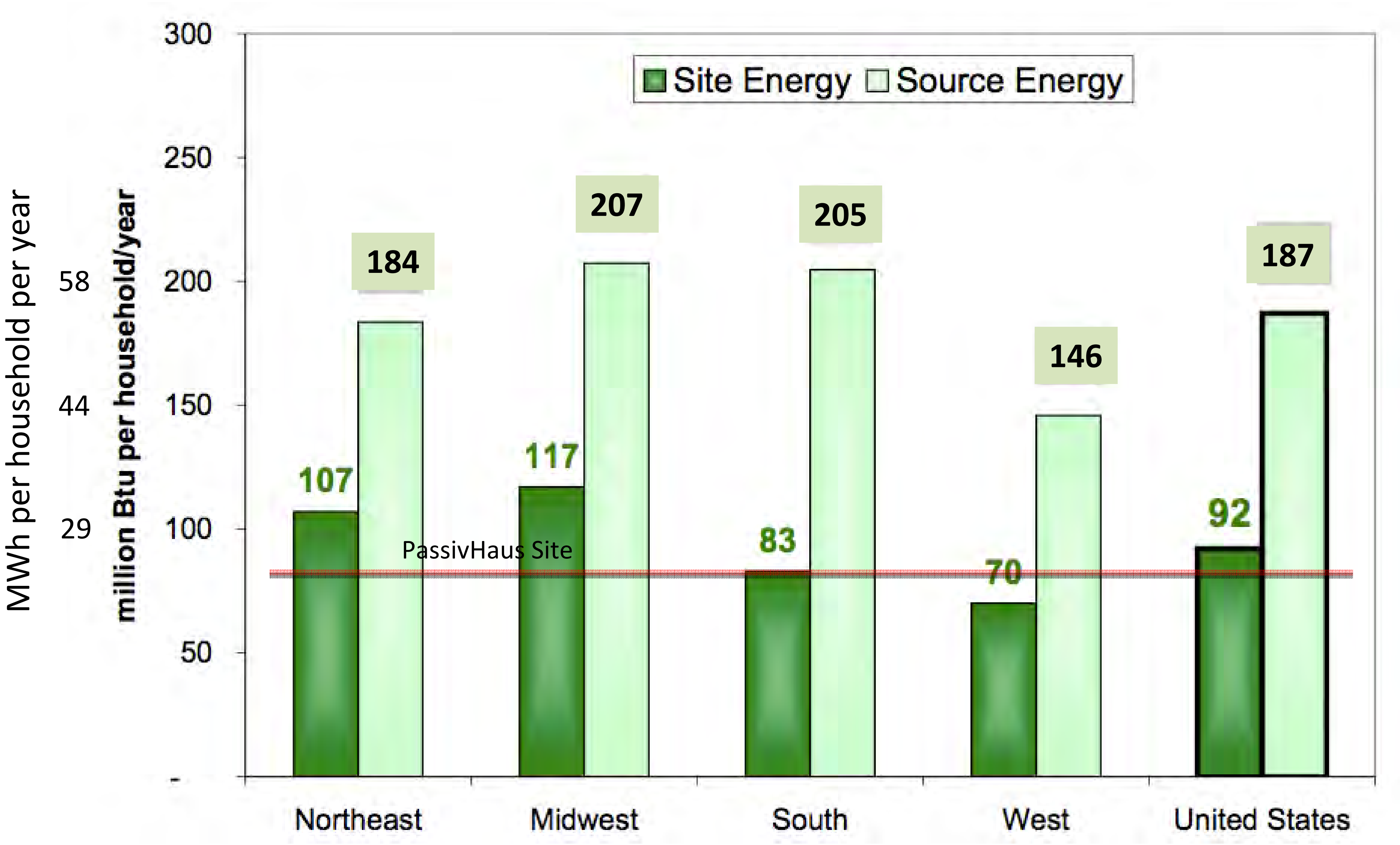


ESTIMATED WHOLE HOUSE ENERGY USE		
Source (10^6 BTU/yr)	Site (10^6 BTU/yr)	Area + Bsmt (sq ft)
116	63	1340 + 816
	% Electric	No. of Bedrooms
	33%	3

Source MWhr/yr	Site
34.0	18.5

Range is 45 to 60 MWh/yr source
20 to 35 MWh/yr site

Energy Use per Household



PassivHaus

- Total heating & cooling demand
  - <15 kWh/m^2/yr (4.7 kBtu/sf/yr)
  - 3000 kWh/yr (10 MMBtu) for 2200 sf house
- Total primary (i.e., source) energy
  - <120 kWh/m^2/yr (38 kBtu/sf/yr)
  - 24 500 kWh/yr (84 MMBtu) for 2200 sf house
- Airtightness
  - <0.6 ACH@50 Pa

Building Energy Determinants

Requirements	**Client**	Restrictions about min size, must use technology, etc
Loads	**Architecture**	Massing, window area, enclosure details, selection of HVAC,
Systems/Equipment	**Mech Eng**	System design, controls, equipment selection
Demand	**Occupant**	Temperature, humidity ranges, operation of appliances, turning off lights, etc
Energy Source	**Utility?**	Generation technology, pricing structure, efficiency of operations

PV versus demand reduction

- Recall total site energy for normal 3 BDR 2200 sf house
  - 20-35 000 kWh/yr
- Requires 15-30 kWp of PV
  - $120,000 to 240,000 capital cost
  - Sloped south area of 1600 to 3500 sq ft
- Reducing energy is much cheaper!

Energy Savings

- Drop Space Heating/cooling to very low values, because it is cheap to do so
  - Typically 50% reduction over “normal”
- Use CFL (future LED) lights everywhere
  - Typically 70% reduction
- Use efficient appliances (Energy Star+)
  - Induction ranges (400 kWh/yr)
  - Front load washer (200 kWh/yr)
  - Dishwasher (200 kWh/yr)
  - Condensing dryer (600 kWh/yr)

Use Efficient Equipment

- Condensing natural gas
  - Furnace 95%, two-stage, ECM motor (<$2000)
  - Tankless condensing DHW with small tank (Navien or Vitodens $2000)
- Air source heat pump where superior
  - HSPF>9, COP >3 for most of the time
- Air Conditioning
  - ECM fan motor, SEER15+

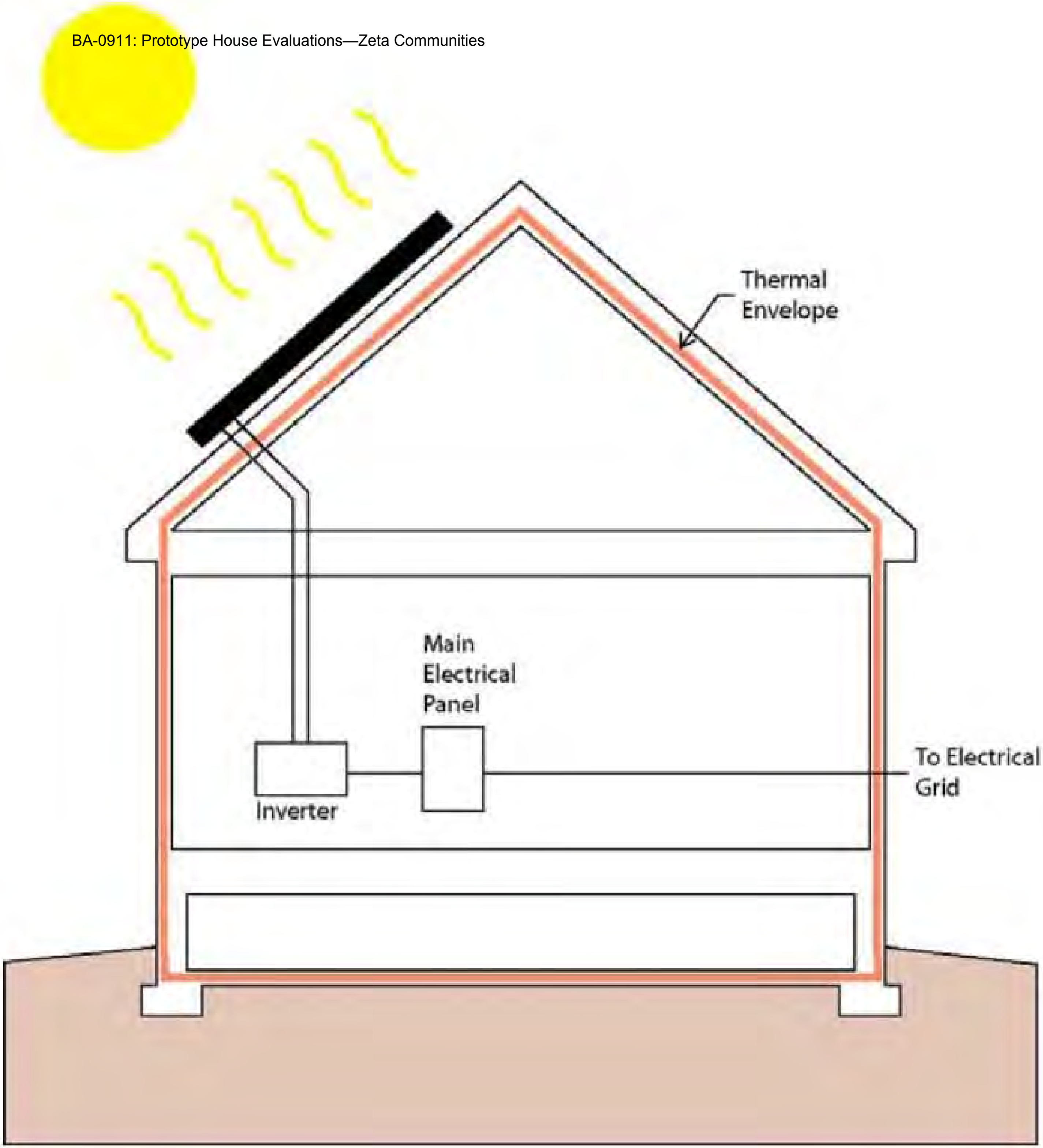
Efficient Equipment

- HRV/ERV always
  - choose less than 1 Watt/ cfm
  - Choose > 60% efficient
  - Right size ventilation!
- Controls
  - Motion sensors, daylight sensors
    - Garage, basement, outdoors, even kitchen

Energy Supply

- Renewable energy (RE) or cleaner energy (CE)
- Net Zero currently demands *site production*
  - This eliminates some good economical RE
- Common choices
  - Solar thermal Warm / Hotwater
  - Photovoltaic: Electricity
  - Wind electricity
  - Combined heat and power

- PV photovoltaic

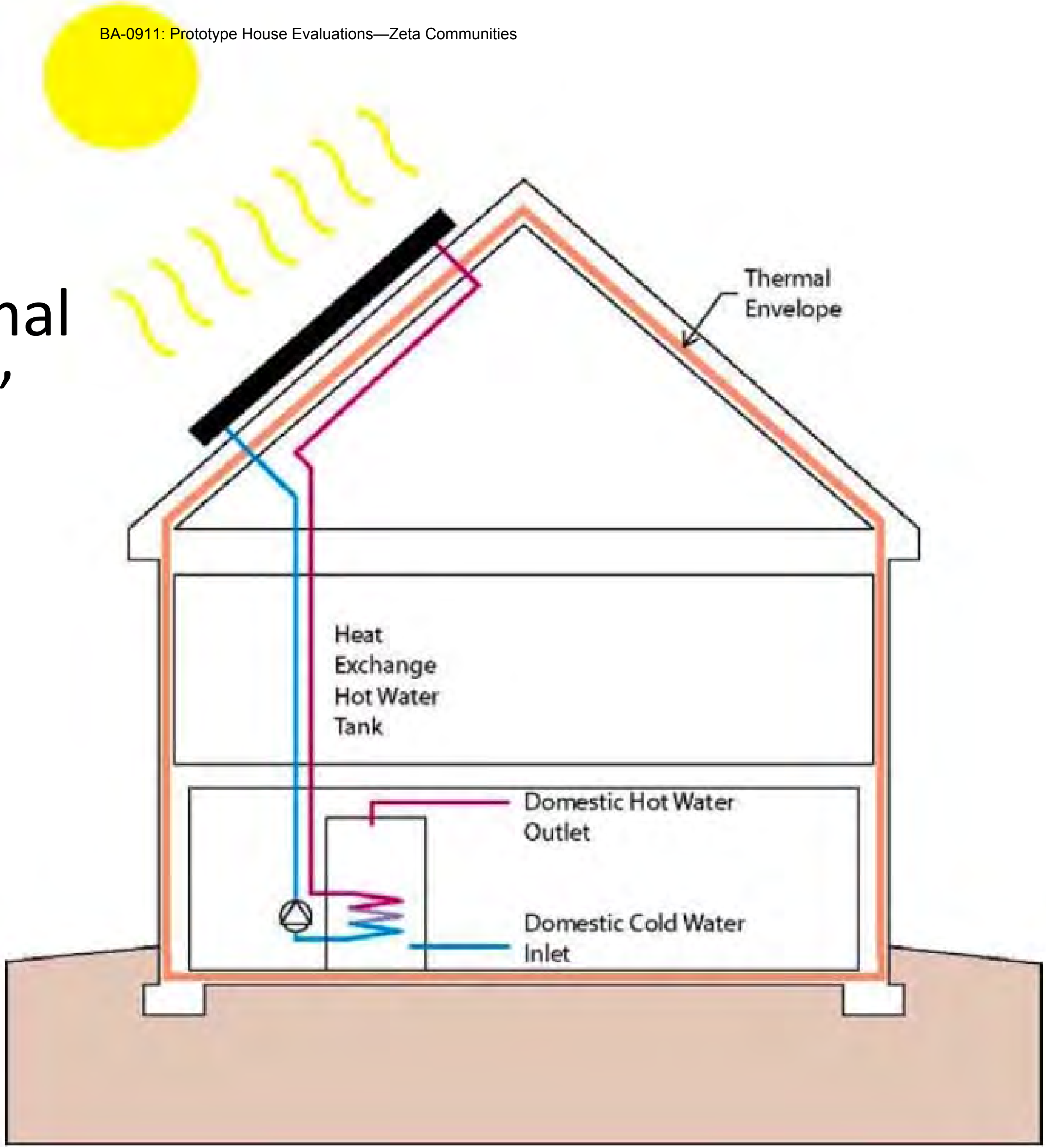


BA-0911: Prototype House Evaluations—Zeta Communities

Energy Supply (RE)

- PV
  - Straightforward installation, easy to predict output
  - Expensive but electricity is very useful and excess can easily be sent to the grid (grid=battery)
  - Rated by peak output under standard solar conditions (peak Watt or W_p)
  - Costs now \$8/W_p (before subsidy) installed
  - In California 1 W_p produces 1.2 to 1.4 kWh/yr if perfectly oriented

- Solar Thermal "hot water"



Solar thermal – flat plate

- Intermittent source of hot water
- Well developed
- Production cost (heat)
  - $0.07 to 0.25 /kWh cool climate average
  - $0.02 to 0.05/kWh summer/pool heating
- Requires big storage tanks in most application
- Freezing, over heating, glycol thickening failures, and low temperature efficiency are issues


Delta-T
WARNING
WARNING


EnerWorks
Solar Hot Water Appliances
How it Works
Self-Limiting Solar Collectors
Cold water in
Heat transfer loop, supply & return
Solar Storage Tank
Heat Exchange Module
Passive Anti-Fouling Protection
www.enerworks.com
Delta-T

Solar thermal- evacuated tubes

- More expensive
- Higher temperature water
- Collects in low sun, low temperature
- Consider for cold & cloudy climes

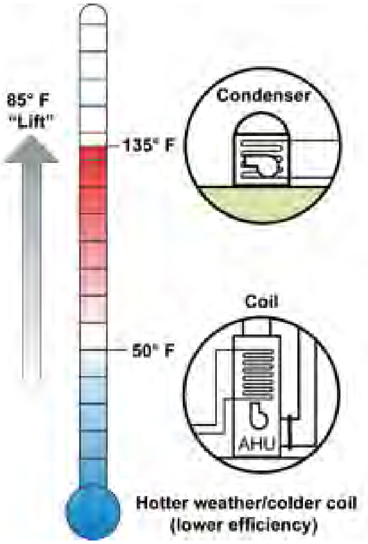
Air Source Heat Pumps

- Aka air conditioning running backwards

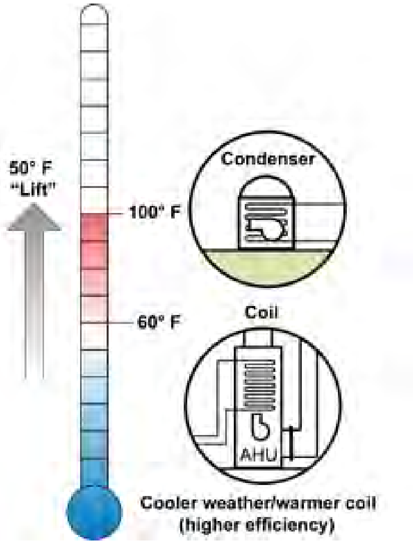
EER = COP * 3.4

COP = 3

SEER? HSPF?



Hotter weather/colder coil
(lower efficiency)

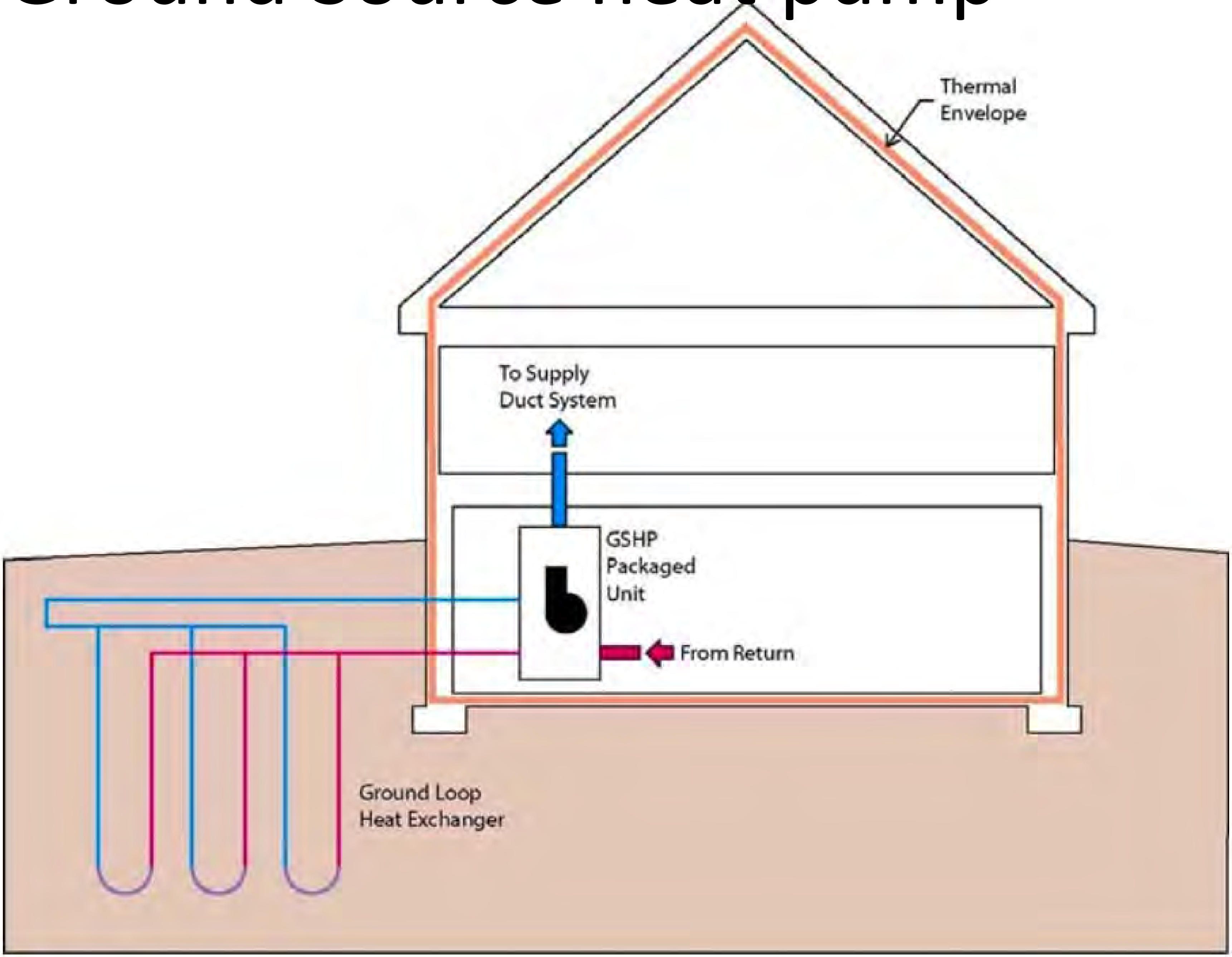


Cooler weather/warmer coil
(higher efficiency)

Ground Source Heat Pumps

- Not renewable energy
- Efficient use of electricity to heat and cool
  - Coefficient of performance COP= 2.5 to 4.0
- Produce mid temp water (35C+/- 95 F for moderate efficiency)
- Capital cost (for 1.5 to 5 ton)
  - $12.5K first ton, 5-7.5K/ton declining
  - $3500/kW + $2000/kW
- Operating cost (heat)
  - $0.02 to 0.06 / kWh with 0.08 – 0.15/kWh electricity

Ground Source heat pump

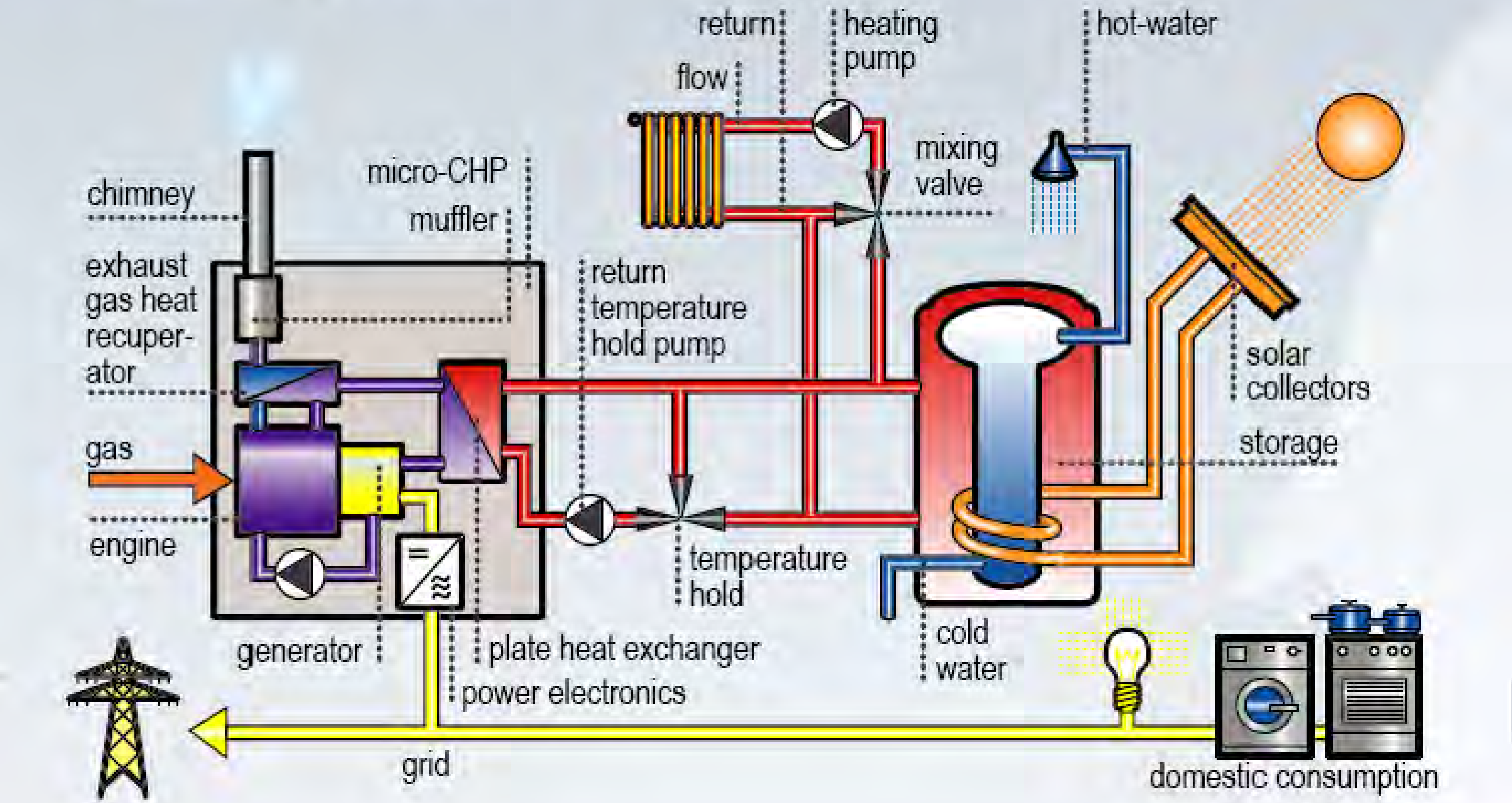


Energy Supply (CE)

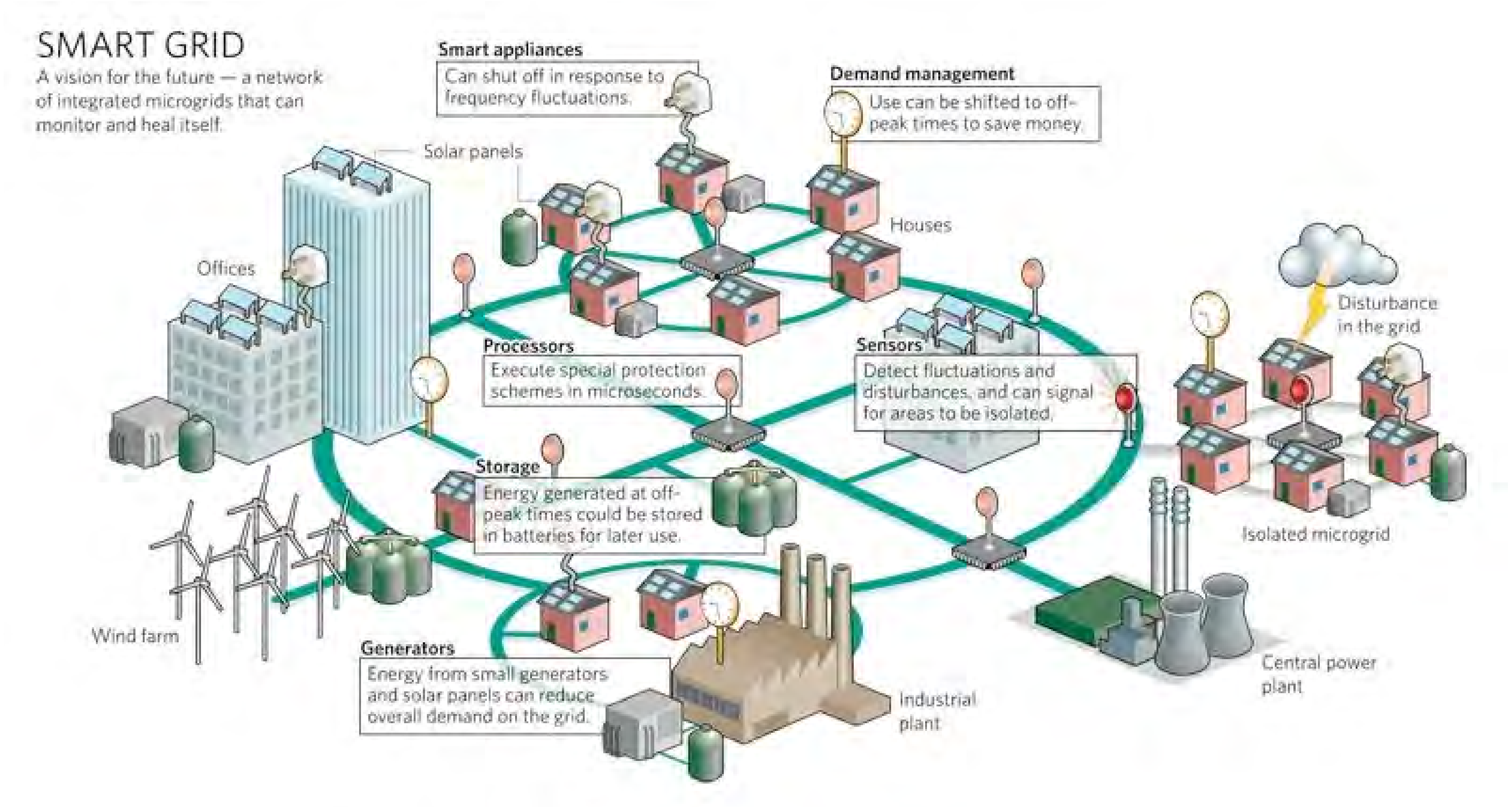
- Ground source heat pump (GSHP) are not renewable energy, they are efficient
- Combined heat and power (CHP)
  - Efficient use of fuel to produce heat & electricity
  - Much lower GHG emissions
  - Supplies on demand
  - Ratio of electricity to heat is fixed

Marathon EcoPower

Typical application



Smart Grid



SMART GRID

A vision for the future — a network of integrated microgrids that can monitor and heal itself.

Smart appliances

Can shut off in response to frequency fluctuations.

Demand management

Use can be shifted to off-peak times to save money.

Processors

Execute special protection schemes in microseconds.

Sensors

Detect fluctuations and disturbances, and can signal for areas to be isolated.

Storage

Energy generated at off-peak times could be stored in batteries for later use.

Generators

Energy from small generators and solar panels can reduce overall demand on the grid.

Long term Grid

- Currently transmission and distribution is about 10% of cost
- If many homes use less and produce more, still need a grid and hence T&D costs rise
- Generator still needs to provide peaking power plants (eg expensive)
- Hence simple reverse metering cant go on for long, or purchased kWh needs to be very expensive

Indoor Air Quality

- Pollutant production
- Pollutant removal
- Dynamic Balance= pollutant level
  - Not a IAQ problem if it is not in the air
- Solutions
  - Reduce pollutant production
  - Increase pollutant removal

IAQ Solutions

- Reduce pollutant production
  - Filter outdoor ventilation air, beware entry point
  - Reduce material off-gassing
  - Cleaning chemicals
  - Occupant activities, hobbies, etc.
- Increase pollutant removal
  - Filter indoor air
    - charcoal filters can remove VOC's at great $
  - Flush/dilute indoor with clean air

IAQ Solutions

- Rate of emissions from most materials, especially behind finishes, is very small
- Rate of emissions declines exponentially over time
- Occupants generate major emissions via cooking, cleaning, painting, purchases, etc
- Dilution ventilation works if outdoor air is filtered, unpolluted, and dry

Ventilation

- Given sensible source control, constant ventilation can dilute pollutants to a low level
  - Ventilation rates are mostly about odour and humidity, not oxygen
  - 7.5 cfm/person + 0.01 cfm / sq ft
  - Commercial and highrise 15 cfm/person (!)
- Mixing is necessary or separate supply to each room to achieve best IAQ

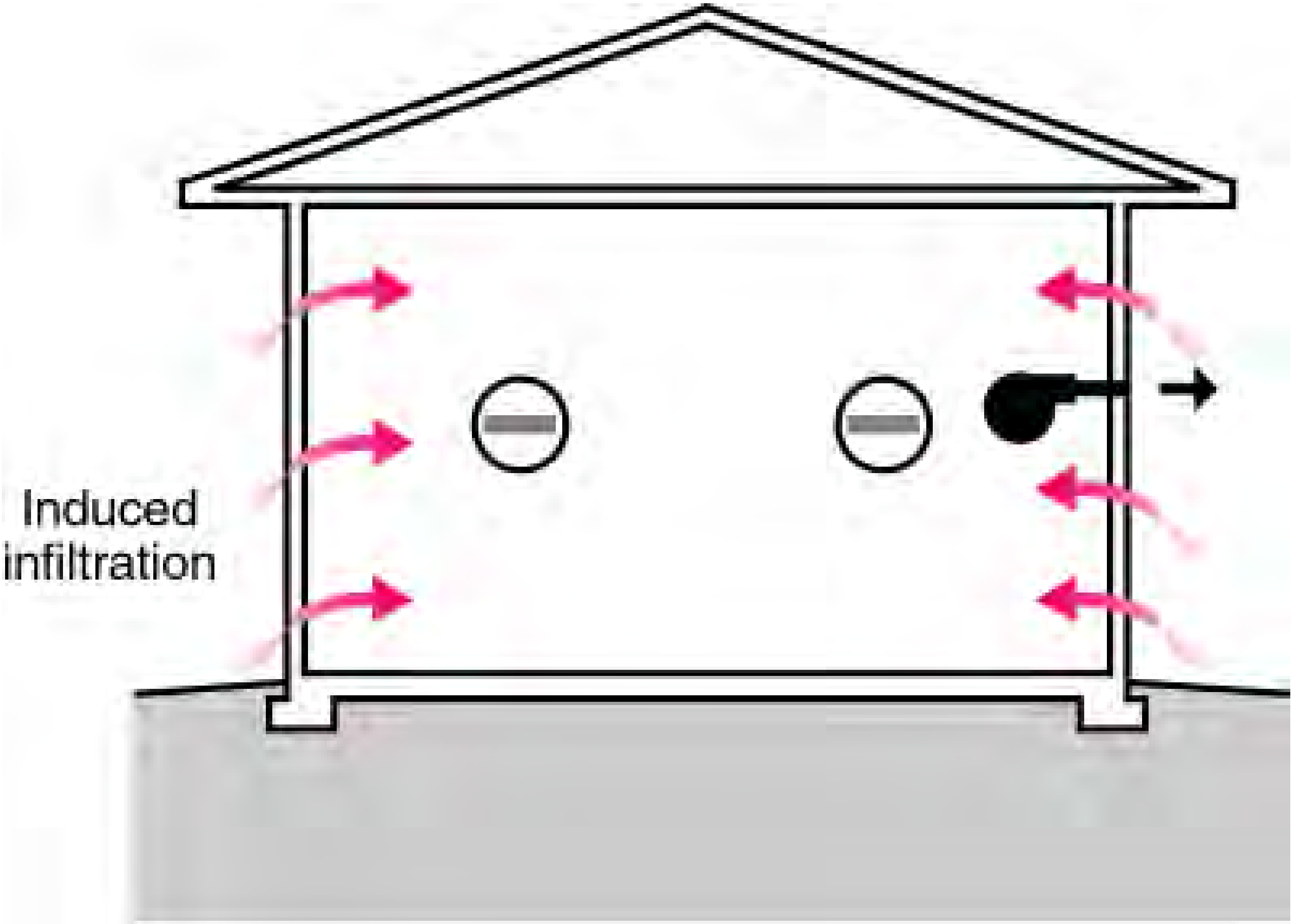
Types of Controlled Ventilation Systems

Exhaust Ventilation

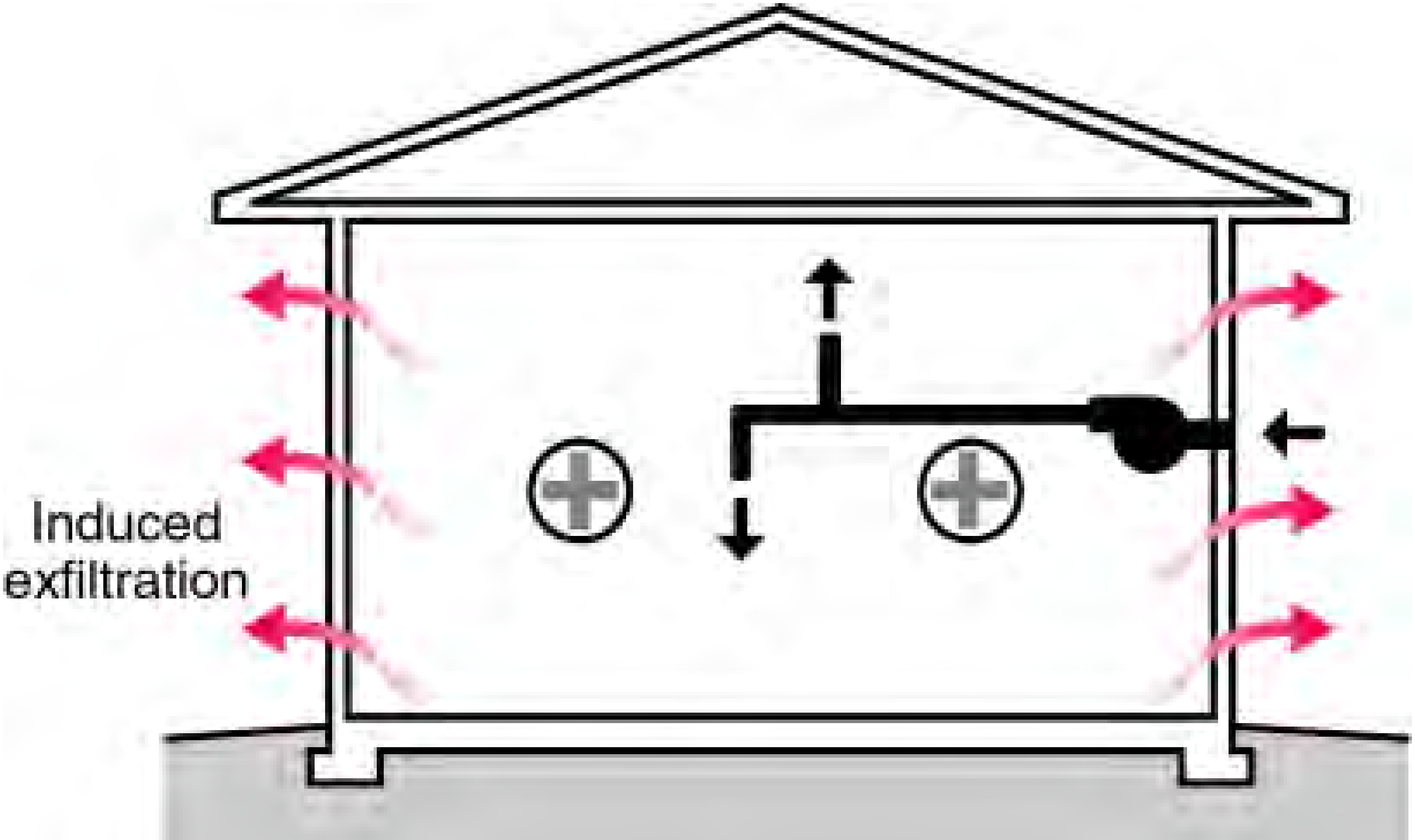
Supply Ventilation

Balanced Ventilation

Exhaust Only: Depressurize

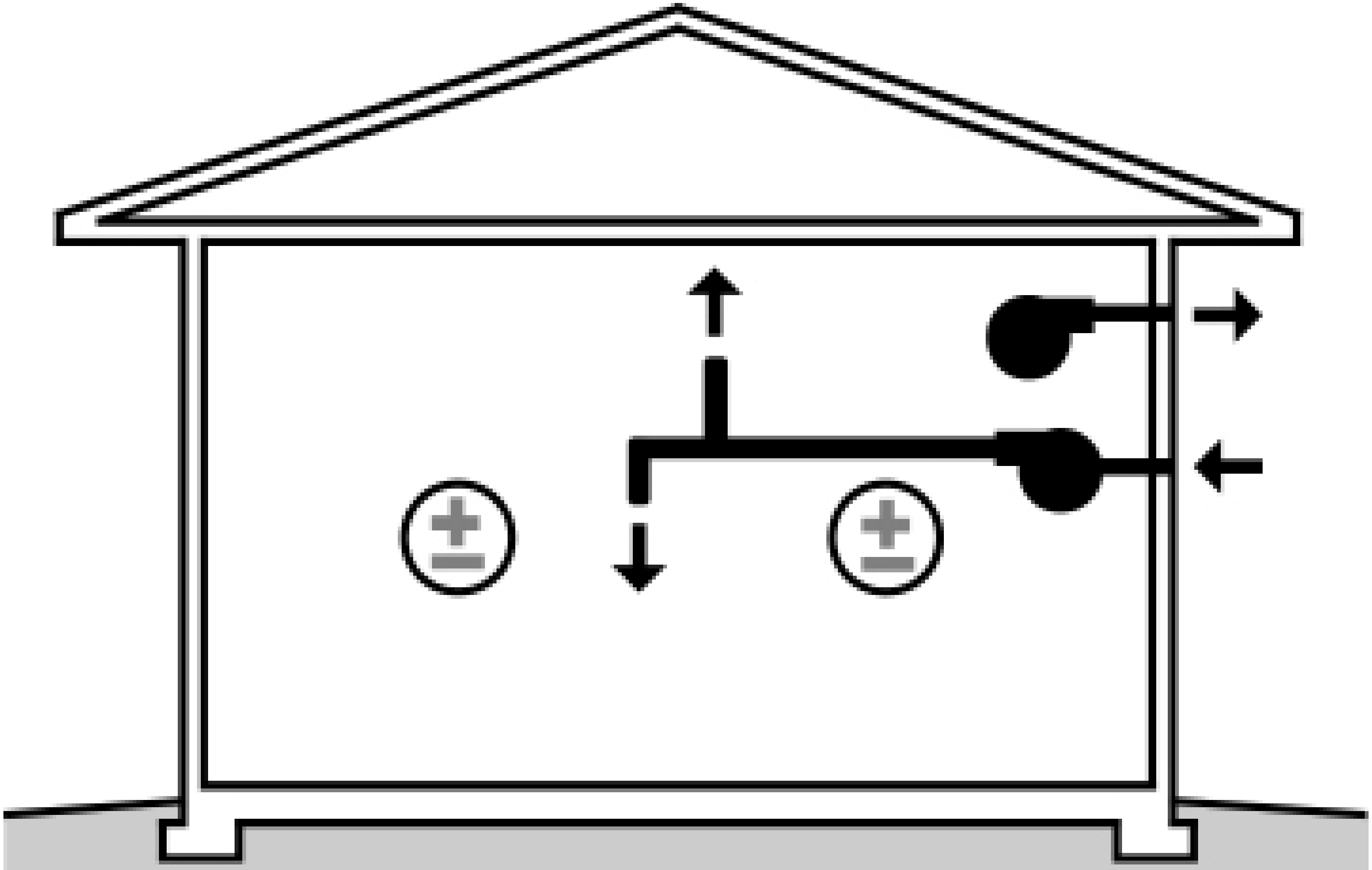


Supply Only: Pressurized



Not common, although most commercial buildings have more supply than exhaust

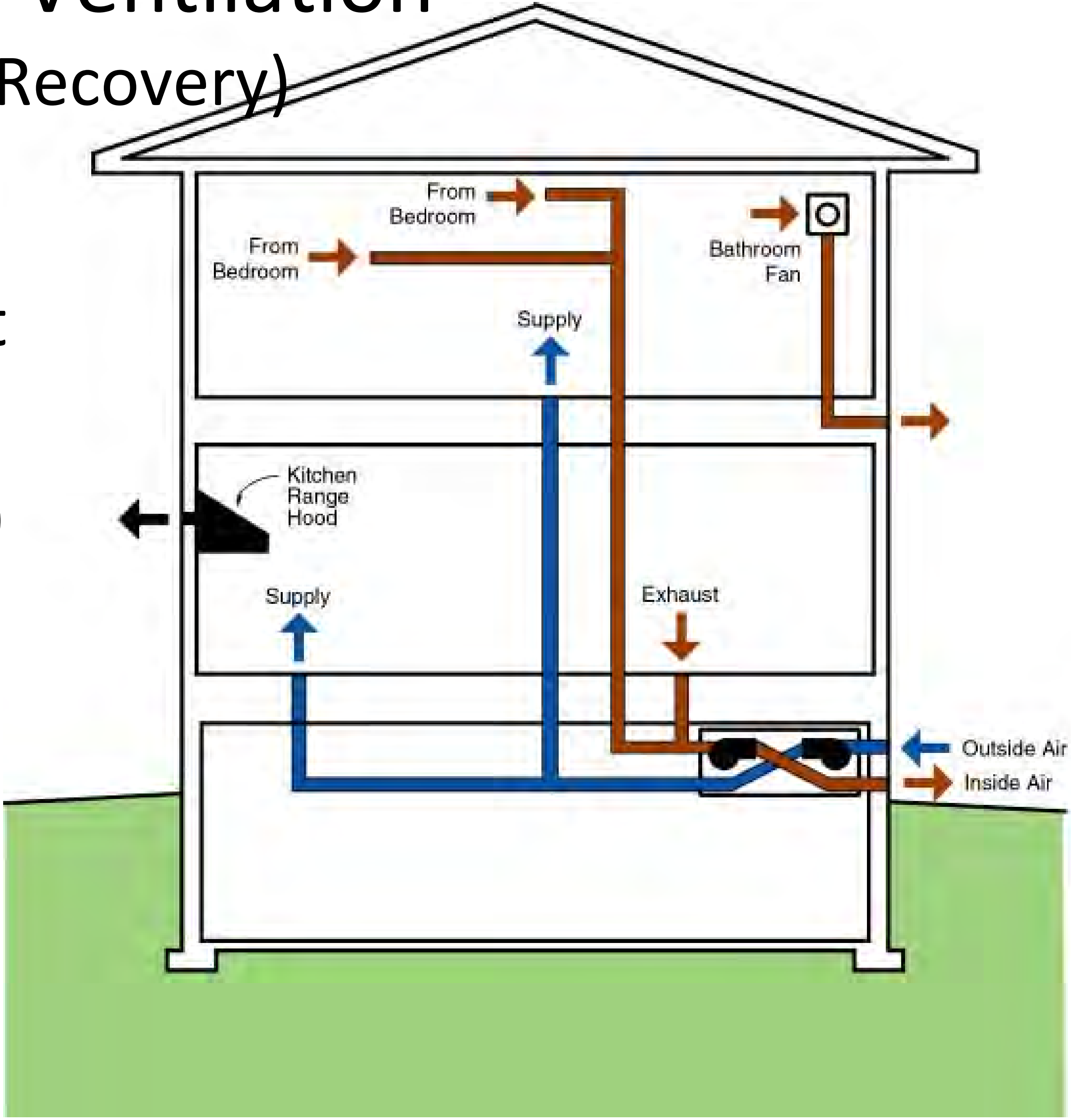
Balanced Supply and Exhaust



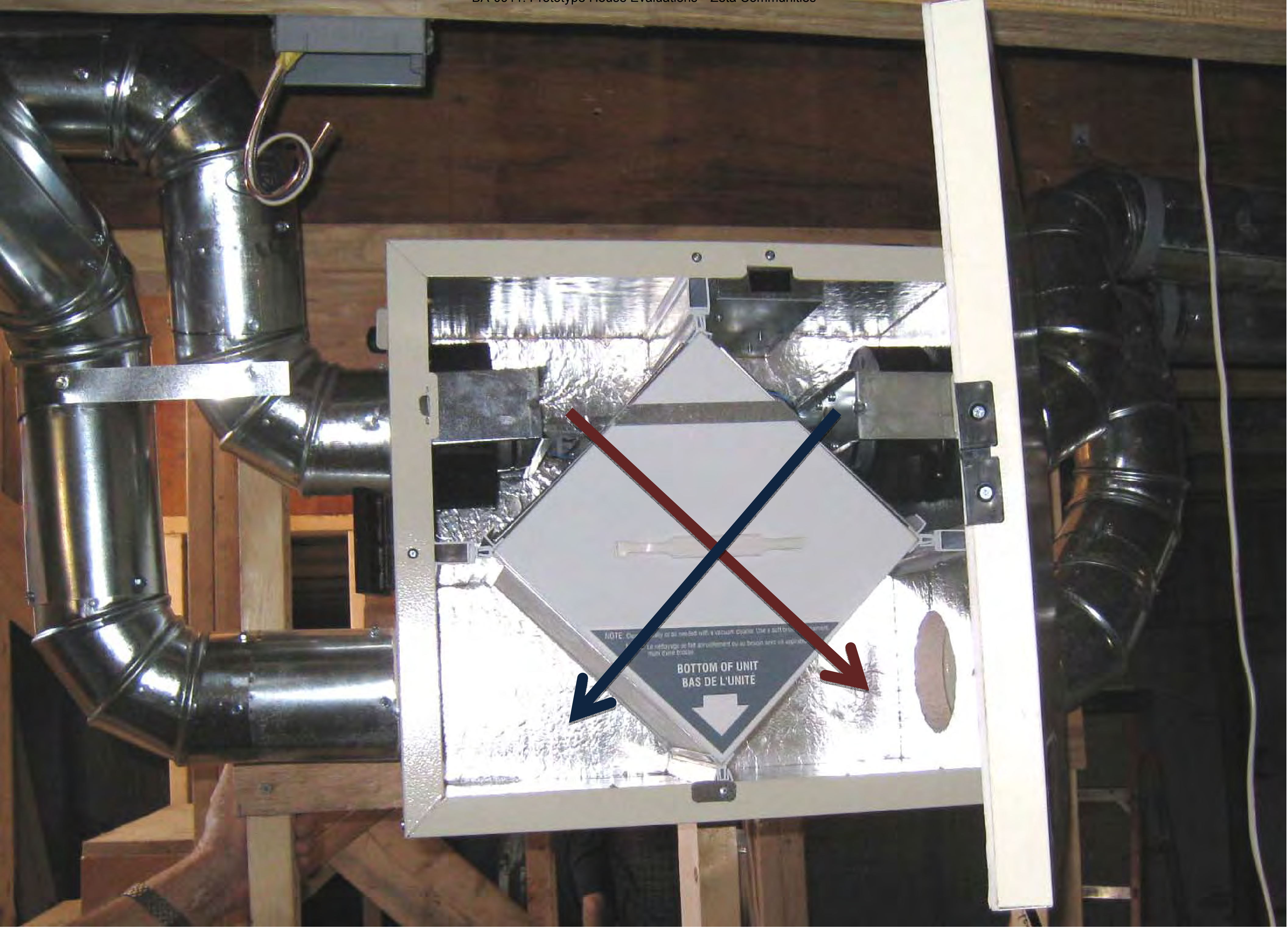
Common Commercial solutions
Residential often combine with HRV/ERV

Balanced Ventilation
(with Heat Recovery)

- HRV/ERV
- Point exhaust
- Fully ducted (need not be)




FRESH
STALE
STALE
FRESH
Fantech


BOTTOM OF UNIT
BAS DE L'UNITÉ

Mechanical Systems

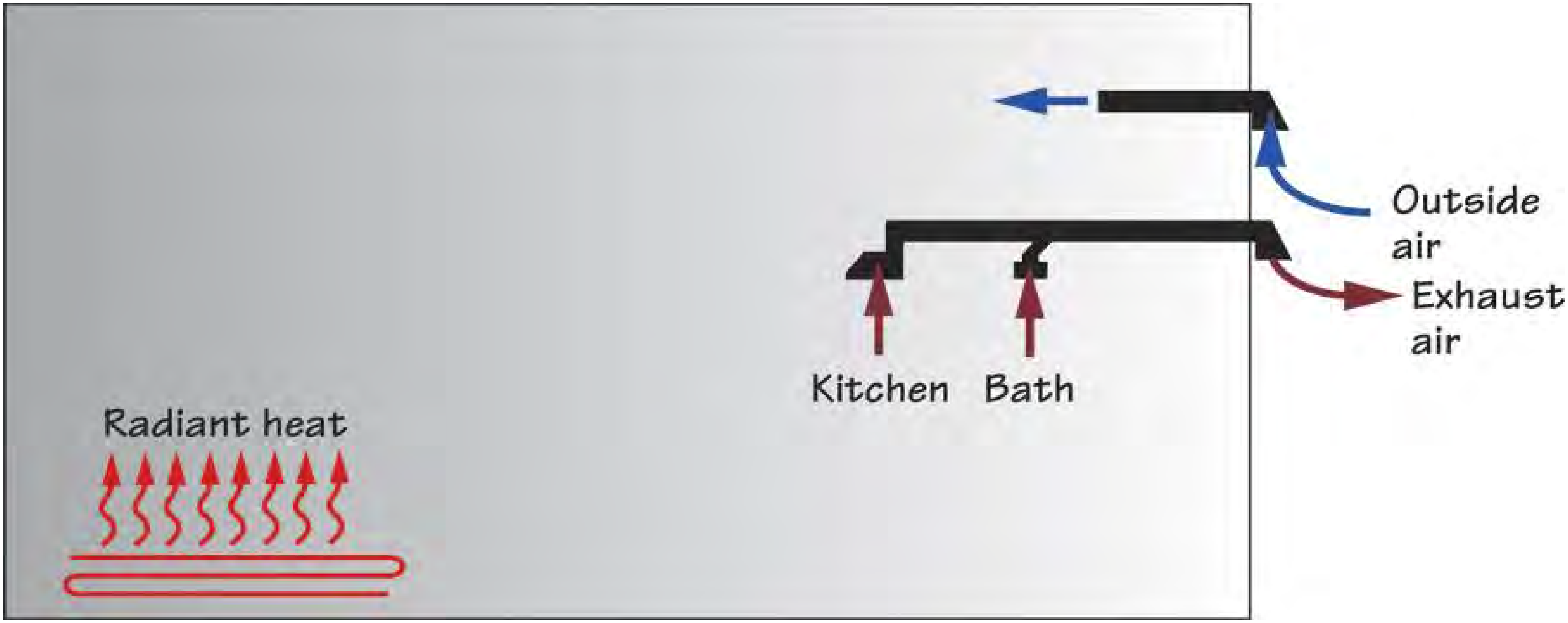
Energy consuming functions

- Ventilation & Filtration
- Heating
- Cooling
- Domestic Hot Water

- Point Exhaust, intermittently operated
- Supply via air handler heating/cooling, intermittently operated

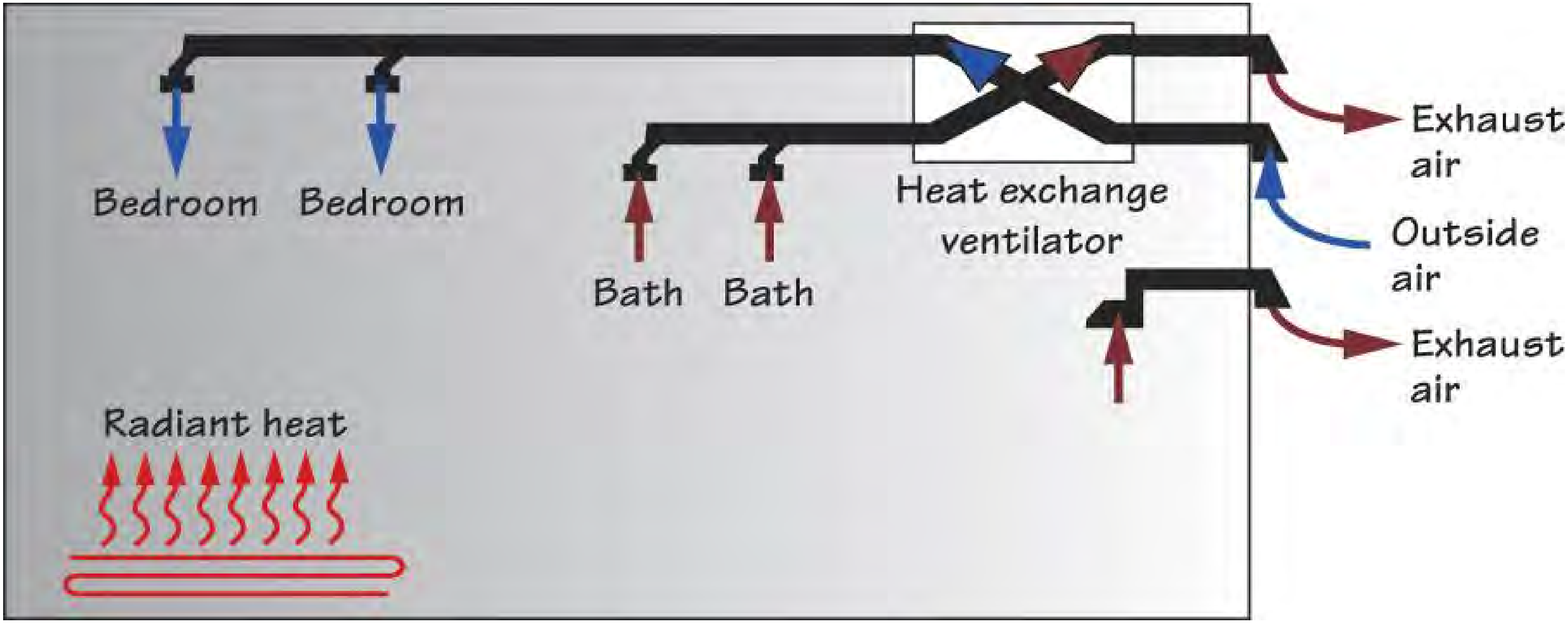
Heating & Cooling can use many sources (hydronic, furnace, split AC or HP)

- Point supply, often continuously operated, may be passive opening
- Point exhaust, intermittently operated



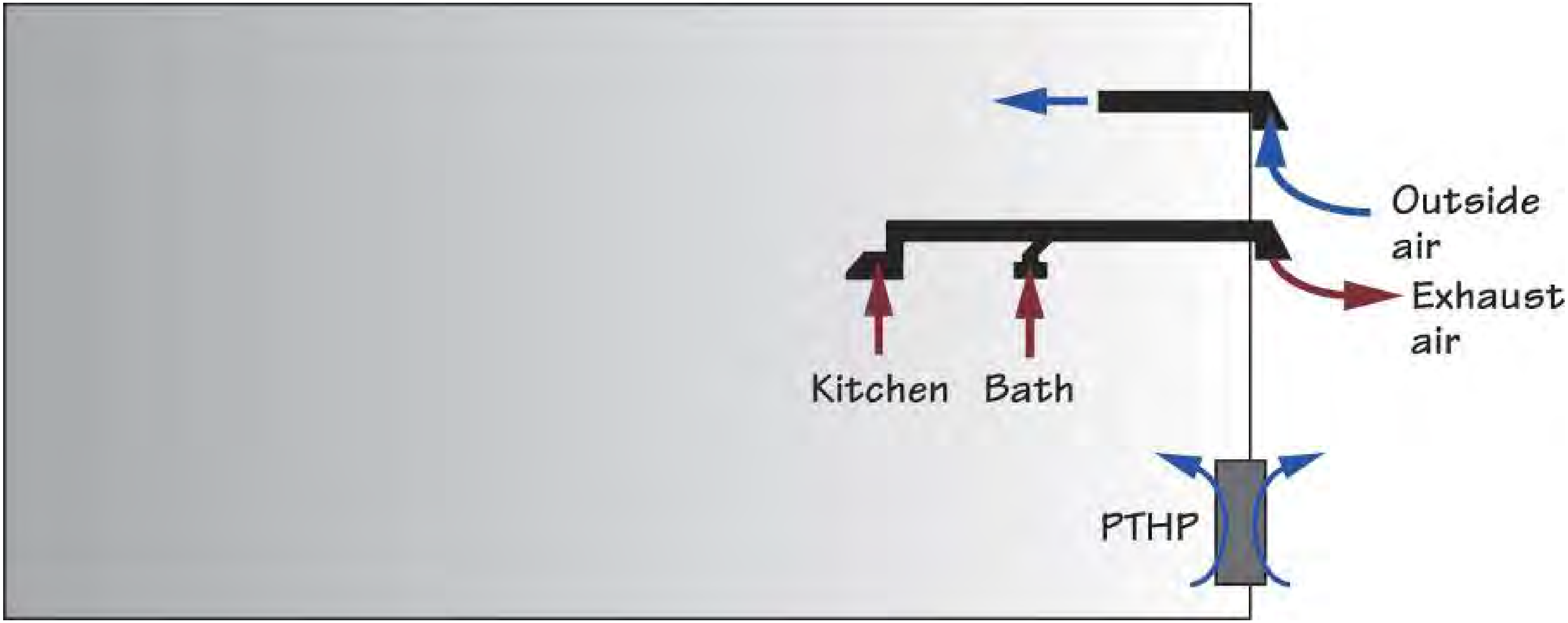
No Cooling. Radiant heat usually from a source of hotwater

- Multi-point supply, often continuously operated
- Multi-Point exhaust, often continuously operated
- Heat recovery of moisture and heat in air add on



No Cooling. Radiant heat usually from a source of hotwater

- Point supply, often continuously operated, may be passive opening
- Point exhaust, intermittently operated



Primary Terminal Heat Pump could be Ductless Mini-split


SUPPLY AIR

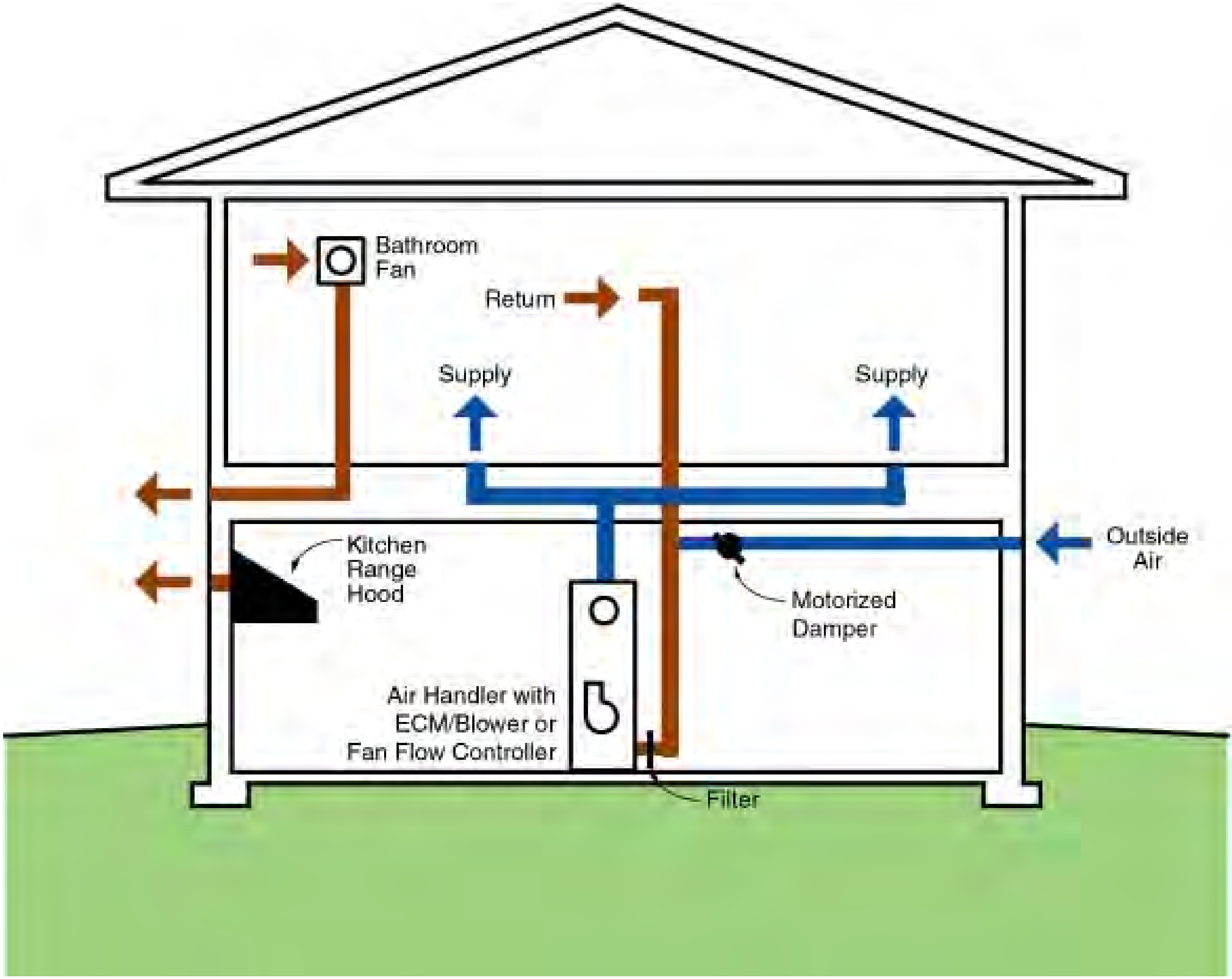
Ductless Mini-split

Ductless Mini-split

- Many systems now variable speed to match load, increase dehumidification, and reduce energy use

Systems with SEER26 and HSPF=11 available

Heating Cooling + Ventilation



Boilers: make hot water

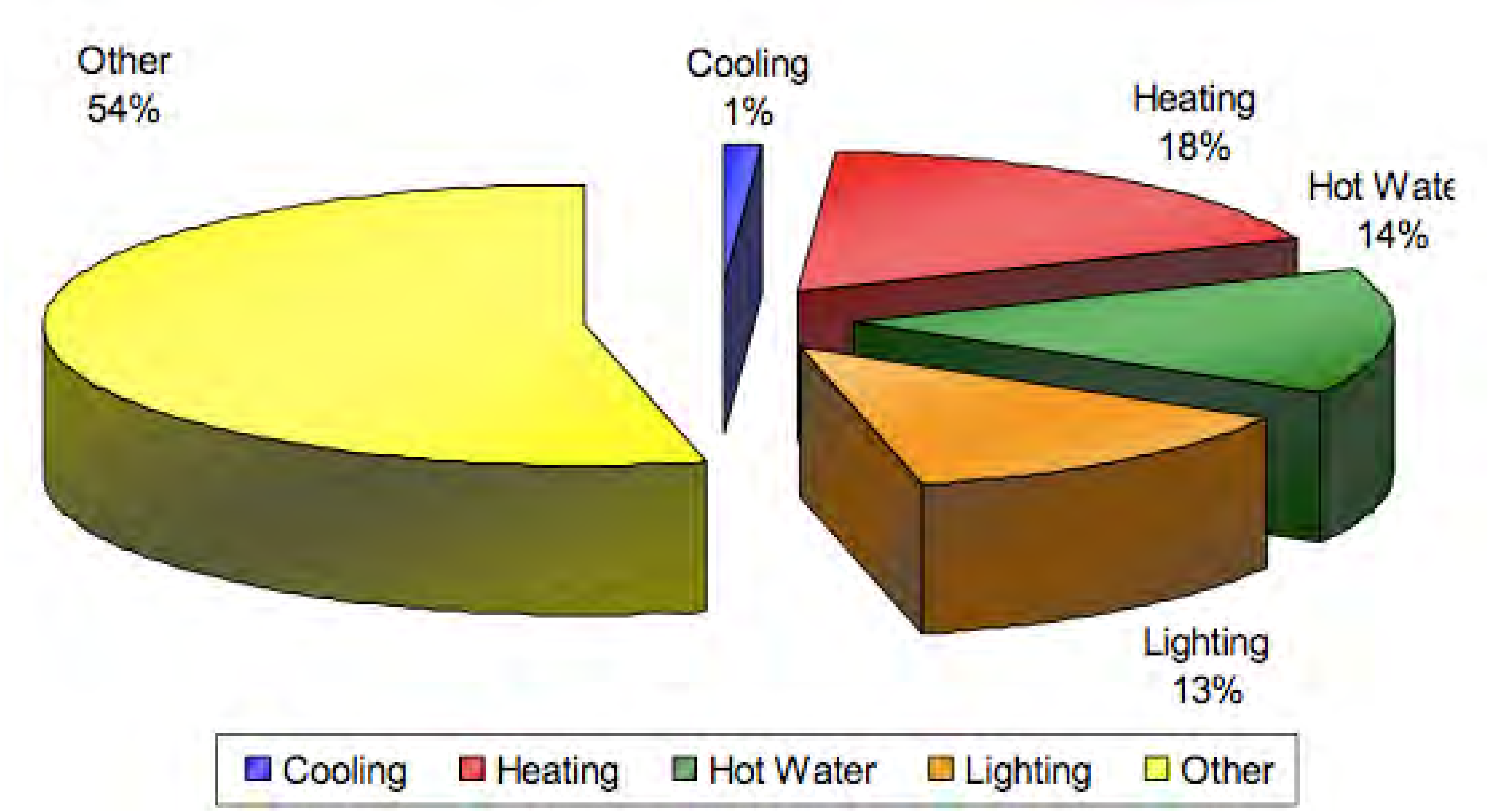
Commercial Multi-unit AC

Lancaster V1

- Net Zero Energy Prototype
- Bay Area is very different climate: Goldilocks
  - Not too hot
  - Not too cold
- Solar is a good resource here
  - Subsidies are great

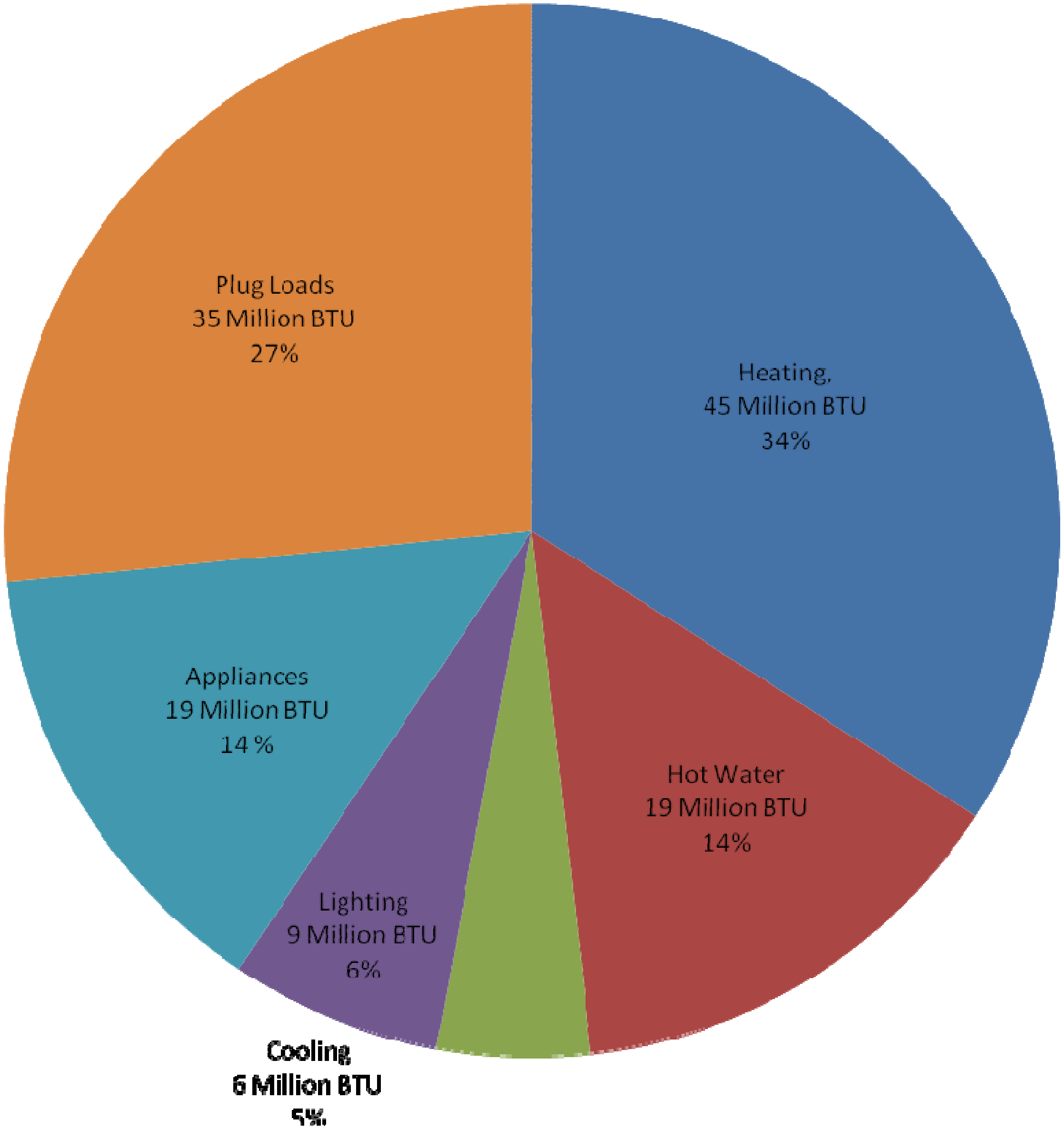
Lancaster

- Energy Use Distribution

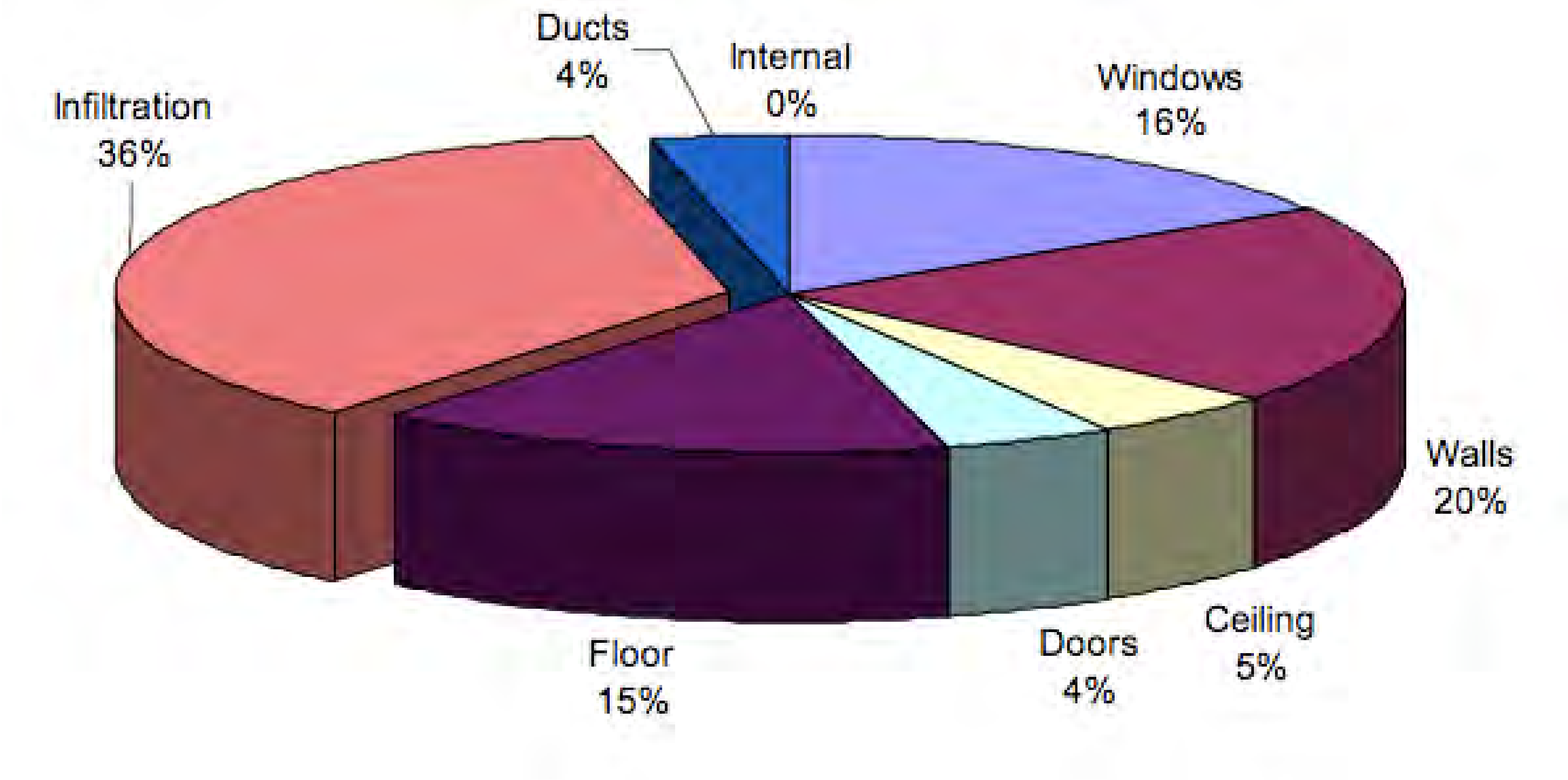


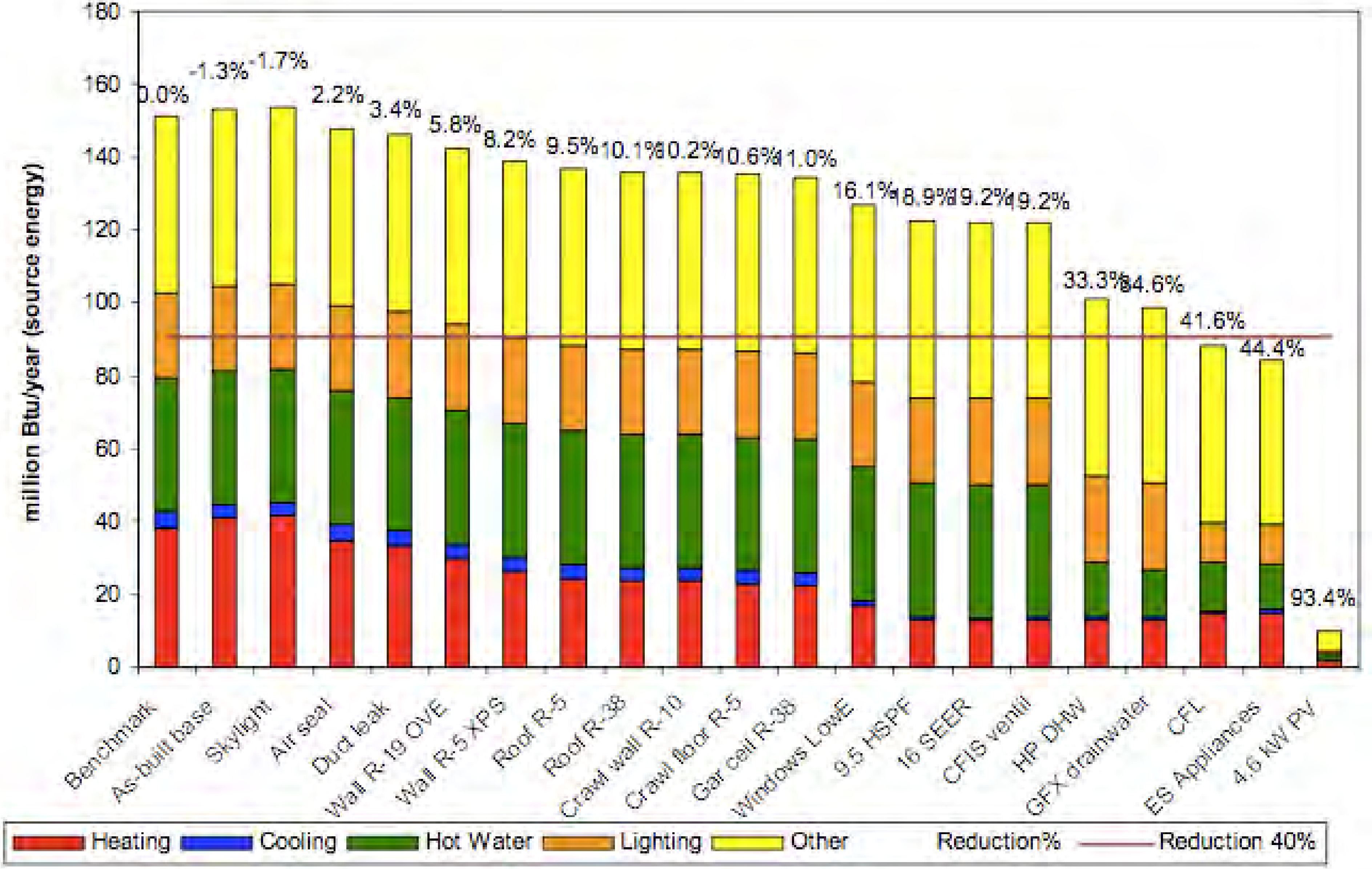
New England Example

5414 kWh and 19000 kWh heating DHW Predicted

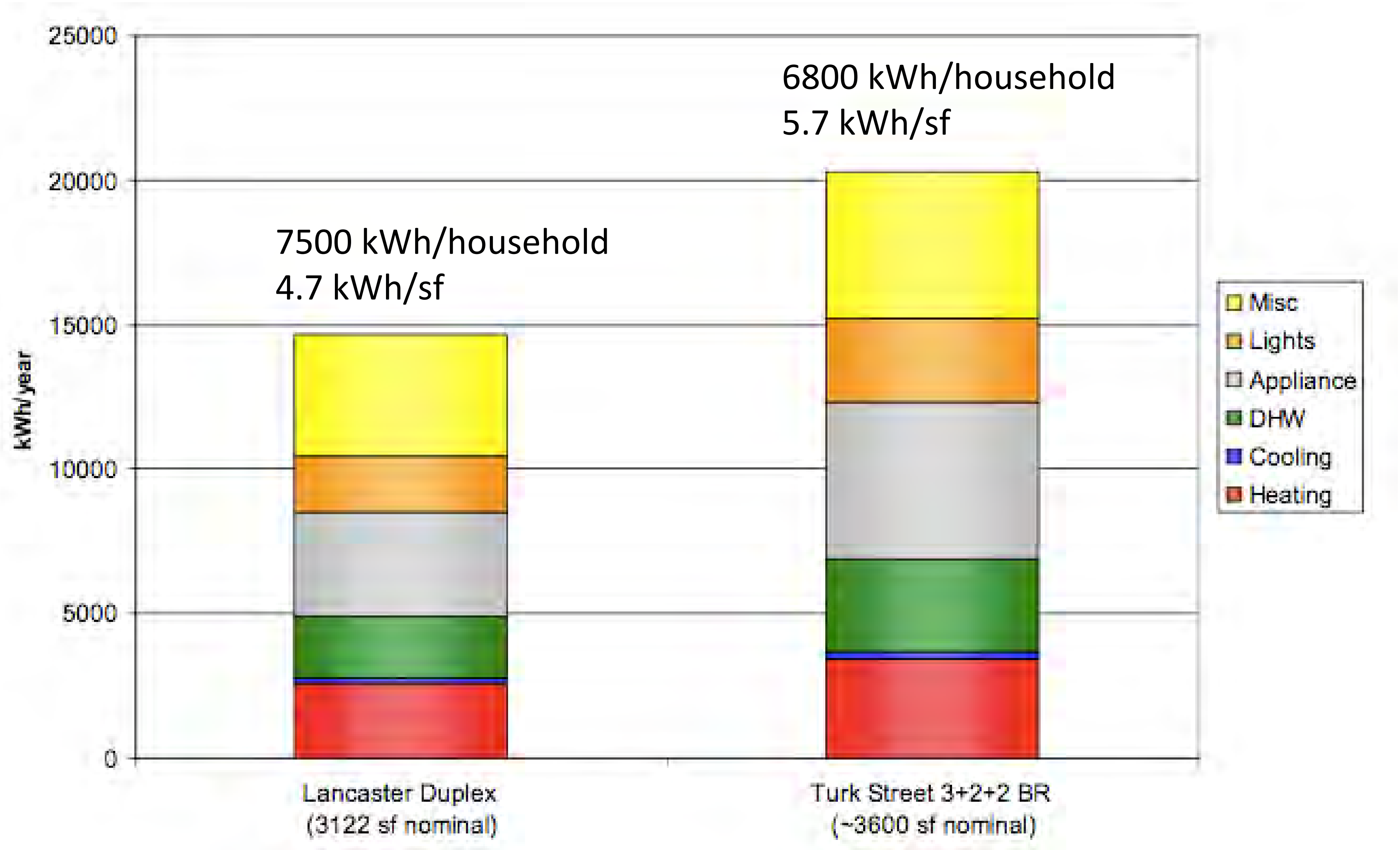


Heating Load Breakdown




million Btu/year (source energy)
180
160
140
120
100
80
60
40
20
0
0.0%
-1.3%
-1.7%
2.2%
3.4%
5.8%
8.2%
9.5%
10.1%
10.2%
10.6%
11.0%
16.1%
18.9%
19.2%
19.2%
33.3%
34.6%
41.6%
44.4%
93.4%
Benchmark
As-built base
Skylight
Air seal
Duct leak
Wall R-19 OVE
Wall R-5 XPS
Roof R-5
Roof R-38
Crawl wall R-10
Crawl floor R-5
Gar ceil R-38
Windows LowE
9.5 HSPF
16 SEER
CFIS ventil
HP DHW
GFX drainwater
CFL
ES Appliances
4.6 kW PV
Heating
Cooling
Hot Water
Lighting
Other
Reduction%
Reduction 40%

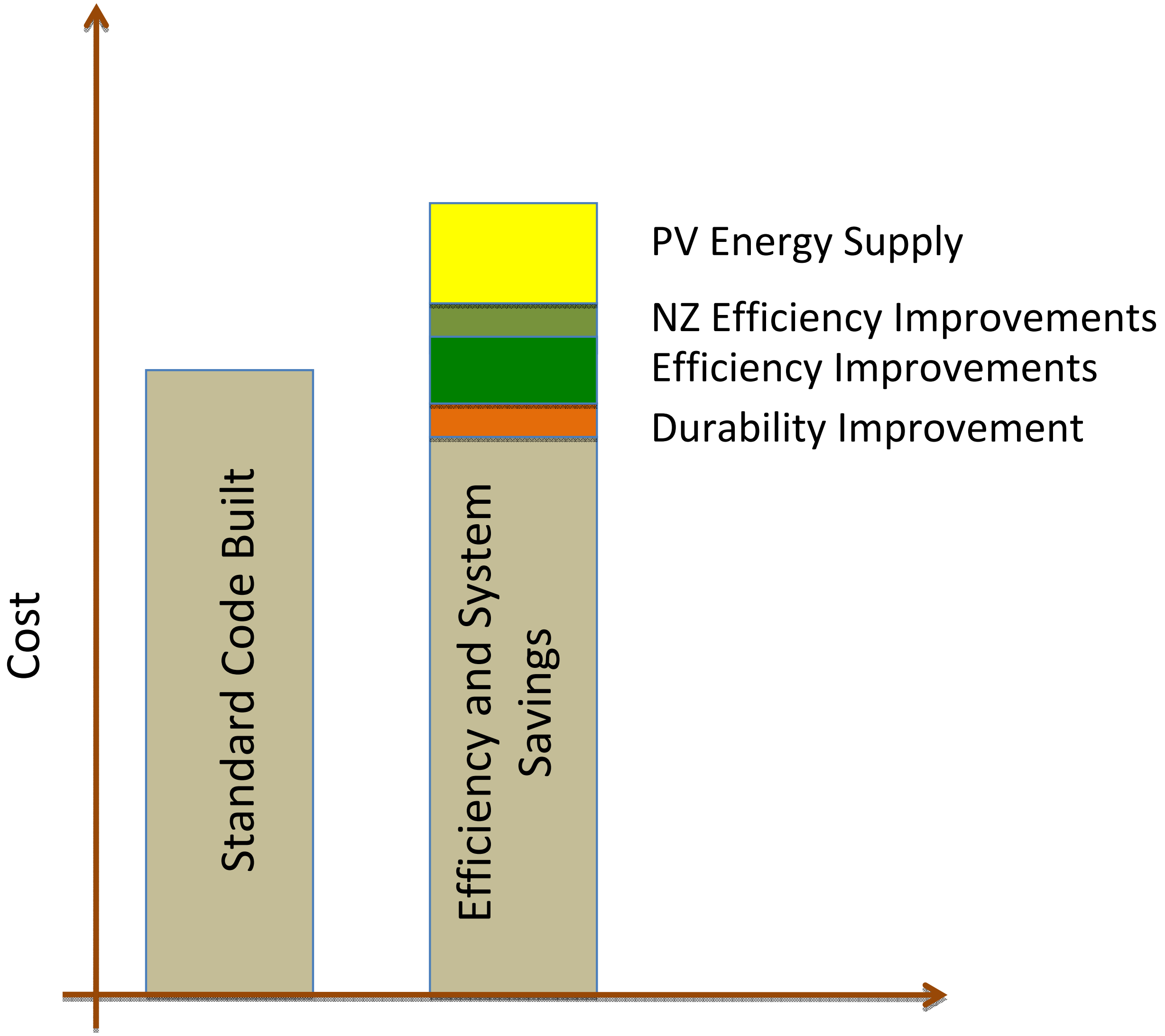
Duplex vs Stacked Apartments



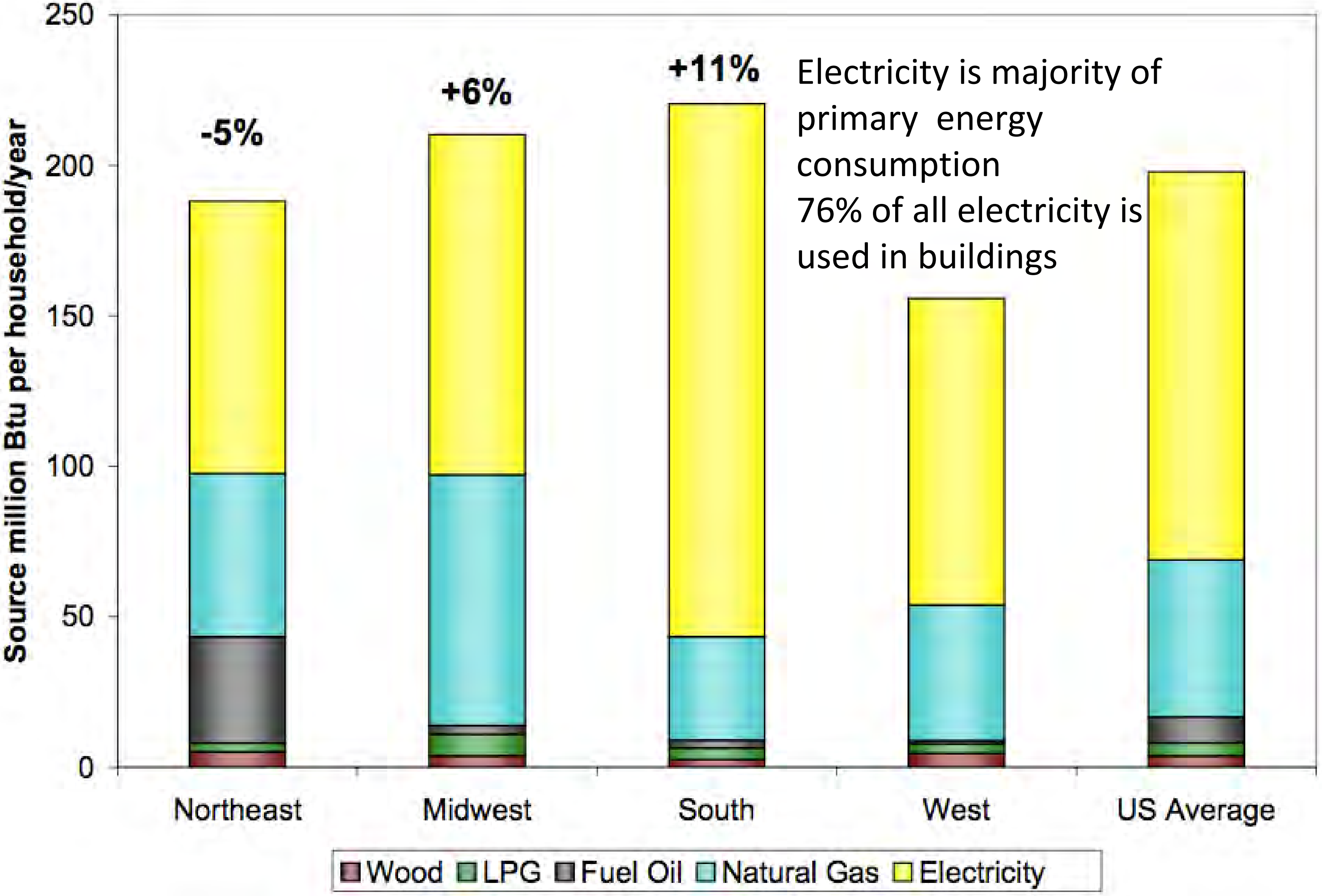
7500 kWh/household
4.7 kWh/sf

6800 kWh/household
5.7 kWh/sf

Costs


Cost
Standard Code Built
Efficiency and System Savings
PV Energy Supply
NZ Efficiency Improvements
Efficiency Improvements
Durability Improvement

Source Energy Use



Electricity is majority of primary energy consumption

76% of all electricity is used in buildings

October 9, 2009

ZETA Communities
848 Folsom Street, Ste. 201
San Francisco, CA 94107
T 415.946.4084 x407
F 415.651.9481
ATTN: Shilpa Sankaran
ssankaran@zetacommunities.com

Re: LEED-H ID (Innovation & Design Process) Request for ZETA Lancaster Lofts Plan

Dear Ms. Sankaran:

The following letter report covers analysis supporting the LEED-H ID (Innovation & Design Process) Request for ZETA Lancaster Lofts Plan—specifically, how the poor overall performance indicated in the California Title 24 Compliance Reports (CF-1R) does not accurately reflect the overall energy performance. It is our understanding that this report will be forwarded, with the ZETA Communities LEED application, to USGBC's Energy & Atmosphere technical advisory sub-committee for homes (EA-TASC).

I am including Ann Edminster and Dan Smith on this correspondence, as I am sure that both of them would have valuable input on whether or not the information stated here will answer the sub-committee's questions adequately.

If you have any questions or comments about this report, please contact Kohta Ueno of Building Science Consulting (kohta@buildingscience.com), or as per contact information shown.

Sincerely,

Kohta Ueno

Cc: Naomi Porat (ZETA Communities)
John Straube, Ph.D., P.Eng., Aaron Grin (Building Science Corporation)
Ann V. Edminster, M.Arch. (Design AVEnues LLC)
Daniel Smith (Daniel Smith & Associates, Architects)

Background: Innovation & Design Process Credit Requirements

ZETA Communities has expressed an interest in pursuing an ID (Innovation & Design Process) request in LEED for Homes for their Lancaster Lofts "V1" Prototype, as a net-zero energy home. The LEED rater (Design AVEnues LLC) has explained that achieving net-zero energy would normally be rewarded in one or both of the following ways (in the California version of the rating system):

1. *Exemplary performance w/r/t EA1 (Energy Star home/equivalent).* ***A project that beats Title 24 by 60% earns all of the 19 points available in EA1****; if you beat T24 by more than 60%, you can earn points for exemplary performance, at the rate of 1 point per additional 5% improvement w/r/t T24, up to a total of 4 ID points (80% better than T24).*
2. *Exemplary performance w/r/t EA10 (Renewable Energy). A project that produces 30% of its annual reference electrical load earns all of the 10 points available (1 point per 3% of load); if you produce more than 30%, you can earn points for exemplary performance, at the rate of 1/2 point per additional 3% of load met by the system, up to a maximum of 4 points (54% of load met by renewable system).* ***However, a project is only eligible for these exemplary performance points if it has first exceeded Title 24 by at least 35%.***

However, the California Title 24 Compliance Reports (CF-1R) only shows performance at 27% better than Title 24, which fails the requirements for either of these criteria.

This report is intended to explain some of the energy design choices made on the ZETA Lancaster Prototype, and to demonstrate that the calculation method used in Title 24 is unfavorable to an all-electric house—specifically, in regards to heat pump water heating.

Background

ZETA Goals

ZETA Communities has as one of its stated programmatic goals the construction of net-zero energy houses, as stated on their website:

> *ZETA produces net zero energy multifamily housing and mixed-use structures for sustainable communities, focusing on urban infill, transit-oriented development, public land development and educational campuses. ZETA's precision-built structures, produced in our clean-tech off-site production facility, exceed the performance of site built at no additional cost while minimizing resources, waste and CO2 emissions.*

Net Zero Performance

Given this goal, it is first useful to provide a definition of net-zero energy buildings; several options are provided in "Zero Energy Buildings: A Critical Look at the Definition" (Torcellini et al., 2006)

- net-zero site energy
- net-zero source energy
- net-zero energy costs
- net-zero energy emissions

The approach that BSC typically takes in its work is net-zero source energy:

> *Net Zero Source Energy: A source ZEB produces at least as much energy as it uses in a year, when accounted for at the source. Source energy refers to the primary energy used to generate and deliver the energy to the site. To calculate a building's total source energy, imported and exported energy is multiplied by the appropriate site-to-source conversion multipliers.*

Torcellini et al. point out that a grid connection is allowed (and is necessary) for energy balances of net zero energy buildings. Therefore, a very reasonable way to achieve net zero energy performance is to burn fossil fuels on site, when it provides the best solution (in terms of capital cost of equipment, operating cost, maintenance and complexity of equipment). The source energy of this site-burned fossil fuel is then counterbalanced by providing excess renewable energy generation (typically photovoltaics), thus netting out to zero source energy.

California Net Metering

The current California net metering laws are described on the DSIRE (Database of State Incentives for Renewables & Efficiency), under Net Metering (California - Net Metering):

http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA02R&re=1&ee=1

> *Net excess generation (NEG) is carried forward to a customer's next bill for up to 12 months. Any NEG remaining at the end of each 12-month period is granted to the customer's utility. Publicly owned utilities may elect to provide co-energy metering, which is the same as net-metering, but incorporates a time-of-use rate schedule.*

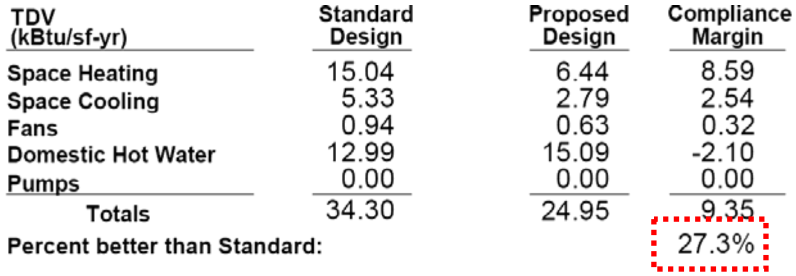
As a result, the solution proposed above (excess PV production to counterbalance site combustion) is economically unfeasible. Instead of trading off the cost of natural gas burned on site with net metering payments for excess PV-based electricity, the excess PV production is simply forfeited to the utility at the end of the year. In effect, achieving net zero performance with this method would simply results in buying an annuity for the utility company.

Therefore, given the constraints of California net metering, the only economically reasonable way to achieve net zero energy performance is with an all-electric house.

ZETA Lancaster Plan Title 24 Performance

The Title 24/CF-1R results for the ZETA Lancaster Prototype ("V1") are shown below in Table 1. These calculations were done by Bill Mattinson, CEPE (Sol*Data Energy Consulting, Santa Rosa, CA), dated 5/1/2009, and reflect the overall 27% improvement vs. Title 24:

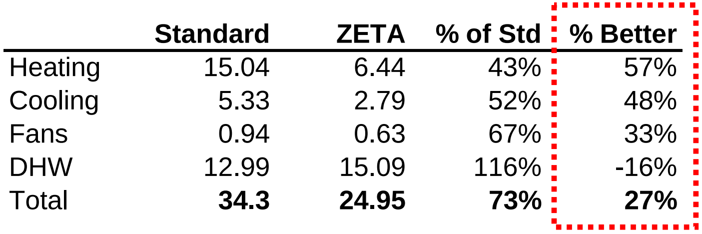
Table 1: Title 24 CF-1R Summary for ZETA Lancaster Plan "V1"



TDV (kBtu/sf-yr)	Standard Design	Proposed Design	Compliance Margin
Space Heating	15.04	6.44	8.59
Space Cooling	5.33	2.79	2.54
Fans	0.94	0.63	0.32
Domestic Hot Water	12.99	15.09	-2.10
Pumps	0.00	0.00	0.00
Totals	34.30	24.95	9.35
Percent better than Standard:			27.3%

These figures can also be recalculated as a “percentage of standard” (i.e., the baseline case) and “percent better than standard” in each category, as shown in Table 2:

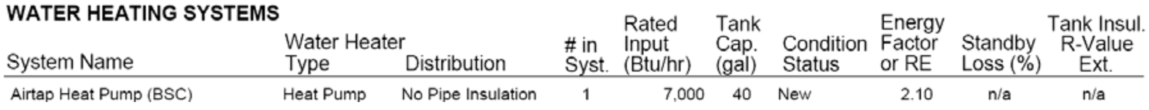
Table 2: Title 24 CF-1R for ZETA Lancaster Plan "V1" Expressed as Percentages per Category



	Standard	ZETA	% of Std	% Better
Heating	15.04	6.44	43%	57%
Cooling	5.33	2.79	52%	48%
Fans	0.94	0.63	67%	33%
DHW	12.99	15.09	116%	-16%
Total	**34.3**	**24.95**	**73%**	**27%**

Obviously, despite excellent performance on heating, cooling, and fan energy, (33 to 57% better than the standard case), the installed heat pump water heater provides performance worse than the base case (by 16%). This brings down the overall performance significantly, given that water heating is a substantial portion of the total load. In fact, the TDV (kBtu/sf·year) values for domestic hot water are 1.5 times greater than the heating/cooling/fan loads combined.

For the record, the Title 24 calculation shows the system entered accurately, with the GAMA-rated 2.11 energy factor, and 40 gallon storage tank.



WATER HEATING SYSTEMS

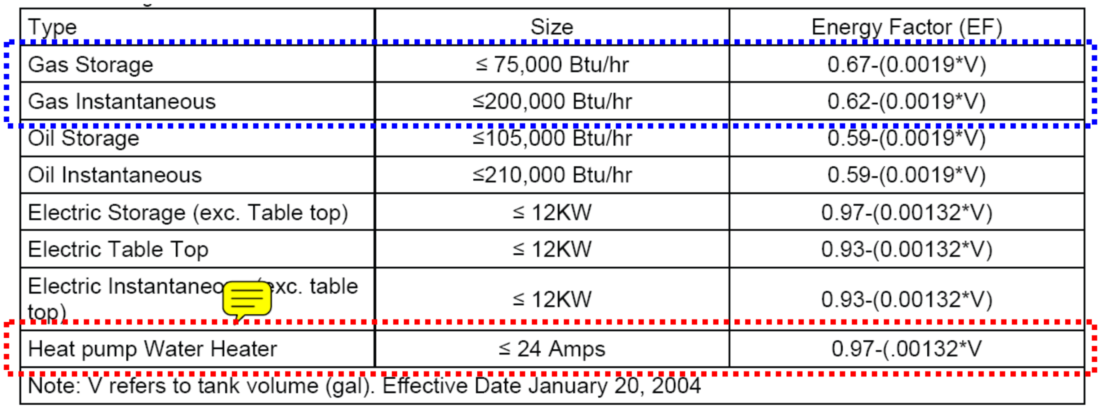
System Name	Water Heater Type	Distribution	# in Syst.	Rated Input (Btu/hr)	Tank Cap. (gal)	Condition Status	Energy Factor or RE	Standby Loss (%)	Tank Insul. R-Value Ext.
Airtap Heat Pump (BSC)	Heat Pump	No Pipe Insulation	1	7,000	40	New	2.10	n/a	n/a

Figure 1: Domestic hot water system entry for ZETA Lancaster Plan "V1"

Heat Pump Water Heater Ratings and Performance

The poor performance of the heat pump water heater was a matter of further research. First, we examined the minimum EF (energy factor) values allowed for “small water heaters,” as noted in Table 3 below:

Table 3: California Title 24 Table 5-2 – Minimum Energy Factor Small Water Heaters



Type	Size	Energy Factor (EF)
Gas Storage	≤ 75,000 Btu/hr	0.67-(0.0019*V)
Gas Instantaneous	≤200,000 Btu/hr	0.62-(0.0019*V)
Oil Storage	≤105,000 Btu/hr	0.59-(0.0019*V)
Oil Instantaneous	≤210,000 Btu/hr	0.59-(0.0019*V)
Electric Storage (exc. Table top)	≤ 12KW	0.97-(0.00132*V)
Electric Table Top	≤ 12KW	0.93-(0.00132*V)
Electric Instantaneous (exc. table top)	≤ 12KW	0.93-(0.00132*V)
Heat pump Water Heater	≤ 24 Amps	0.97-(.00132*V
Note: V refers to tank volume (gal). Effective Date January 20, 2004		

Although the state of California uses time dependent valuations (TDV) when calculating Title 24 performance, the Building America program (and therefore BSC's analysis) uses source energy as a metric. Therefore, calculations were done to translate from these minimum EF levels to a comparison of source energy consumption. The dimensionless comparison terms used in this calculation were:

- "Relative site consumption" (RSiC), which was calculated as 1/EF
- "Relative source consumption" (RSoC), which was Relative site consumption multiplied by the relevant (gas or electric) site/source conversion factor (from Deru and Torcellini 2007)

The RSic and RSoC figures were calculated for the specified heat pump water heater (AirGenerate AirTap A7) both at its GAMA-rated efficiency (2.11 EF), and then assuming that operating tank losses were not included in this "book" value (therefore 1.90 EF).

Table 4: Calculations of Relative Source Energy Consumption

Unit	Fuel	Minimum EF	Gallons	EF	RSiC	RSoC
Gas Storage	Gas	0.67-(0.0019*V)	40	0.59	1.68	1.84
Gas Instantaneous	Gas	0.62-(0.0019*V)	0	0.62	1.61	1.76
Electric Storage	Electricity	0.97-(0.00132*V)	40	0.92	1.09	3.67
Electric Instantaneous	Electricity	0.97-(0.00132*V)	0	0.97	1.03	3.47
Heat pump Water Heater	Electricity	0.97-(0.00132*V)	40	0.92	1.09	3.67
AirTap Unit	*Electricity*	*n/a*	*40*	*2.11*	*0.47*	*1.59*
AirTap w tank loss	*Electricity*	*n/a*	*40*	*1.90*	*0.53*	*1.77*
Good instantaneous	Gas			0.82	1.22	1.33

RSiC = "Relative site consumption" = 1/EF
RSoC = "Relative source consumption" = RSiC * Site_Source_[Fuel type]

Site-to-source conversion factors (Deru & Torcellini 2007)

Site_Source_Gas	1.092	US Average
Site_Source_Electric	3.365	US Average

The following conclusions can be drawn from these calculations:

- The maximum allowed source energy for an electric water heater is much larger than the allowed source energy for a gas water heater. However, based on the Title 24 calculation, the maximum allowed water heating energy, overall, is closer to the gas heating number than the electric number.
- The heat pump water heater substantially outperforms any minimum standard for electric water heating: 1.6 to 1.8 source energy consumption, vs. 3.5 to 3.7 minimums.
- The heat pump water heater has a source energy consumption lower than the minimum requirements for either gas water heating appliance.
- However, the heat pump water heater **does not** outperform a typical gas instantaneous water heater ("good instantaneous," at 0.82 EF).

Overall, it appears that source energy calculations should reflect better-than-average performance for heat pump water heaters.

Time Dependent Valuation (TDV)

The performance simulations used in Title 24 use "time dependent valuation" (TDV) as their metric of energy use. It is a method described as follows in *Joint Appendices California Energy Commission for the 2005 Building Energy Efficiency Standards for Residential and Nonresidential Buildings* (CEC 2005):

> *Time dependent valuation (TDV) is the currency used to compare energy performance when the performance compliance method is used. TDV is also used to evaluate the cost effectiveness of measures and to perform other codes analysis. TDV replaces source energy, which was used to compare performance prior to the 2005 Standards.*

Basically, it is a method that penalizes electrical use during peak load periods, and consequently, provides extra value to electricity savings measures that are active during those peak loads. For an example of these TDV values, see Figure 2, which shows that summertime—especially at peak cooling times—is critical. The TDV energy use can be 5 or 6 times greater than the "base level" (roughly 10-12 kBtu/kWh) that is in effect for the majority of the non-cooling peak parts of the year (i.e., winter and "shoulder" seasons).

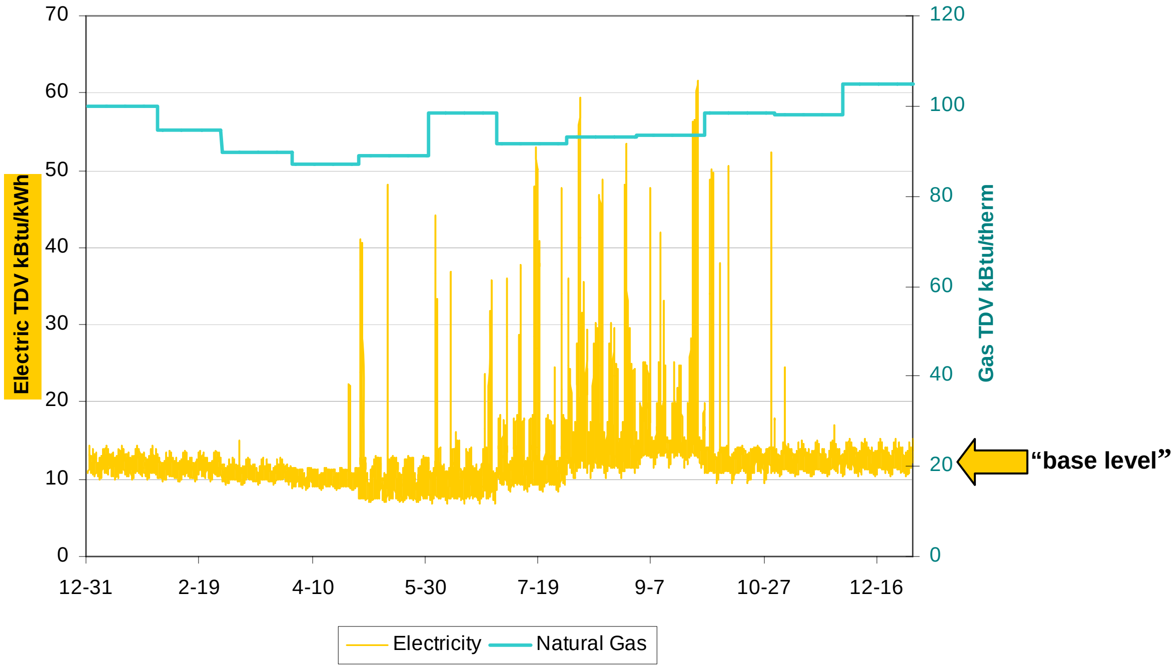


Figure 2: Time Dependent Valuation for residential electricity, Zone 3 (CEC 2004)

If these TDV values are plotted with hot water electric usage (assuming a typical operating schedule, as per the Building America Benchmark, Hendron 2009), there are some hours when portions of the hot water electrical use is coincident with TDV peaks, thus resulting in high energy consumption figures.

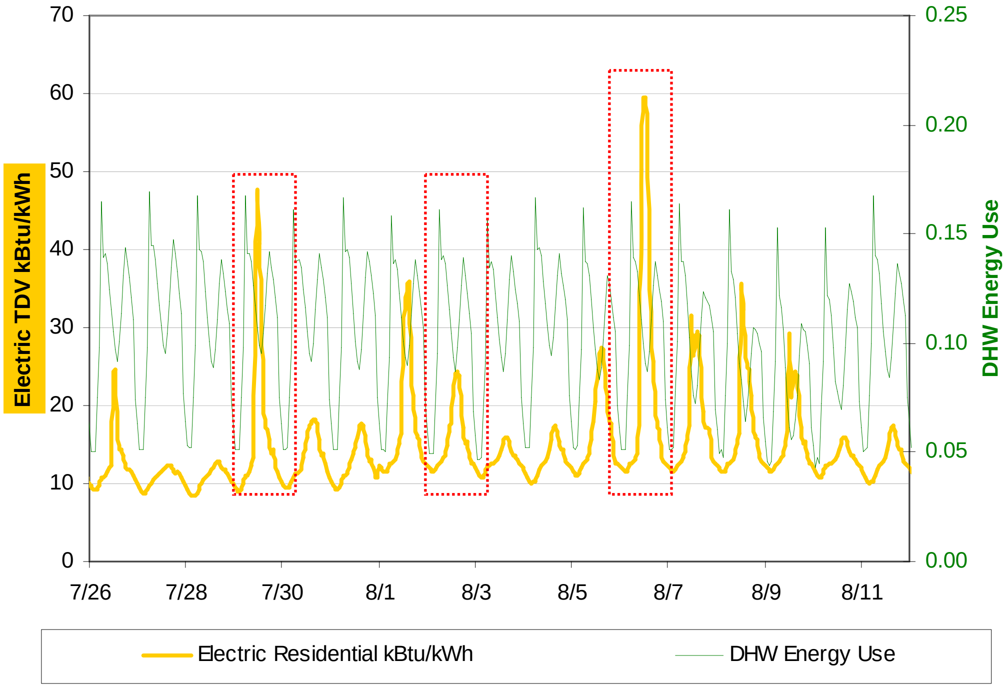


Figure 3: Zone 3 TDV values with domestic hot water energy use

Therefore, it appears that the use of electrical energy for domestic hot water heating would be heavily penalized due to the use of TDV in calculations.

Title 24 Source Energy Performance

Given the effect that time-dependent valuation appears to have on the domestic hot water performance of the Lancaster plan, the rater was asked to produce source energy-based output (as opposed to TDV-based), from the same original model, in order to isolate the effects of TDV calculations; the results are shown below in Table 5.

Table 5: Title 24 CF-1R Source Energy Calculation for ZETA Lancaster Plan "V1"

Source (kBtu/sf-yr)	Standard Design	Proposed Design	Compliance Margin
Space Heating	13.52	5.64	7.88
Space Cooling	2.03	1.08	0.95
Fans	0.36	0.24	0.12
Domestic Hot Water	13.70	12.03	1.67
Pumps	0.00	0.00	0.00
Totals	29.60	19.00	10.60
CHERS score / Percent better:		91.2	35.8%
NOT FOR TITLE 24 USE			

The results are also shown in Table 6, expressed as a percent improvement in each category (analogous to Table 2 above).

Table 6: Title 24 Source Energy calculation for Lancaster Expressed as Percentages per Category

	Standard	ZETA	% of Std	% Better
Heating	13.52	5.64	42%	58%
Cooling	2.03	1.08	53%	47%
Fans	0.36	0.24	67%	33%
DHW	13.7	12.03	88%	12%
Total	**29.61**	**18.99**	**64%**	**36%**

These results both show a significant improvement:

- Overall performance is 36% better than the standard case (vs. 27% better in the TDV case above).
- Water heating performance is 12% better than the standard case (vs. -16% better in the TDV case above).
- The heating, cooling, and fan energy % improvements are mostly unchanged from the previous TDV calculations.
- It can be noted that the Source Energy calculation would nominally meet the prerequisite in order to qualify for “Exemplary performance w/r/t EA10 (Renewable Energy)” (i.e., exceeding Title 24 by at least 35%)

Photovoltaic Production and Time-Dependent Valuation

One fact to keep in mind is that the Title 24 TDV calculations being examined here do not include the addition of renewable energy sources. Therefore, we thought it would be useful to present the TDV data, in conjunction in predicted hourly photovoltaic production, as shown in Figure 4 below.

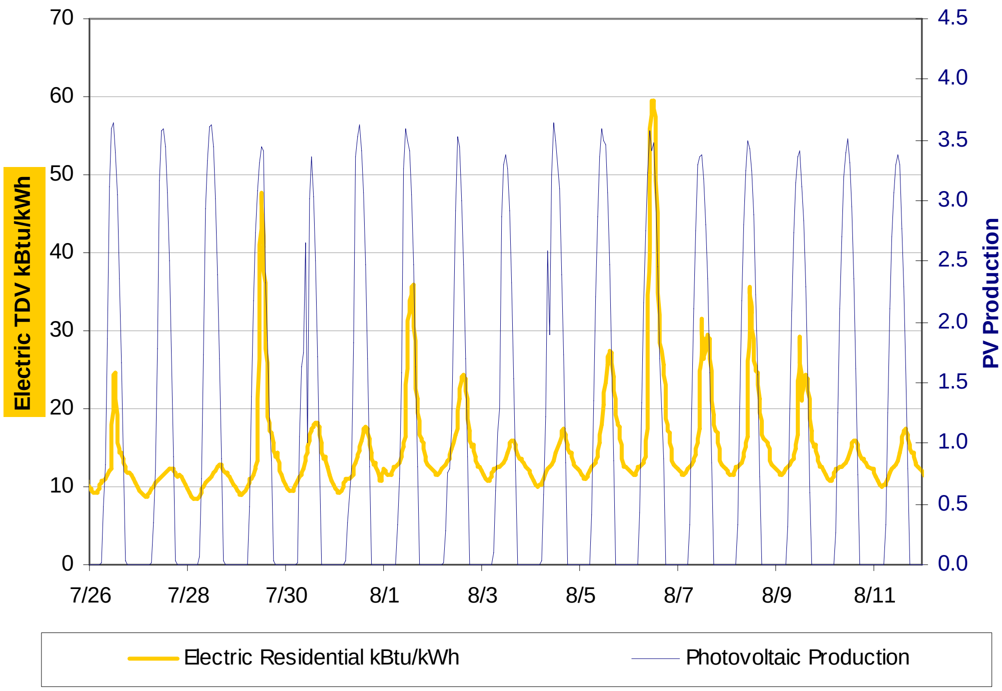
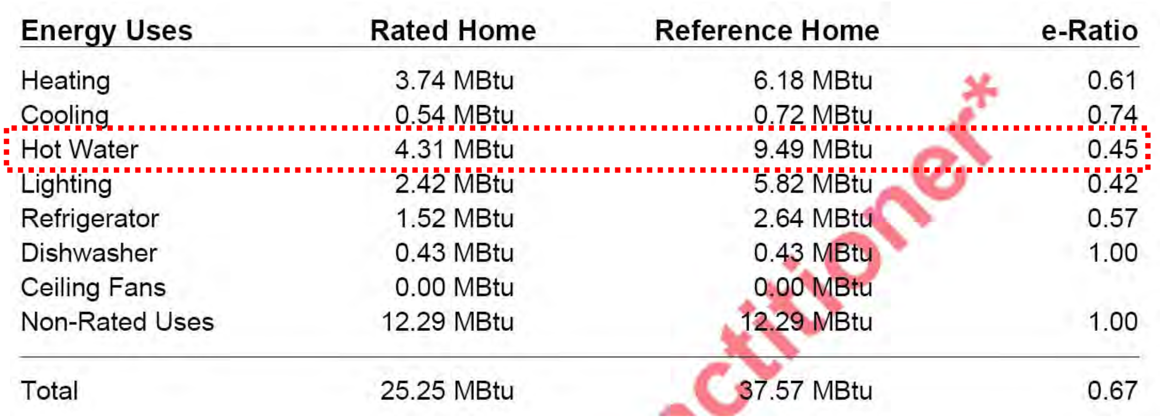


Figure 4: Zone 3 TDV values with photovoltaic electricity production

These results show that photovoltaic production is largely coincident with TDV peaks. As a result, if PV production were included in these Title 24 calculations, this renewable energy would have a large “value multiplier” under the TDV system. Furthermore, this PV energy produced during TDV peaks would work to partially offset any electricity consumed by domestic hot water productions during those periods.

ZETA Lancaster Plan Energy Performance (HERS Index)

However, the “V1” Lancaster plan was analyzed in several other energy metric systems. For example, the performance was calculated in terms of the HERS Index, using Energy Gauge USA (Florida Solar Energy Center, Version 2.8.02). The resulting breakdowns by load, comparing the “rated home” and “reference home” are shown below.



Energy Uses	Rated Home	Reference Home	e-Ratio
Heating	3.74 MBtu	6.18 MBtu	0.61
Cooling	0.54 MBtu	0.72 MBtu	0.74
Hot Water	4.31 MBtu	9.49 MBtu	0.45
Lighting	2.42 MBtu	5.82 MBtu	0.42
Refrigerator	1.52 MBtu	2.64 MBtu	0.57
Dishwasher	0.43 MBtu	0.43 MBtu	1.00
Ceiling Fans	0.00 MBtu	0.00 MBtu	
Non-Rated Uses	12.29 MBtu	12.29 MBtu	1.00
Total	25.25 MBtu	37.57 MBtu	0.67

Figure 5: HERS Summary Report Excerpt, EgUSA 2.8.02 Simulation

This shows that assuming a 2.1 EF electric water heater, the hot water consumption of the rated home was less than half of the reference home (0.45 “e-Ratio”).

ZETA Lancaster Plan Energy Performance (Building America Benchmark)

BSC’s support for ZETA Communities is funded under the Department of Energy’s Building America program. In this program, the energy performance of the research houses (i.e., “Prototype”) is gauged against the “Building America Benchmark.” The Benchmark is a reference house, somewhat similar to a HERS reference house, but with further assumptions required for appliance, lighting, and miscellaneous end use loads. The Benchmark is defined in “Building America Research Benchmark Definition” (Hendron 2009). As mentioned above, the energy metric used in Building America is source energy, assuming conversion factors from Deru & Torcellini (2007).

The performance of the ZETA Lancaster Prototype is shown in the parametric energy analysis graph shown in Figure 6. It shows the effect of incremental changes (from the Benchmark to Prototype), broken down by heating, cooling, domestic hot water, lighting, and appliance/miscellaneous end use load categories (in terms of source energy).

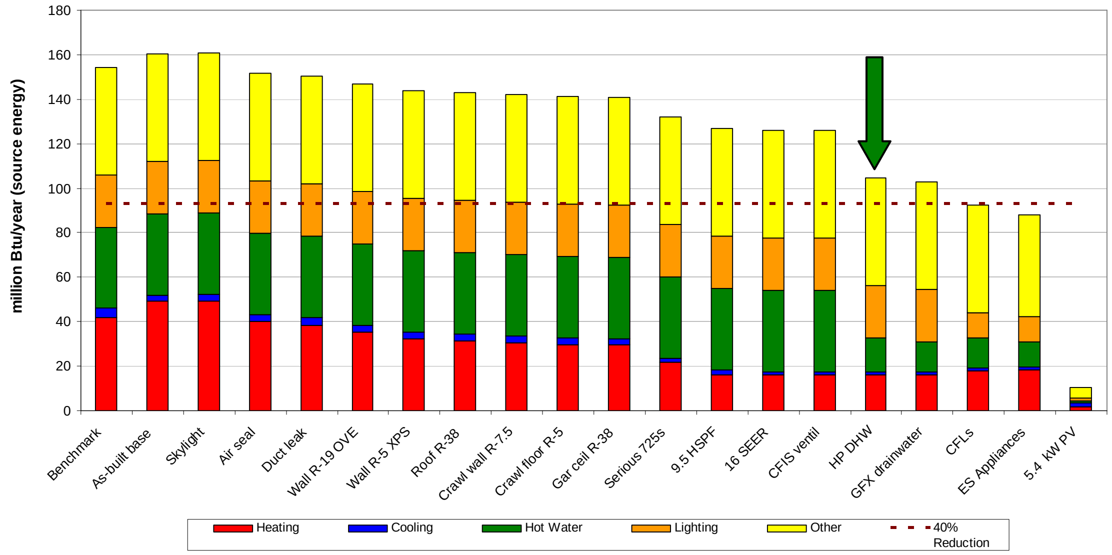


Figure 6: Parametric energy analysis of ZETA Lancaster plan

It can be noted that the single largest incremental change is switching to the heat pump water heater. The Benchmark case assumes electric resistance hot water heating (as per Figure 7); one fundamental condition in the Benchmark analysis is the avoidance of "fuel switching" when comparing Prototype to Benchmark. Going from a typical 0.8 to 0.9 EF electric resistance tank to a 2.1 EF heat pump water heater would reduced predicted energy use by more than a factor of two.

	Water Heater Fuel Type in Prototype	
	Electric	*Gas*
Storage Capacity (V) (Gallons)	See Table 8	See Table 8
Energy Factor (EF)	0.93 – (0.00132 x V)	0.62 – (0.0019 x V)
Recovery Efficiency (RE)	0.98	0.76
Burner Capacity	See Table 8	See Table 8
Hot-water Set-Point	120°F	
Fuel Type	Same as Prototype[a]	
Tank Location	Same as Prototype	

Figure 7: Characteristics of Benchmark Domestic Hot-Water System, from Building America Benchmark Definition (Hendron 2009)

Summary and Conclusions

The intent of the analysis presented here is not to judge whether or not TDV is a "more correct" metric to use for energy analysis: it accurately reflects the state of California's priorities of reducing peak loads, and therefore penalizing electricity use during those peak periods.

However, given the constraints of building a net zero energy building, combined with California net metering laws, an all-electric house is the only economically rational choice. This results in strong penalties when using electricity—even at the greater efficiency of a heat pump unit—when heating domestic hot water. This penalty does not reflect the substantial improvement in source energy performance, which is evident in other rating systems (Title 24 source energy calculation, HERS Index, and Building America Benchmark, as per Table 7).

Table 7: Summary of Relevant Energy Metrics for Three Rating Systems

Program	Energy Metric	Base Case DHW (Energy Factor)	% Improve. DHW	% Improve. Overall
CA Title 24	Time-dependent valuation (TDV)	Gas based? Minimum electric 0.97-(0.00132 × V)	-16%	27%
CA Title 24	Source Energy	Gas based? Minimum electric 0.97-(0.00132 × V)	12%	36%
HERS Index/ Energy Star	Modified End Use Loads	Electric system: EF = 0.88 Gas system: EF = 0.54 ‡	55%	33%†
Building America Benchmark	Total Source Energy (Deru & Torcellini 2007 conversions)	Electric system: 0.93 – (0.00132 × V) V=gallons	58%	43%

†: HERS Index in Energy Gauge USA simulation did not include effect of Energy Star appliances or drainwater heat recovery

‡: “The HERS Rating Method and the Derivation of the Normalized Modified Loads Method”, Fairey et al. 2000.

Therefore, it is with these constraints in mind that we would request consideration for the ID credit for “Exemplary performance w/r/t EA10 (Renewable Energy),” waiving the prerequisite to first exceed Title 24 by at least 35%, and/or allowing qualification to be met by use of the Source Energy Title 24 calculation.

Appendix D.10.7.4
Site Visit Reports and Monitoring

July 3, 2009

ZETA Communities
3145 Geary Boulevard, #733
San Francisco, CA 94118
tel 415.753.1810
fax 415.564.6911
ATTN: Naomi Porat
nporat@zetacommunities.com

**Re:	Monitoring and Field Testing Report for ZETA Lancaster Prototype**

Dear Ms. Porat:

The following report covers the field testing completed by BSC (John Straube, Kohta Ueno, and Aaron Grin) on June 16-19, 2009. Some of the most important points were covered in a preliminary email ("ZETA Field Testing Summary," June 23, 2009). But to reiterate, the key findings can be summarized as follows:

- The building air leakage numbers were good; however, these tests were run on a substantially incomplete air barrier. The results also show the importance of air sealing the mechanical room from the exterior
- The HVAC installation had the wrong (oversized) air handler, which results in high flows and excess pressures in the duct system, which can have energy and durability penalties
- The economizer ("free cooling") system was installed incorrectly, and should be modified as directed in the report (remove 4" duct, add gasketed damper, upsize duct to 12"). Note that in the current configuration, at 75° F indoors/65° F outdoors, the "free cooling" is **less** efficient than running the air conditioner.
- The MERV 13 filter was not installed; a filter located at the return side of the air handler (in the crawl space) is our recommendation
- Duct leakage test results were reasonable, although not completely conclusive, given some problems during testing
- The heat recovery ventilator, as currently installed, will consume significant electricity by running continuously at low speed, with a concurrent performance (HERS/Energy Star) penalty. However, flows are currently too low for the system to operate as an intermittent fan. Ramifications are discussed in the report.
- The drainwater heat recovery system appears to be installed incorrectly, and should be modified as per manufacturer's illustrations.
- The monitoring system has been installed, and will collect full data once permanent power is provided.

Various actions items (for BSC or for ZETA) are stated at the end of each section (see Table of Contents). It is vital that ZETA keep BSC appraised of progress on action items in preparation future trips; lack of progress may be a reason for postponement or cancellation of the trip.

If you have any questions or comments about this report, please contact Kohta Ueno of Building Science Corporation (kohta@buildingscience.com), or as per contact information shown.

Sincerely,

Kohta Ueno

Cc: Bill Malpas, John Paddock, Shilpa Sankaran, Jeremy Fisher (ZETA Communities)
John Straube, Ph.D., P.Eng., Aaron Grin (Building Science Corporation)

Table of Contents

Building Air Leakage (Blower Door) Testing

BSC performed air infiltration ("blower door") tests to measure airtightness of the constructed house (see Figure 1). However, one fundamental problem was that the house's air barrier is still incomplete, which means that although this test is a reasonable estimate of final airtightness, it is not an ideal/final test by any means.

Specifically, in the mechanical room, the ceiling (second floor framing), plumbing core wall, and electrical panel wall are all open. The ceiling and plumbing core are highly connected to the rest of the house—we could feel airflow at plumbing core openings during the tests. This connection is also shown by results with the mechanical room sealed from the outside to various degrees:

Table 1: Building air leakage initial test results

Configuration	CFM 50	ACH 50	Leak Ratio
Target for Building America	**1154**	**4.3**	**0.25**
Mechanical room door open (see Figure 3)	~1800	6.7	0.39
Mechanical room door shut but untaped	~1100	4.1	0.24
Mechanical room door shut and taped (see Figure 4)	728	2.7	0.16

Figure 1: Blower door testing, showing installation of fan in door to garage

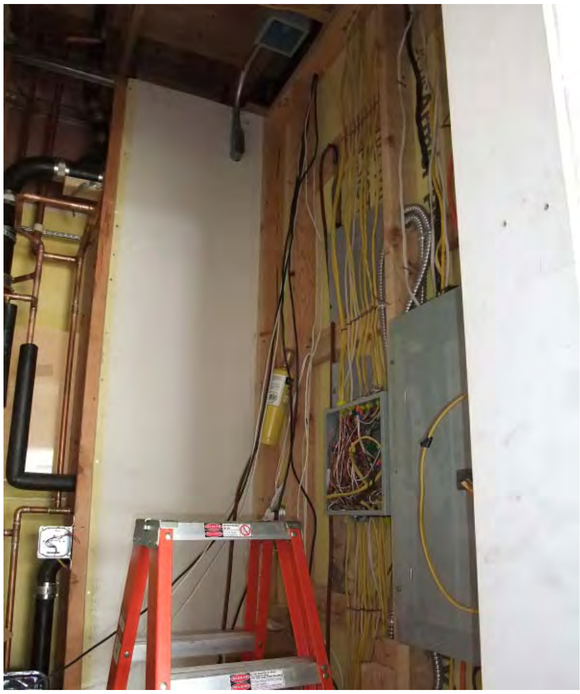


Figure 2: Mechanical room, showing open plumbing core, ceiling, and electrical panel wall

We then performed *multipoint* air infiltration tests, which provide more detailed data; the results are shown in Table 2 below; the target leakage for Building America is a "Leak Ratio" of 0.25.

With the mechanical room door sealed, the house consistently met this target by a fair margin. Three multipoint tests were run to determine the effect of connection/leakage to the thermal basement, and leakage through the heat recovery ventilator (HRV):

- Basement hatch open, downstairs grilles sealed off, HRV sealed
- Basement hatch sealed off; registers sealed off; HRV sealed off
- Basement hatch sealed off; registers open, HRV opened up

Table 2: Multipoint air leakage testing results

Test	CFM50	ACH50	Leak ratio	C	n	Correlation R^2
Basement hatch open	703	2.6	0.15	53.4	0.659	0.99862
Basement hatch closed	728	2.7	0.16	58.2	0.646	0.99871
HRV registers unsealed	737	2.7	0.16	60.8	0.638	0.99952

The results are presented in terms of CFM (cubic feet per minute) at 50 Pascals (Pa) test pressure, air changes per hour (ACH) at 50 Pa, CFM50 per square foot surface area leakage ratio, and test-specific parameters (C, n, R^2).

Figure 3: Mechanical room door open

Figure 4: Mechanical room door sealed

We do not understand how the previous tester obtained ~500 CFM 50; this might be a difference in test equipment, procedure, or testing protocols. I verified BSC's numbers using two different manometers (pressure measurement devices) as a check.

Also, the front door was taped shut for this testing, given the lack of weatherstripping. It is recommended that the exterior doors (front, garage, and mechanical room) be upgraded to exterior insulated units, but it is critical that they be properly weatherstripped.

Action Items

- ZETA to install weatherstripped doors (upgrade to insulated units recommended)
- BSC possible retest after full completion

HVAC System

The principal problem with the HVAC system was that there was a serious communications breakdown somewhere in this process. It appears that many recommendations from BSC were lost in the shuffle, and the system was built as per an old set of plans. Some specific items were as follows:

- The incorrect interior HVAC unit (air handler) was installed
- The "free cooling" (economizer) ductwork was not correctly installed
- The MERV 13 filter was not installed (as per LEED requirements)
- The entire basement ductwork system was insulated, even though BSC stated that this was not necessary—in fact, probably detrimental to the "thermal basement" coupling aspects.

Air Handler and Equipment Sizing

BSC ran some initial load calculations, which indicated that the loads on this airtight, well sealed building are very small (under 1-½ tons cooling, under 1 ton “heating equivalent”). Since the loads were so low, we recommended a small modular air handler (Goodman MBE 1200), which is set up to work with 1-½ to 3 ton systems (600 to 1200 CFM). This unit was connected to a 2-ton outdoor unit (SSZ160241A); although 1-½ tons would have met the building’s load, this 16 SEER series only comes in sizes 2 tons or higher. The interior coil, however, was oversized (CHPF 3642, 3 to 3-½ tons) in order to achieve high efficiency, as per manufacturer’s specifications.

These components were called out in “Z MechEqpmt.Schd.03.17.xls” excerpted below:

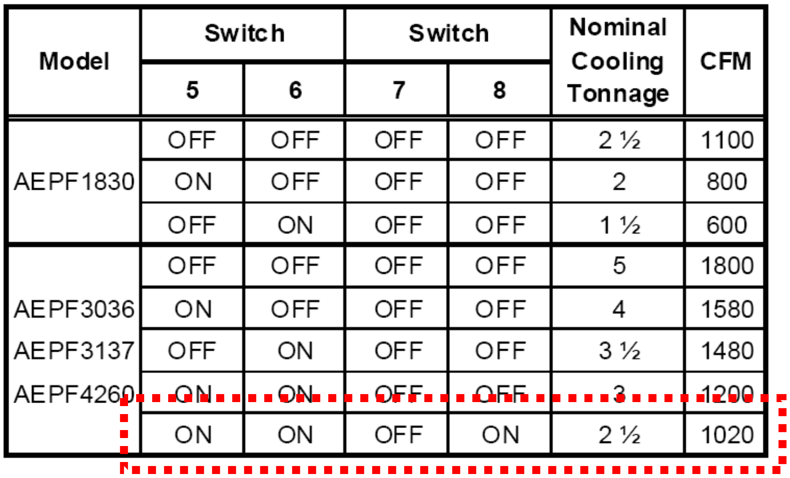
Table 3: Excerpt from mechanical specifications, showing air handler and coil

1	HEAT PUMP OUTDOOR UNIT	SPLIT SYSTEM	GOODMAN 2 TON SSZ160241A	16 SEER R-410A SYSTEM
2	AIR HANDLER		GOODMAN MBE1200	VAR. SPD. FAN
3	COIL	HORIZONTAL COIL	GOODMAN CHPF 3642	OVERSIZED COIL TO ACHIEVE HSPF/SEER; DRAW-THROUGH COIL

However, instead, a substantially larger air handler was installed instead: a Goodman AEPF 313716 (2-½ to 3 ton capacity), although with the correct outdoor unit (SSZ160241AB).

During BSC’s testing, we attempted to turn down the air handler as much as possible using the switch settings (see Figure 5 and Figure 6). Although we tried to reach the lowest speed (1000 CFM), we only hit ~1200 CFM. I believe this is because the equipment is still set on electric heating instead of heat pump mode; this can be fixed by cutting a jumper, or by switching DIP switches 1 and 2.

The oversized air handler means (a) more electricity is being used to perform distribution of space heating and cooling than expected (i.e., fan energy), and (b) the duct systems are operating at a higher static pressure than originally designed for (i.e., pushing 1.5× to 2× the amount of air relative to the original design down the same ductwork system).



Model	Switch		Switch		Nominal Cooling Tonnage	CFM
	5	6	7	8		
AEPF1830	OFF	OFF	OFF	OFF	2 ½	1100
	ON	OFF	OFF	OFF	2	800
	OFF	ON	OFF	OFF	1 ½	600
AEPF3036 AEPF3137 AEPF4260	OFF	OFF	OFF	OFF	5	1800
	ON	OFF	OFF	OFF	4	1580
	OFF	ON	OFF	OFF	3 ½	1480
	ON	ON	OFF	OFF	3	1200
	ON	ON	OFF	ON	2 ½	1020

Figure 5: Goodman AEPF DIP switch settings

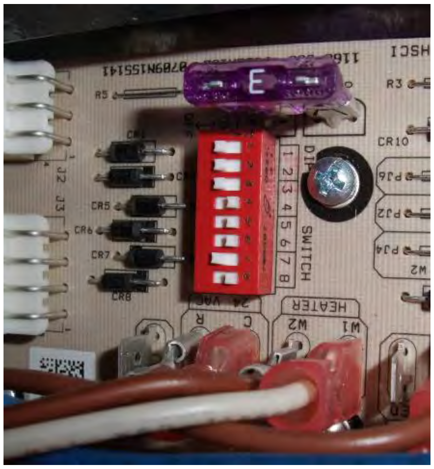


Figure 6: DIP switch settings

HVAC Flow Measurement and Distribution

The flows from the HVAC system were measured with two pieces of equipment:

- A flow hood (see Figure 7), which can measure the flow in or out of a return grille or supply register
- A filter slot measurement plate (Energy Conservatory TrueFlow, see Figure 8), which measures whole-air handler airflow.

Figure 7: Measurement of registers using flow hood

Figure 8: Energy Conservatory TrueFlow filter slot flow measurement plate

The air handler measurements are shown in Table 4 below.

Table 4: Air handler pressure and flow measurements

	Supply (Plenum)	Return (Plenum)	Total	IWC	Watts	Corrected Flow	CFM/ Watt
Fan On Speed	36 Pa	85 Pa	121 Pa	0.48	130	701 CFM	5.4
Cooling Speed	90 Pa	195 Pa	285 Pa	1.14	445	1185 CFM	2.7

These measurements included:

- Static pressure: this measurement gives an indication of the "relative health" of the HVAC system. This measurement adds the pressure drop across the air handler (supply + return). A large number (over 125 Pa or 0.5 inches of water column/IWC) exceeds typical manufacturer's limits. It is an indication that the ductwork system is too constricted for the amount of air being pushed through the system. This is indicated in the Goodman installation manual:

  To ensure correct system performance, the ductwork is to be sized to accommodate 375-425 CFM per ton of cooling with the static pressure not to exceed 0.5" WC. Inadequate duct work that restricts airflow can result in improper performance and compressor or heater failure.
- Power (watt) draw: an Energy Detective (TED) was installed on the air handler, to allow measurement of wattage draw (see Figure 38). This is a useful piece of information for measuring system performance.
- Overall airflow (as measured with TrueFlow plate)
- Calculated fan efficiency (in terms of CFM/Watt). As a baseline, typical assumptions for fan efficiency are in the 2.0 CFM/W range for ECM (high efficiency electronically commutated) motors.

Some points to note:

- The air handler "fan on speed" was lower than cooling speed, as expected. This is the speed that is to be used for economizer use, and for fan cycling (i.e., mixing) use.
- Static pressures were much higher than recommended levels. At low (fan on) speed, the system was already close to 125 Pa or 0.5 IWC. At cooling speed, the system was running at double the recommended pressure (1.14 IWC).
- Fan efficiencies were very good: at low speed, 5.4 CFM/W; even at the high pressures run during cooling speed, we achieved 2.7 CFM/W. The effect of static pressure on fan efficiency is shown in the graph below (see Figure 9). Obviously, if we can decrease static pressure (e.g., by lowering pressure—by reducing speed, or increasing the size of the duct system), we can get better fan efficiencies.

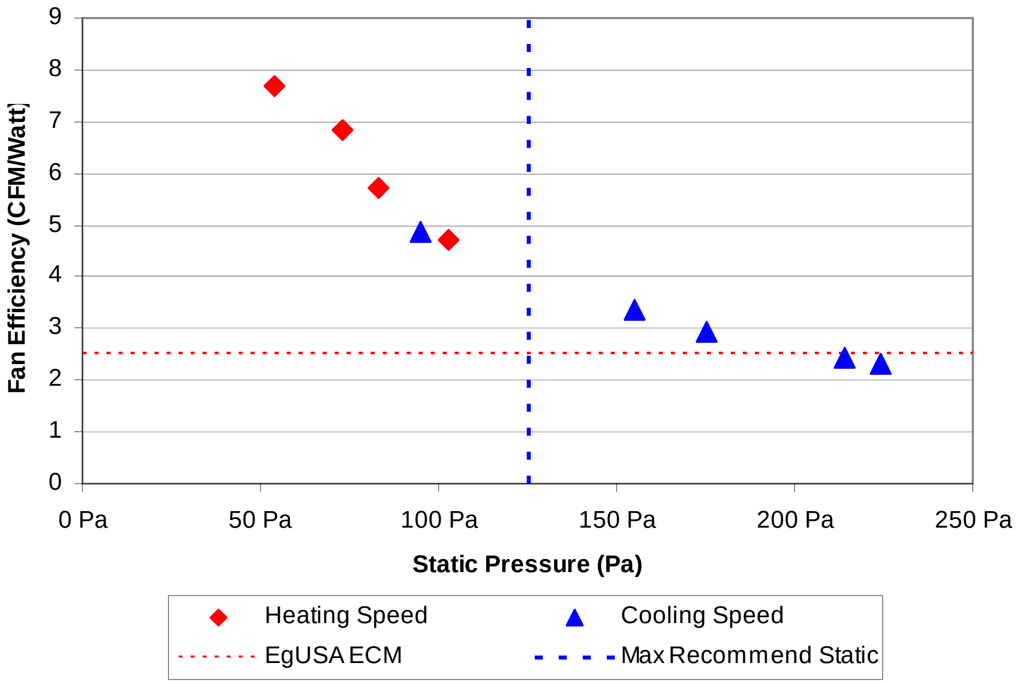


Figure 9: Fan efficiency (CFM/W) vs. static pressure, from BSC measurements

Economizer ("Free Cooling") Ductwork

The economizer system was built according to an old set of plans: there was a 4" duct from the exterior to the return plenum without a damper—this duct was eliminated in the 3/17/09 plan set. That duct basically acts as a duct leak to outside whenever the air handler is run, increasing loads and decreasing efficiency. BSC eliminated this problem in the field by disconnecting the duct and temporarily taping off the two openings (see Figure 10 and Figure 11).

Figure 10: Removed 4" duct from outdoor air (economizer/free cooling) box

Figure 11: Removed 4" duct connection to return side of air handler (temporary seal)

The 10" round motorized damper for the economizer duct (DuroZone NSPRD024-10) leaves a 1/8" to 1/4" gap, instead of sealing positively (see Figure 12 and Figure 13). It appears that a gasket kit comes with this damper (manufacturer's brochure mentions "Gasketing included for high integrity seal"), but that it was not installed.

Figure 12: Motorized damper used on 10" economizer duct (DuroZone NSPRD024-10)

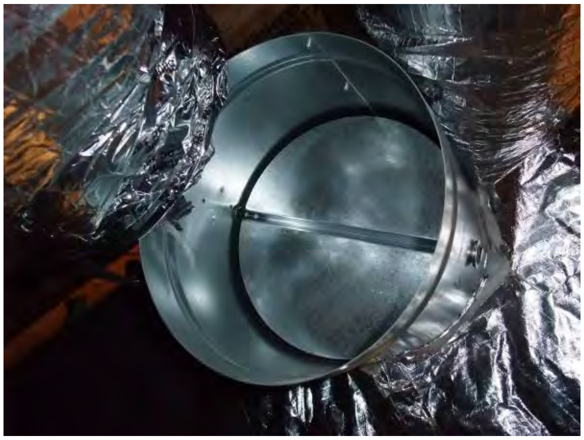


Figure 13: Motorized damper shown without any stop or gasket installed

Given the emphasis on air sealing the ductwork system (mastic on all joints), it is a terrible waste to have that large of a hole directly to the outside (i.e., worst type of duct leakage). Instead, a normally-closed motorized damper with a gasketed seal (against a direct stop) is required in this application. Examples are shown in Figure 14 and Figure 15.

Figure 14: Example of 10" motorized damper with stops and gaskets

Figure 15: Close up of motorized damper gasket seal as example

In addition, BSC's recommendation was to use a 14x8 duct to the outside (112 square inches), with a motorized damper. However, instead, a 10" round duct (79 square inches—70% of recommended size) round duct was used. Using this smaller duct decreases the efficiency of this economizer system. A 12" round duct (113 square inches) could be used instead.

The efficiency of this economizer system can be calculated; it is important to note that this "free cooling" is not really free—it takes some fan energy to run it. We can take previous measurements (airflow and fan wattage), and make assumptions of interior and exterior conditions, to determine an EER (energy efficiency ratio, measured in Btu/(W·hr). This can then be compared to running the air conditioner (SSZ16), using manufacturer's data to calculate an EER. Note that moisture effects are ignored in this analysis; only dry bulb temperature was used.

Economizer Calculation

Flow @ Fan on	160	CFM
Electric Use	130	Watts
Fan efficiency	1.23	CFM/W
Interior T	75	F
Exterior T	65	F
Cool Capacity	1284	Btu/hr
EER	**9.9**	**Btu/(W•hr)**

Includes 130W/444 Btu/hr fan energy reducing cooling capacity

Comparison to SSZ16 EER @ 65 F ext; 75

Cool Capacity	24600	Btu/hr
Electric Use	1480	W-h
EER	**16.6**	**Btu/(W•hr)**
Cool Capacity	23900	Btu/hr
Electric Use	1470	W-h
EER	**16.3**	**Btu/(W•hr)**
Cool Capacity	22100	Btu/hr
Electric Use	1430	W-h
EER	**15.5**	**Btu/(W•hr)**

We first used 75° F interior/65° F exterior; at those conditions, the economizer has an effective EER of roughly 10 Btu/(W·hr), while the air conditioner is running closer to 15.5-16.5 Btu/(W·hr). **Unfortunately, this means that the "free cooling" is less efficient than running the air conditioner when it is 65° F out, due to the low airflow and high wattage.**

However, if the exterior temperature is lowered to 60°F, the EER for the economizer increases to roughly 16.5. No data is given for the air conditioner at that outdoor condition. It appears that nighttime temperatures do drop to the 60° F level or below regularly (see Figure 16).

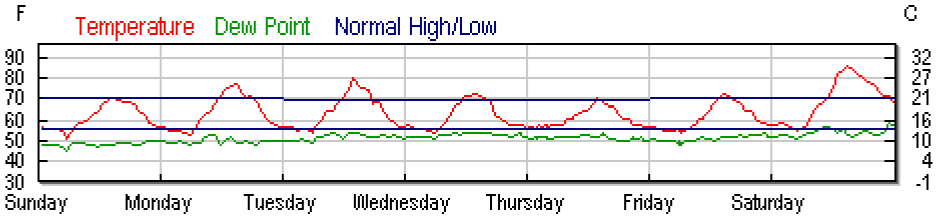


Figure 16: Week temperature data for Oakland in June, showing diurnal patterns

However, if the economizer duct were upsized, we would be drawing more air from the exterior at roughly the same fan wattage, thus raising efficiency. For instance, if we could boost economizer duct flow to 250 CFM (from 130), the EER at 65° F would be 17.4 Btu/(W·hr).

Filtration

The BSC team has had an ongoing discussion with ZETA on solving the filtration issues; MERV 8 is the recommended minimum value for Building America, and there are LEED points gained from installing filtration of MERV 13 or higher. The original solution was to add filters to the return registers, building a custom deep grille cover that would accept a 5" filter. However, if you look at the geometry of the system (see Figure 33, top figure), the air passing through the economizer duct is completely unfiltered, which is a poor situation.

Therefore, we would recommend retrofitting a MERV 13 pleated media filter (~4-5" thick; see Figure 17 and Figure 18) at the return side of the air handler (in the crawl space). Note that given the high flow (1000 to 1200 CFM), a larger size filter (20x25 minimum) is recommended, to keep filter face velocities below 300 FPM.

Figure 17: Example of MERV 13 pleated media filter (Trion AirBear)

Figure 18: Example of 20x25x5 filter used in Air Bear housing

Transfer Grilles/Pressure Relief

One common BSC recommendation is the use of transfer grilles or jump ducts, to relieve pressures due to HVAC supply operation in closed rooms. The rationale and details are shown in

- Information Sheet 604: Transfer Ducts and Grilles http://www.buildingscience.com/documents/information-sheets/hvac-plumbing-and-electrical/information-sheet-transfer-grilles-and-ducts/

We measured room pressurization in cooling operation (maximum airflow). BSC’s target for Building America is 3 Pa or less pressurization. However, several items mean this test is not the “final” condition:

- The air handler was operating at ~1200 CFM; it is our goal to reduce this flow to ~1000 CFM to improve fan efficiency
- The door undercuts and finish floor are not in their final configuration; the room pressurization is strongly affected by these items

The test results were as follows:

Table 5: Transfer grille zone pressurization results

	Pressure	Undercut	Airflow
Thermal Basement-fan on	2.2 Pa	n/a	138 CFM
Thermal Basement-cooling	8.0 Pa	n/a	310 CFM
Bedroom 1-cooling	2.5 Pa	1"	76 CFM
Bedroom 2-cooling	5.0 Pa	7/8"	84 CFM

Bedroom 2 was slightly over targets (5 Pa), as was the thermal basement in cooling mode (8 Pa). These tests should be redone at the final state of completion, once airflows are set.

Note that if BSC's transfer grilles are a concern for noise or light transmission, Tamarack Technologies offers a product ("Return Air Pathways") that deal with these issues quite well. However, BSC has seldom noted transfer grille complaints in operation.

http://www.tamtech.com/userfiles/RAP%20Sales%20Sheet.pdf

> *The Return Air Pathway (R.A.P.) allows the movement of air from one room to the next, equalizing pressure in the home while dampening sound and light. It is easily installed in a new construction or retro-fit application.*

Action Items

- BSC to try to reduce air handler flow to ~1000 CFM from ~1200 CFM (DIP switches 1 and 2 to ON and ON), and possibly retest airflow, static pressures, and fan efficiency. Also might be possible to change air handler flow to lower speed by bypassing high speed controls, and wiring system to run in "fan only" mode during heating and cooling.
- BSC possibly retest air handler and register flows after changing air handler settings
- ZETA to remove remains of 4" "bypass" duct at economizer
- ZETA to installer larger economizer duct (12" round), and replace damper with gasketed motorized damper
- ZETA to insulate economizer duct completely to exterior (uninsulated at plenum box in current installation; see Figure 10)
- BSC to re-measure economizer performance (airflow) with reconfigured system
- ZETA to install MERV 13 and filter box at return side of air handler
- ZETA and BSC: on V2, redesign of ductwork system to reduce static pressure

Duct Leakage Testing

BSC performed a duct air leakage ("duct blaster") test (see Figure 19); it involves depressurizing the ductwork system with all intentional openings (registers and grilles) temporarily covered with tape (see Figure 20). The results are shown in terms of CFM 25: cubic feet per minute at the 25 Pa test pressure, which is comparable to the pressures seen in a duct system in operation.

In addition, a further test measured the leakage of the duct system to the exterior; this is the critical measurement, in terms of overall energy efficiency. This test was done by using the blower door and duct blaster together, to eliminate leakage to the interior of the house.

Figure 19: Duct leakage testing, showing fan

Figure 20: Sealing of registers with duct mask

Unfortunately, the duct leakage was tested while the 4" duct open to the outside was in place, without our knowledge, which results in a distorted, non-representative test. However, some items can still be seen in the results (see Table 6).

- Overall duct leakage is a significant amount (15-22%), but is within typical ranges seen for sheet metal ductwork systems
- Taping over the economizer duct removed a significant fraction of the leakage (42 CFM 25), showing the effect of that open 4" duct and the ungasketed economizer duct
- Leakage to the exterior was relatively low—46 CFM 25, or 4 to 6% of flow—which is within the range of Building America targets. However, this should ideally be close to zero.
- When the economizer was taped, this leakage to outside dropped to zero (below measurement limits), as would be expected given previous results.

I am sure that with the 4" duct removed and the motorized damper replaced with a gasketed model, that the duct leakage to outside would be very low.

Table 6: Duct leakage testing results; % AHU flow shown as %1200 CFM and (%800 CFM)

Test	Leakage	% of AHU flow	Notes
Total leakage	175 CFM 25	15% (22%)	
Total leakage (economizer taped)	133 CFM 25	11% (17%)	
Leakage to exterior	46 CFM 25	4% (6%)	
Leakage to exterior (economizer taped)	0 CFM 25	0% (0%)	Below meas. limits

Duct leakage results are typically expressed in terms of percent of nominal air handler flow at high speed. However, this was an odd situation: we had the actual "oversized" speed (1200

CFM), and the "design" speed (800 CFM, for a 2 ton system). The results are presented in terms of both metrics.

Action Items

- None required (motorized damper item addressed above).

Ventilation system (Heat Recovery Ventilator)

The heat recovery ventilation system (Suncourt Airiva HE100 HRV) was installed during our field visit, and is ducted to act as both a bathroom exhaust system (exhaust duct runs to both bathrooms), and for general dilution ventilation. The outside supply is at the second floor hallway (see Figure 21, blue tape), near the second floor return; cycling of the central air handler will redistribute outside air throughout the house.

The current wiring setup runs the HRV continuously at low speed, and when a switch is hit in either bathroom, it increases to high speed to ventilate the bathrooms.

Testing

BSC's testing included measurement of airflows at all registers (supply and exhaust), as well as power measurements of the unit at low and high speed (see Figure 22). Results are shown in Table 7.

Figure 21: HRV installed on shelf in second floor closet

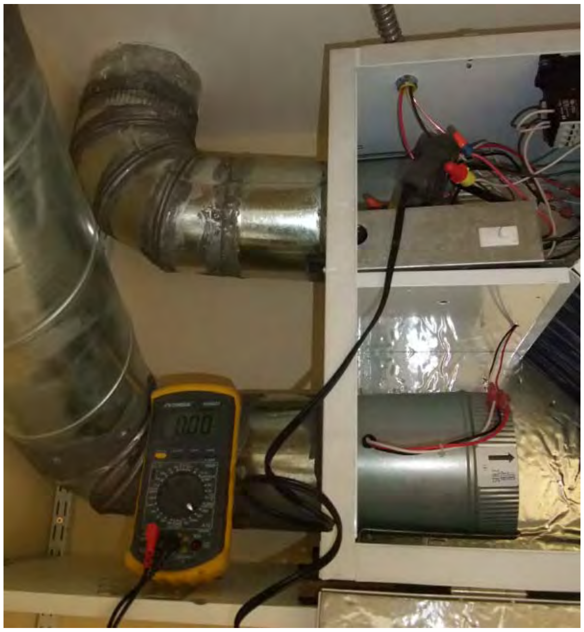


Figure 22: Power measurement of HRV using amp clamp (HRV door closed during test)

Table 7: Airflow and power use test results for Suncourt Airiva HE100 HRV

	Supply total	Upper bath	Lower bath	Exhaust total	Watts	CFM/W (avg)
High speed	91 CFM	31 CFM	26 CFM	57 CFM	145	0.5
Low speed	84 CFM	28 CFM	20 CFM	48 CFM	104	0.6

The HRV system is providing relatively unbalanced flows: 84 CFM supply/48 CFM exhaust (low speed), and 91 CFM supply/57 CFM exhaust (high speed). This difference (~35 CFM) will cause some slight pressurization of the building; but this would be insignificant in terms of causing pressure-driven moisture issues (0.4 Pa at current airtightness level). This behavior is somewhat to be expected—the ducts for the "supply" side are very short (up to the roof, and out of the closet), while the "exhaust" runs are longer (up to the roof, but down/across to both bathrooms, splitting into two ducts).

It was interesting to note that switching to high speed did not have a very large effect on flows, although it did increase power consumption noticeably. This is reflected in the drop in efficiency (CFM/W).

The fan efficiency is stated for the **average** of supply/exhaust flows, given the mismatch. The CFM/W rating is on the middling to low end up typical HRV efficiency levels; other units are in the 0.6 to 1.0 CFM/W range, with some smaller units up to 1.5 to 2.1 CFM/W.

Impacts on HERS/LEED/Builders Challenge Compliance

There was a great deal of complexity to wire the controls for the HRV, because it needs to run both for general ventilation, as well as bathroom exhaust (i.e., electrician-installed relay in HRV box, three-way switches in both bathrooms). **However, the current controls (low speed full time, and high speed when either bathroom switches on) will result in serious overventilation (84 CFM continuous), with a resulting energy penalty.**

This was modeled in our energy simulations, which **made the HERS Index noticeably worse: from 60 to 67.** In addition, this change adds ~600 kWh/year (both fan energy and additional heating/cooling), which is equivalent to the production of two PV panels (2 x 225 W peak).

We talked through an alternate control system with Jeremy and Mike (the electrician); this will run the HRV on a timer for general ventilation, and on demand for bathroom exhaust (see "Alternate Controls" section below). I believe that we all understand this system, and that Mike could retrofit it soon.

However, there is one fundamental problem with switching over to this demand-based system: bathroom exhaust flows being drawn by the HRV—even at high speed—are too low to meet the requirements of LEED/ASHRAE 62.2/Builder's Challenge. Those programs all require 50 CFM minimum for a bathroom exhaust fan (see Table 5.1 from ASHRAE 62.2-2007, below)

Table 8: ASHRAE 62.2-2007 requirements for intermittent or continuous local exhaust

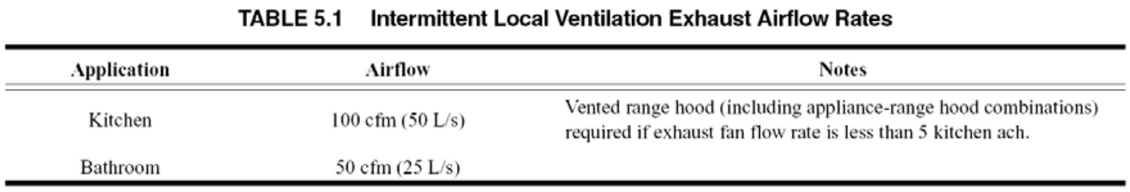


TABLE 5.1 Intermittent Local Ventilation Exhaust Airflow Rates

Application	Airflow	Notes
Kitchen	100 cfm (50 L/s)	Vented range hood (including appliance-range hood combinations) required if exhaust fan flow rate is less than 5 kitchen ach.
Bathroom	50 cfm (25 L/s)	

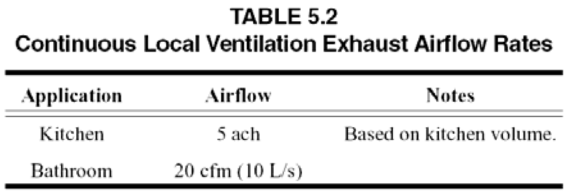


TABLE 5.2
Continuous Local Ventilation Exhaust Airflow Rates

Application	Airflow	Notes
Kitchen	5 ach	Based on kitchen volume.
Bathroom	20 cfm (10 L/s)	

The alternate way to meet program requirements would be to run a 20 CFM fan continuously at the bathrooms (see Table 5.2, above)—i.e., the current control strategy. However, this is the problem of overventilation described above.

Ultimately, this is the "rock and a hard place" situation—either:

- take a serious penalty in energy performance, or
- not have a system that meets LEED/ASHRAE 62.2/Builder's Challenge minimum requirements

The best approach, I think, would be to see if we could increase the flows from the bathrooms, to roughly close to 50 CFM. I don't know if this is possible with the equipment in place, but some options include:

- See if the roof "mushroom" cap is too restrictive, and possibly increase free area to increase flow
- Possibly reverse the fans directions (see installation instructions, under "Manually Reversible Fans"), if this removes elbows from the exhaust duct run (1 elbow is equivalent to ~35 feet of straight ductwork), possibly shifting them to the supply side of the HRV
- If any exhaust ducts to the bathrooms are accessible, possibly increase size to reduce restriction of flow

As discussed previously, we do not recommend the use of the HRV in future applications in this climate zone; the mild climate reduces the benefits of heat recovery of ventilation air, and there is a penalty associated with

Alternate Controls

The alternate control system is a Fantech Ventech controller (see http://www.fantech.net/fantech_ventech_flyer_031407_mlr.pdf).

This system works as follows:

- When a button in the bathroom is pressed, it runs the fan for 20 minutes
- In addition, the controller has a built-in timer, and will turn on the fan for a certain number of minutes per hour (user settable, 0 to 60) for general dilution ventilation
- The fan speed at timer-based ventilation can also be set by this controller
- The fan power is directly connected to a VT20M main control; other bathrooms have a VT20A auxiliary control, which sends a signal to the VT20M via low voltage wires.

This system would meet all our requirements if—but only if—the exhaust flows were close to 50 CFM.

Figure 23: Fantech Ventech control

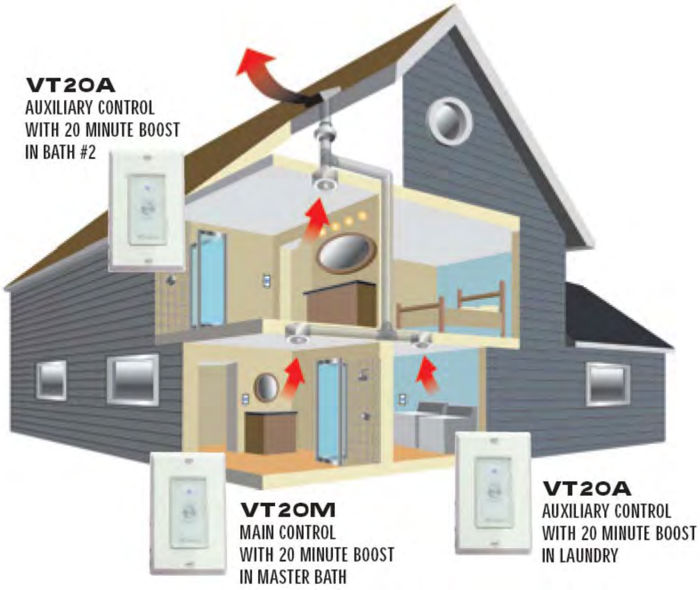


Figure 24: Ventech layout: VT20M master, with VT20A aux.

Action Items

- ZETA to determine whether installation changes as described above can increase exhaust airflows
- If flows are increased, ZETA to change fan control to Fantech Ventech controls
- ZETA to install condensate drain from HRV to available drain

Domestic Hot Water (DHW) System

BSC did not complete any of the domestic hot water system testing or monitoring installation, since the domestic hot water system has not yet been installed.

In a quick look at the drainwater heat recovery system, it appears that it is plumbed incorrectly. The intent is for cold water to pass through the drainwater heat recovery exchanger, and then feed into the hot water heater, as preheated water.

Instead, if I have traced the pipes correctly, it is feeding the tempered water (from the GFX) into the **hot water supply pipe**. This would simply result in the addition of lukewarm water into the hot water supply, diluting the output of the water heater. I have brought this to the attention of Daniel and Jeremy.

For more detailed installation directions see “GFX Heat Exchangers - Installation Page” (http://gfxtechnology.com/Install-Page.pdf).

Figure 25: Drainwater heat recovery plumbing setup

Figure 26: Incoming drainwater pipe temperature sensor (thermistors)

We would recommend the "Unequal Flow B" installation method.

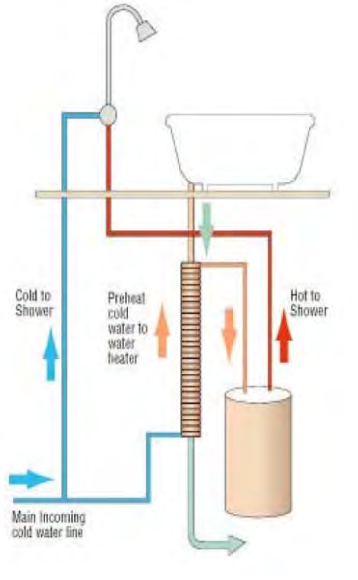


Figure 27: GFX installation method "Unequal Flow B"

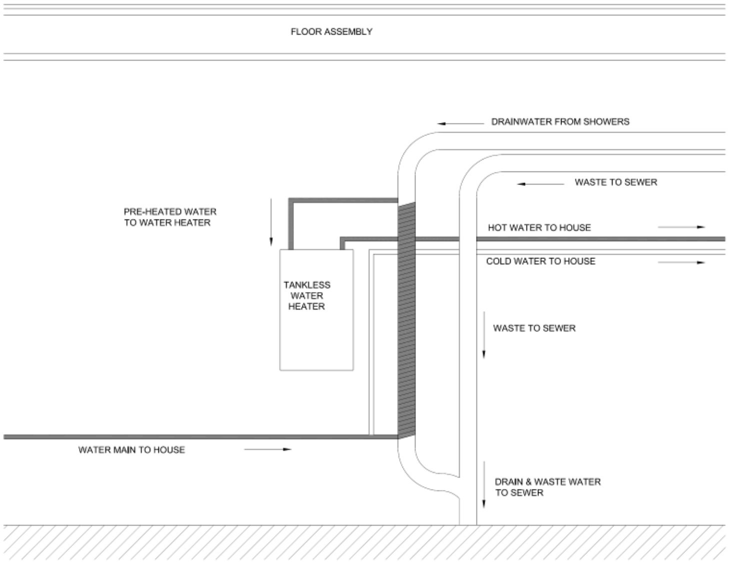


Figure 28: BSC schematic of drainwater heat recovery installation in basement, with instantaneous water heater

Although the "Equal Flow" method recovers the most heat, it will result in a slight "drift" of delivered shower temperature as the drainwater heat recovery unit comes up to temperature.

Action Items

- ZETA to check drainwater heat recovery piping, to correct plumbing if necessary.
- ZETA to install flow meter (previous discussion with John Paddock & Jeremy Fisher)
- BSC to install remaining drainwater heat exchanger sensors when system is complete and hot water system is installed.

Monitoring Setup

We finished installation of the data logger, which will monitor temperatures and humidities throughout the house, exterior T/RH/solar radiation, HVAC system runtimes, and hourly power consumption of the HVAC system (see Figure 29 through Figure 39). Since the hot water system was not completed, the data logging of that system will need to be completed on the next (mid-July?) trip. It will not start to collect data consistently until it receives power continuously (i.e., from the circuit breaker panel). However, powering the system on and off will not harm it; it will simply collect data when powered up, and shut down when powered off.

Figure 29: T/RH sensor installed in first floor return duct

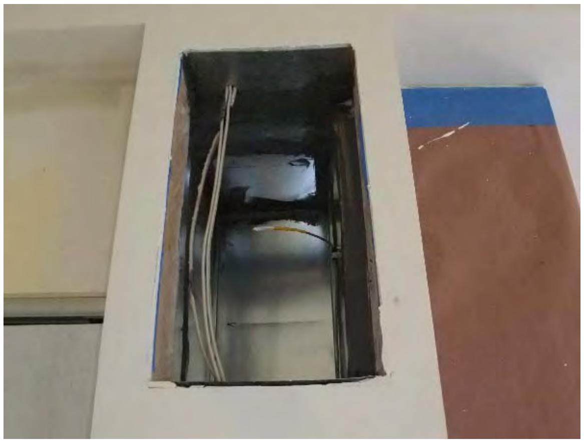


Figure 30: T/RH sensor installed in second floor return duct

Figure 31: Bedroom 1 T/RH sensor (in plastic box on wall behind door)

Figure 32: Skylight well temperature sensor (left hand side of well, in plastic box)

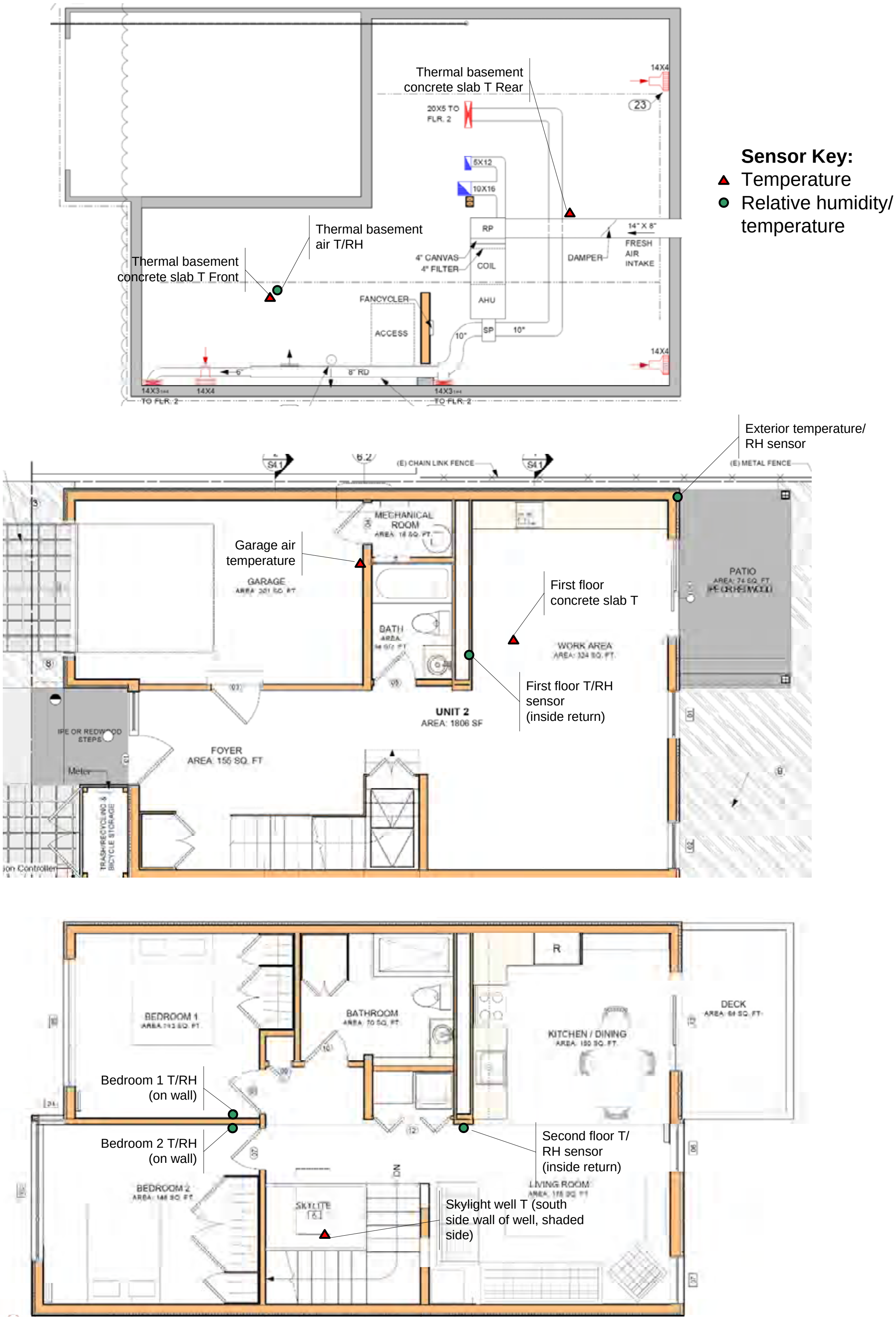


Figure 33: Sensor locations for ZETA Lancaster prototype monitoring

Figure 34: Concrete slab surface T (front of basement); pipe provides physical protection

Figure 35: Garage air temperature (box at corner of mechanical room doorway)

Figure 36: Exterior T/RH sensor

Figure 37: Horizontal solar radiation sensor

Figure 38: Air handler monitoring installation (TED & switching relays for runtime)

Figure 39: Watt-hour transducer for outdoor HVAC unit (in lower electrical box)

Action Items

- ZETA to provide permanent power to house, to allow for data collection
- ZETA to install 10BaseT or 100BaseT network jack near data logger, to allow for remote collection of data.
- BSC to install domestic hot water system sensors (AirTap runtime, electric resistance runtime) when system is installed.
- ZETA to remove yellow protective cap from outdoor T/RH sensor when exterior finish work is completed (see Figure 36).

September 3, 2009

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ATTN: Naomi Porat
nporat@zetacommunities.com

**Re:	Monitoring and Field Testing Report for ZETA Lancaster Prototype Trip II**

Dear Ms. Porat:

The following report covers the field testing completed by BSC (Kohta Ueno, and Aaron Grin) on August 10-12, 2009. The immediate action items have been covered in the previous report "2009-08-14 ZETA Lancaster Trip Follow Up Items." This report covers the more technical items that required some analysis; our work and conclusions were as follows:

- Air leakage/blower door tests were performed a final time. The house is tight enough that it can be tested with a small duct blaster fan, instead of the larger blower door used on the previous test. All results met targets, but the holes from the mechanical room to the mechanical core should be sealed during completion of the house (once mechanical systems are finalized).
- The airflows to each room were tested; delivery volumes look reasonable. However, the wooden registers on the upper floors restrict airflows (e.g., 20% lower than using a metal register, in one case).
- The revised economizer ("free cooling") system has greater airflow than in previous tests. However, the efficiency is still not great; it will only function more efficiently than the refrigerant-based cooling system at outdoor temperatures of roughly 60° F or lower. Basically, the way this system is configured now, when the indoor-outdoor temperature difference is ~15° F or greater, it makes sense to run the economizer system. In future buildings, the design of the economizer should be rethought and redesigned from this "prototype" implementation: it will need to make it easier to install, and more effective. This is especially true given the economizer damper duct leakage issues, which could completely overwhelm any benefit from the economizer system—damper leakage losses would occur throughout the year.
- We measured the delivery temperature out of various ducts as a function of time with data loggers, at various locations (air handler, first floor, second floor). This was intended as a "snapshot" test of how the HVAC system interacts with the basement thermal mass. It should be noted that when the thermal basement is "starting from cool" (i.e., 68° F), the second floor has more heat delivered out of the registers than the first floor—by a ratio of 2:1 to 3:1. But the thing to remember is that the basement is being heated at the same time—and some of that heat will later "soak" from the basement to the first floor. However, if the thermal mass is often at a cold temperature during the heating season, this might cause temperature distribution/evenness problems between floors; this can be addressed by dampering off the second floor registers.

- The drainwater heat recovery system was tested in various modes: sink drainage, and showers at 130° F and 111° F. The overall reduction in water heating use for showers was 19%; this is substantially lower than savings estimated in previous DOE work of roughly 40%. Several possible explanations are given for this difference; however, there is no clear single cause of the difference in results.
- A TED (The Energy Detective) was installed for whole-house use, near the ee PC in the kitchen; we did a quick check for "phantom loads" (i.e., always-on loads). Overall, these are not unreasonable "always-on" loads, but of course, this house is not actually occupied, with associated phantom loads (cell phone chargers, television on standby, Tivo/DVR). I would recommend that everyone working in the Lancaster unit keep an eye on the TED, just to get a feel for how electrical consumption varies over the course of the day.
- One proposed solution to the extremely low efficiency of the AirTap water heater was to relocate the unit in the garage. However, there were worries that this might cause problems (chilling down the garage, frosting the coil, loss of efficiency, condensation on walls). Based on the flow rate of the exhaust fan, the presence of the PV inverter, and garage temperatures, **it appears that placing the heat pump water heater in the garage should work**. To be safe, though, we will continue to monitor the temperature of the garage with our data logger system; it will be critical during wintertime months.

The action items associated with this report are summarized as follows:

- **Weatherstripping of mechanical room door; seal off open sump pipe (as per previous report, if not already completed)**
- **Install 4" MERV 13 filter; BSC possible retest on return trip (as per previous report, if not already completed)**
- **As per previous memos, ZETA is to deal with economizer damper leakage (as per previous report, if not already completed)**
- **Only run economizer cycle when outside air temperature drops below approximately 60° F (see relevant section for details)**
- **ZETA to look at option of moving water heater into garage (with associated plumbing and electrical connections, support platform). BSC to continue to monitor garage temperatures, once operation begins, for signs of problems.**

Future design recommendations are as follows:

- **In future designs, BSC recommends upsizing supply ductwork and use of less restrictive register (i.e., not wood register).**
- **In future buildings, the design of the economizer should be rethought and redesigned from this "prototype" implementation: it will need to make it easier to install, and more effective.**

If you have any questions or comments about this report, please contact Kohta Ueno of Building Science Corporation (kohta@buildingscience.com), or as per contact information shown.

Sincerely,

Kohta Ueno

Cc: Bill Malpas, Shilpa Sankaran, Andrew Silverman (ZETA Communities)
John Straube, Ph.D., P.Eng., Aaron Grin (Building Science Corporation)

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Building Air Leakage (Blower Door) Testing

BSC performed one additional air infiltration ("blower door") tests to recheck airtightness of the completed house (see Figure 1). Note that our leakage is low enough that the house can be tested with a duct blaster fan (1350 CFM 50), instead of the blower door used on the previous test.

We performed *multipoint* air infiltration tests, which provide more detailed data; the results are shown in Table 1 below; the target leakage for Building America is a "Leak Ratio" of 0.25. Three multipoint tests were run, which looked at the unsealed portion at the mechanical room (see Figure 2), and opening/closing the basement hatch.

Table 1: Multipoint air leakage testing results

Test	CFM50	ACH50	Leak ratio	C	n	Correlation R^2
Target for Building America	1154	4.3	0.25	-	-	-
Basement hatch open (initial test)	770	2.9	0.17	53.5	0.682	0.99704
Basement hatch open; mechanical room poly re-sealed	711	2.7	0.16	47.7	0.691	0.99759
Basement hatch closed, poly re-sealed	682	2.5	0.15	52.1	0.657	0.99733

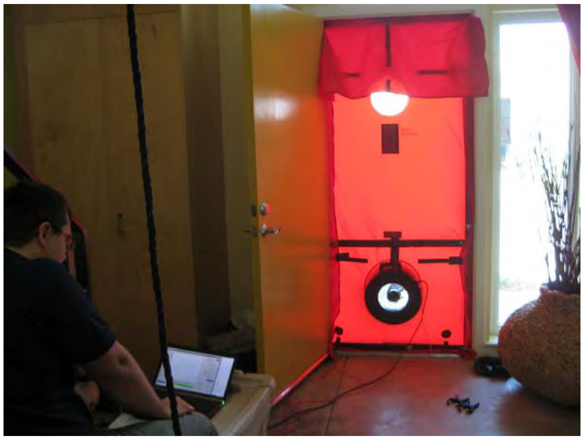


Figure 1: Blower door testing, showing duct blaster fan used in front door

Figure 2: Mechanical room, showing open penetration connected to mechanical core

All of these results are good; some points below:

- You might be surprised that sealing that hole in the mechanical room wall makes a difference; this is known as a "series leak." Air leaks along the following path: around the door to the garage (which requires weatherstripping) → hole around pipe → the mechanical core, which is connected to the entire house and basement. Sealing this hole resulted in a noticeable reduction in leakage.

- There was a similar reduction in leakage by sealing the basement hatch. However, this is not a problem—the basement is a good portion of the total building surface area, so some reduction in leakage would be expected by sealing off a portion of the house.

Action items: weatherstripping of mechanical room door; seal off open sump pipe.

HVAC System Testing

Air Handler

One issue noted in the previous report was that the wrong air handler was installed (3-5 ton system, vs. 2 tons), which provided excessive airflows, and therefore high system pressures.

I found that I could provide a bypass jumper to run the air handler at "fan on" speed (~750 CFM), instead of cooling/heating speed, providing a better match to target airflows. Note that it is documented inside the air handler cabinet, and can be reversed if necessary (snap-in connectors; see Figure 3).

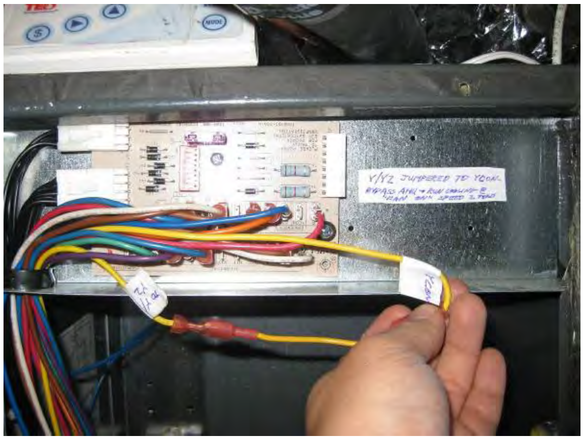


Figure 3: Air handler cooling wire bypass, results in lower flow through system

Figure 4: Testing air handler total system flow with duct blaster as metered orifice

The airflow through the system was tested using the duct blaster as metered orifice (see Figure 4); the flow was tested with the 4" MERV 8 filter (not the 2" MERV 13). Unfortunately, the final configuration of this system will be a 4" MERV 13, which was not tested. But it should be noted that the pressure drop across the 2" filter was 1-½ times the drop vs. the 4" filter (20 Pa vs. 33 Pa, or 0.08 IWC vs. 0.13 IWC).

The results of this airflow testing had to be modified by a correction factor; with that calculation, the total air handler flow was in the 750 CFM range, which is a good match to the 2 ton outdoor unit (375 CFM/ton).

Action items: install 4" MERV 13 filter; BSC possible retest on return trip

Ductwork/Distribution System

The individual register flows were measured using the duct blaster as a powered capture hood (see Figure 5); this method can be more accurate than conventional flow hood measurements, due to the elimination of "insertion losses" (restricting flow at the measured register, making the air flow out elsewhere). The results are shown in Table 2; the toe kick registers in the bathrooms could not be measured, so were estimated to be roughly 40 CFM as a placeholder.

Figure 5: Duct blaster used as a powered capture hood

Table 2: Measured register airflows (supply and return)

Supply Air

Space	Register	Heat/Cool/Fan (CFM)
First Floor	Patio Door	108
	Condenser	90
	Foyer	105
	Bathroom	40
Second Floor	Kitchen	55
	Living Room	84
	Bedroom 1	66
	Bedroom 2	55
	Bathroom	40
Whole House	Total	643
Duct Blaster @ AHU		745
Delta	Subtraction	102
Difference		14%

Return Air

Space	Register	Heat/Cool/Fan (CFM)
First Floor	Work Space	330
Second Floor	Kitchen	430
Economizer	Outdoor	39
Whole House	Total	799
Duct Blaster @ AHU		745
Delta	Subtaction	-54
Difference		-7%

These results show the first and second floors have comparable totals (~340 CFM vs. ~300 CFM), and that operating duct leakage might be in the 100-150 CFM range.

The total air handler static pressure should be kept under 125 Pa (0.5 inches of water column). With the reduced speed and 4” MERV 8 filter, it was within this range (119 Pa); however, future designs could have a slightly upsized supply duct system, to avoid pushing this limit; the diameters of the supply runouts result in a velocity (feet per minute) slightly above recommended guidelines.

Finally, the first floor registers were stamped sheet metal, while the second floor registers were wood covers. Measurements indicated that wood registers are more restrictive, resulting in a 5-

20% reduction in flow (see Table 3, Figure 6, and Figure 7). All tests were with the grilles fully open in both cases.

Table 3: Flow measurements with wood vs. metal registers

	Wood	Metal	Wood vs. Metal	No cover
Second Living Room	84 CFM	87 CFM	4%	90 CFM
Second Kitchen	55 CFM	66 CFM	20%	73 CFM

Figure 6: Comparison of metal and wood register

Figure 7: Plastic flow control grate; wood register

Action items: in future designs, BSC recommends upsizing supply ductwork and use of less restrictive register (i.e., not wood register).

Economizer ("Free Cooling") System

In our previous testing, we found that the economizer ("free cooling") system operates less efficiently than the air conditioner at moderate outdoor temperatures (65° F). This was ascribed to the limited flow through the economizer duct.

The same calculations were re-run with the recently modified system, taking measurements (airflow and fan wattage), and making assumptions of interior and exterior conditions, to determine an EER (energy efficiency ratio, measured in Btu/(W·hr). This can then be compared to running the air conditioner (SSZ16), using manufacturer's data to calculate an EER. Note that moisture effects are ignored in this analysis; only dry bulb temperature was used.

Economizer Calculation		
Flow @ Fan on	170	CFM
Electric Use	120	Watts
Fan efficiency	1.42	CFM/W
Interior T	75	F
Exterior T	65	F
Cool Capacity	1427	Btu/hr
EER	**11.9**	**Btu/(W•hr)**

Comparison to SSZ16 EER @ 65 F ext; 75		
Cool Capacity	24600	Btu/hr
Electric Use	1480	W-h
EER	**16.6**	**Btu/(W•hr)**
Cool Capacity	23900	Btu/hr
Electric Use	1470	W-h
EER	**16.3**	**Btu/(W•hr)**
Cool Capacity	22100	Btu/hr
Electric Use	1430	W-h
EER	**15.5**	**Btu/(W•hr)**

Economizer EER includes 120W/410 Btu/hr fan energy, which reduces cooling capacity

In summary:

- Current efficiency (@ 65° F out/75° inside): **11.9 Btu/(W•hr)**
- Previous efficiency (@ 65° F/75° inside): **9.5 Btu/(W•hr)**
- Current efficiency (@ 60° F/75° inside): **19.5 Btu/(W•hr)**
- Current efficiency (@ 65° F/78° inside): **16.5 Btu/(W•hr)**

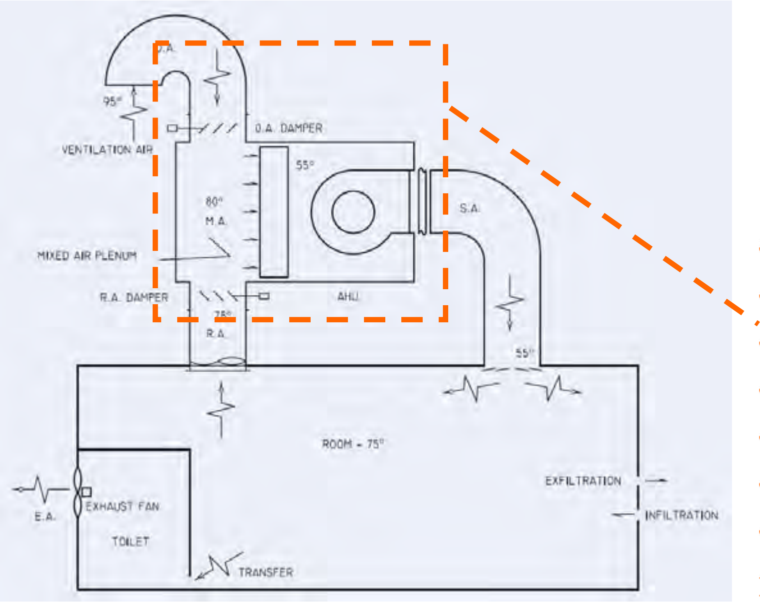
Unfortunately, the efficiency of this system—while better than previous results—is lower than running the air conditioner at 65° F. However, at 60° F exterior T, it is more efficient than the air conditioner. Also, this assumes operation at 75° F interior temperature: at 78° F inside, the efficiency jumps to the same level as the air conditions. Basically, the way this system is configured now, when the indoor-outdoor temperature difference is ~15° F or greater, it makes sense to run the economizer system.

This does not take in account the effect of economizer damper leakage, which could completely overwhelm any benefit from the economizer system—damper leakage losses would occur throughout the year.

Part of the reason for the low efficiency of the system is that the air handler fan is moving its full airflow (800 CFM, at 120 W), but only 170 CFM of that is outside air. So the air handler is running at a good "fan efficiency" (6.2 CFM/W), but for the job of bringing in outside air, it is only operating at 1.4 CFM/W.

This can be compared to the layout of a commercial-style economizer, which dampers off the

interior return side (see Figure 8 and Figure 9), thus pulling all of its air from **outside** (thus increasing effective W/CFM of outside air). This step could be done (adding several normally-open motorized dampers to the air handler return); however, this becomes a more complex and less reliable system.



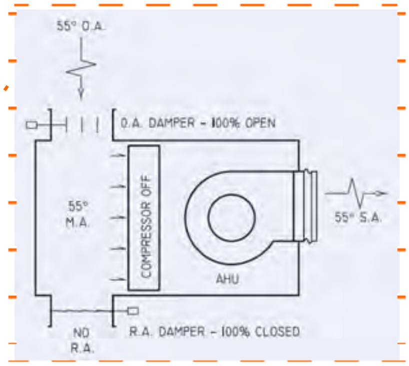


Figure 8: Commercial economizer conceptual layout with building interactions (Äsk, 2008)

Figure 9: Economizer in all-outside air mode (Äsk, 2008)

Action items: Only run economizer cycle when the indoor-outdoor temperature difference is ~15° F or greater. In future buildings, the design of the economizer should be rethought and redesigned from this "prototype" implementation: it will need to make it easier to install, and more effective. A dedicated whole-house fan would provide better energy performance and simpler operation, but would (a) require occupant operation of windows (thus defeating a key feature), (b) have a greater initial cost, and (c) could still be a source of air leakage problems. As per previous memos, ZETA is to deal with economizer damper leakage.

Time-Temperature Response: Heating

We conducted an experiment to get a better feel for the behavior of the HVAC distribution system's interaction with the thermal basement. In order to do this, the system was briefly run in heating and then cooling mode, and temperatures were taken in various ducts—both in the basement (directly inside the duct, measuring system output), on the first floor (showing the effect of the thermal basement), and on the second floor (see Figure 10 and Figure 11). These temperatures would indicate how much heat or cooling is being delivered to various spaces, when combined with the previous airflow measurements.

Figure 10: Use of data loggers to collect delivered register air temperature

Figure 11: Data logger placed in open duct in basement ('Bsmt Duct')

Temperature measurements in heating mode are shown below for the basement duct (direct output of unit), first floor register (near sliding glass door), and a second floor front bedroom.

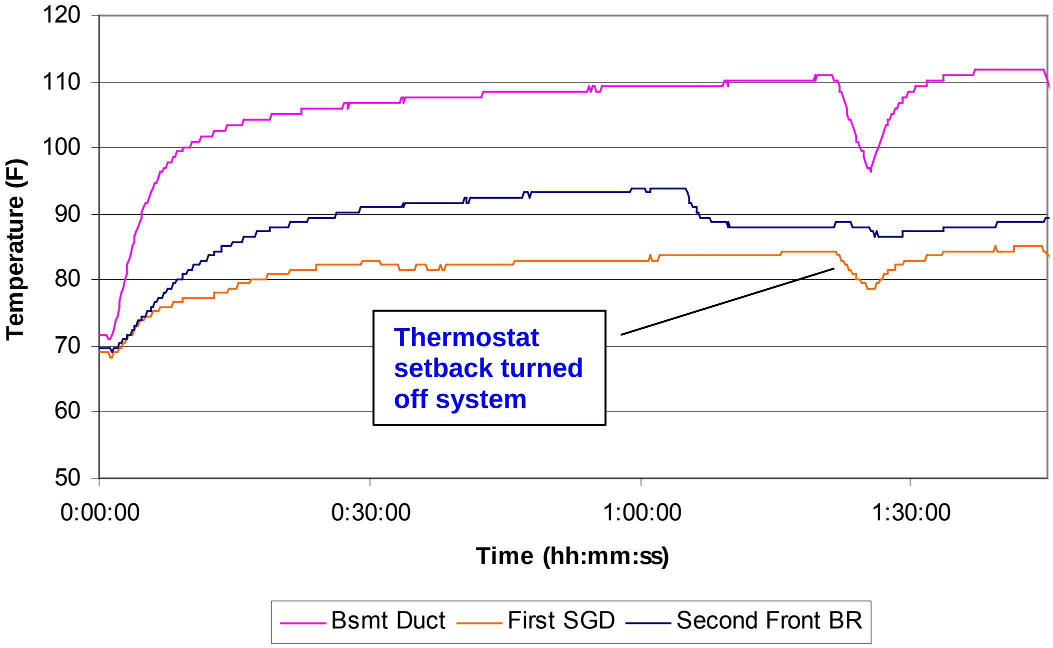


Figure 12: Heating delivery temperatures vs. time

The boundary conditions during this test were:

- Exterior: 61-62° F
- Thermal basement: started at 68° F (air and slabs)
- First floor: started at 68° F
- Second floor: started at 70° F

The temperatures of in the ducts rose to a steady-state condition; they appear to be close to their final temperatures by 30 minutes of runtime. There is a brief drop in temperatures around 1:25; the thermostat reached a programmed setback time, shutting down the system (which was manually turned back on).

The heat pump puts out air at ~110° F (pink line); however, by the time the air gets to the second floor (dark blue), it is closer to 95° F; this can be ascribed to conductive losses through the ductwork. A secondary measurement with a Vaisala T/RH meter was closer to 101° F. It is unclear why the later portion (after 1:00) is closer to 88° F.

However, at the first floor, the delivery temperature is cooler—closer to 84° F. It is clear that some of the heat is getting “soaked” into the basement. This can also be seen from the main data logger temperatures: the basement air temperature rises faster than the first floor. This is expected—the system is supplying air to the basement, and “bleeding” some of it to the first floor.

Of course, it should be noted that the delivery temperatures from the first floor registers are a function of the thermal basement temperatures—i.e., the stored thermal energy in the slab and concrete walls. In this case, the thermal basement was neutral-to-cool (68° F). The performance of the system will depend heavily on whether heat can be “banked” into the thermal basement or not.

The bottom line is that when the thermal basement is “starting from cool” (i.e., 68° F), the second floor has more heat delivered out of the registers than the first floor. For instance, a quick calculation estimates the first floor is getting ½ to 1/3 of the heat of the second floor. But the thing to remember is that the basement is being heated at the same time—and some of that will “soak” from the basement to the first floor. We will need to measure the system in operation to have more definitive results. However, if the thermal mass is often at a cold temperature during the heating season, this might cause temperature distribution/evenness problems between floors; this can be addressed by dampering off the second floor registers.

Time-Temperature Response: Cooling

A similar exercise was done immediately after the heating experiment, with the same set of data loggers, as shown in Figure 13.

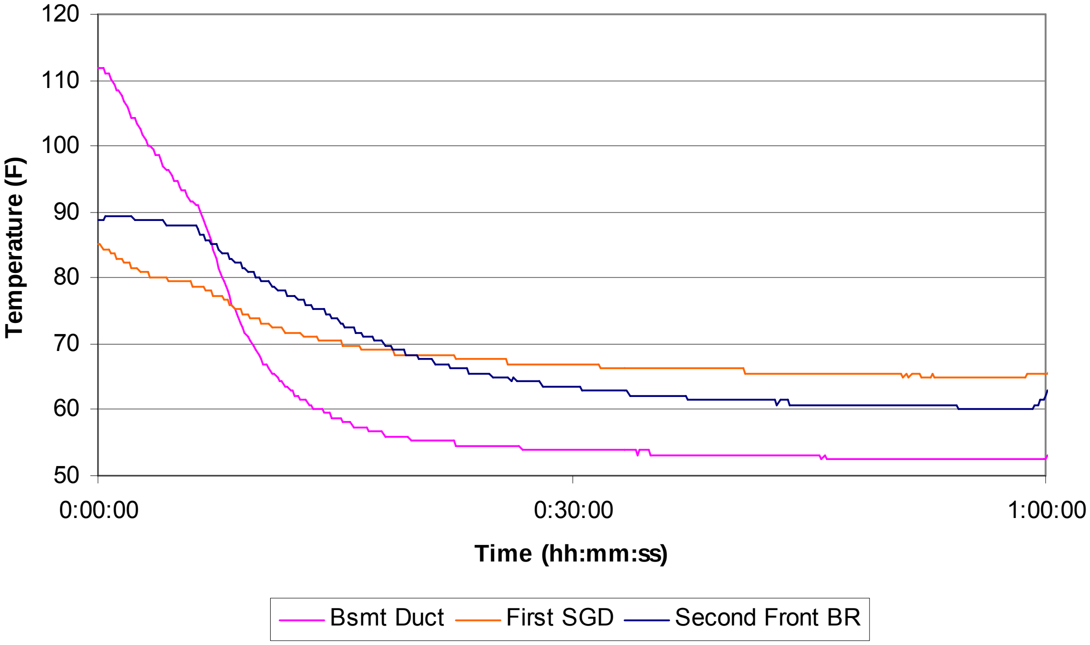


Figure 13: Cooling delivery temperatures vs. time

The cooling system delivery temperature quickly drops to ~53° F; note that the system has to recover from heating system operation, initially blowing 100° F air (which would not occur in real operation of the cooling system).

The second floor register stabilizes are roughly 60° F. However, the first floor register only delivers a warmer temperature (65° F); it seems likely that some of this is due to the stored heat in the thermal basement, from the recent HVAC runtime.

Drainwater Heat Recovery Testing

Background and Instrumentation

A set of experiments was done to determine the effectiveness of the drainwater heat recovery ("GFX") system installed. Temperature measurements were taken of the incoming fresh water ("cold mains supply"), the fresh water that was heated by the GFX ("Tempered Out"), the drain water entering the GFX ("Drainwater In"), and the drain water exiting ("Drainwater Out"). These measurement points are noted in Figure 14.

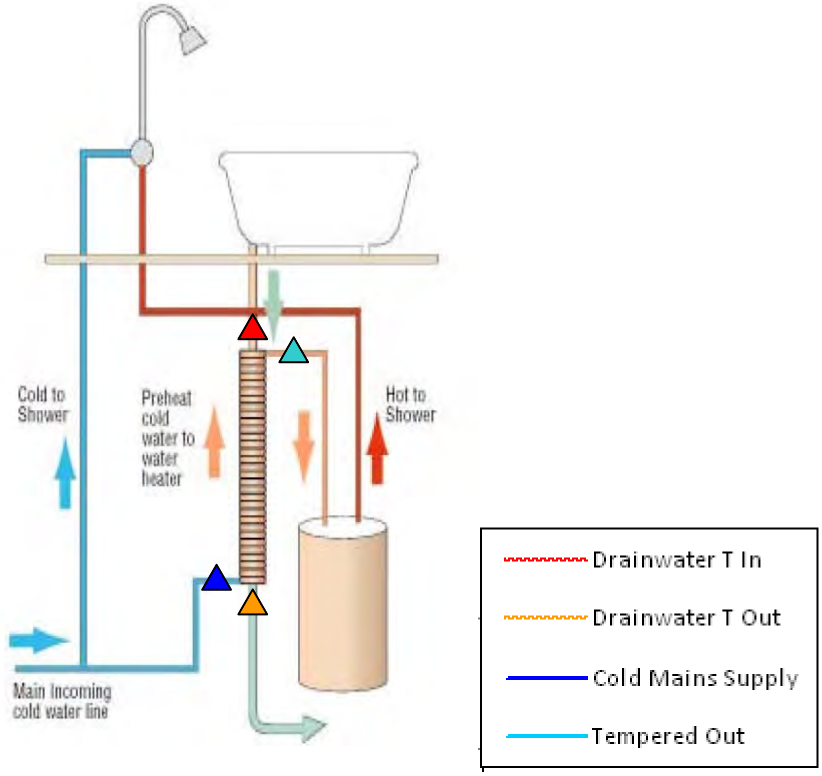


Figure 14: Schematic diagram of temperature measurements

These temperatures were measured using precision thermistors (±0.2° C) attached to the exterior of the copper pipes, and then covered by insulation (as shown in Figure 15 and Figure 16). These measurement points were connected to a Campbell CR500 data logger (Figure 17). In addition, point temperature measurements were taken of the supplied shower/sink water, and the draining water, with a handheld thermocouple (see Figure 18).

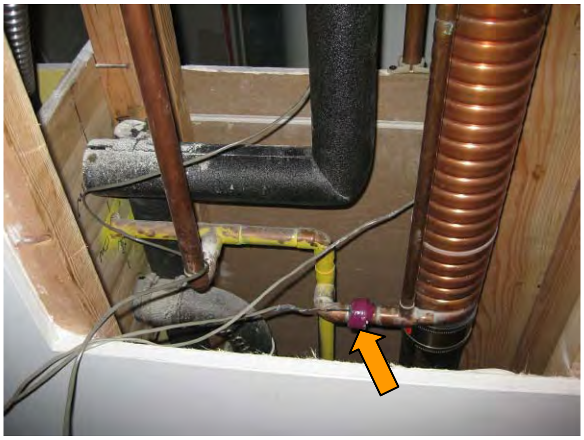


Figure 15: Drainwater heat recovery system, showing cold water input temperature sensor

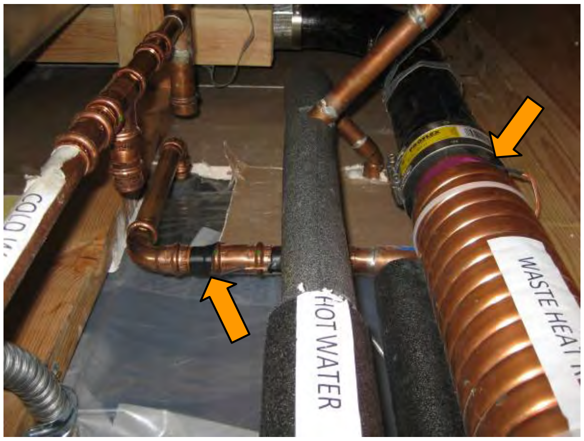


Figure 16: Tempered water output sensor (left) and incoming drain water temperature (right)

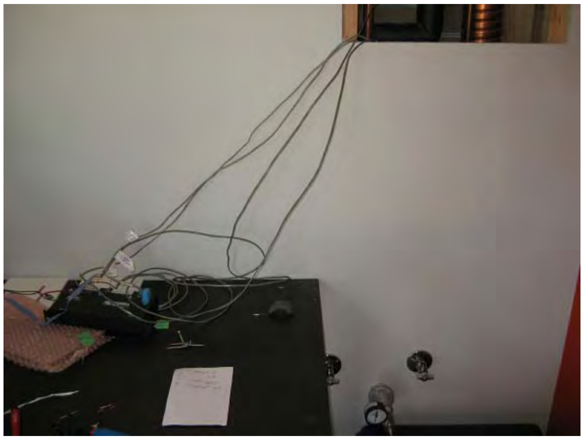


Figure 17: Data logger temporary setup for DHW heat recovery measurements

Figure 18: Handheld thermocouple reader, for hot water measurements (drain water T shown)

Note that this monitoring system not the ideal way to measure water temperatures; some error is introduced by measuring the pipe (as opposed to directly measuring the water). If this experiment is to be repeated on a similar drainwater heat recovery system, the use of test ports (e.g., Pete's Plugs; http://www.petesplug.com/index.html) is recommended.

Water flow rates were measured for the shower, using a stopwatch and a bucket, to determine an average flow (gallons/minute or liters/second). This was measured for the mixed shower temperature, as opposed to any separate measurements of the mixture of cold vs. hot water.

Results

Three tests were completed with this experimental setup, as shown in Figure 19, as follows:

- **Hot water (only), at kitchen sink (133° F/56° C)**
- [Pipes cooled down naturally]
- **Hot water (maximum temperature), at shower (130° F/53° C)**
- [Measurement of flow after test, using bucket and stopwatch. Bucket of hot water poured down drain after testing.]
- [Ran cold water to cool drain lines to more neutral temperature]
- **Hot water (moderate temperature), at shower (111° F/44° C)**
- [Measurement of flow after test, using bucket and stopwatch. Bucket of hot water poured down drain after testing.]
- [Pipes cooled down naturally]

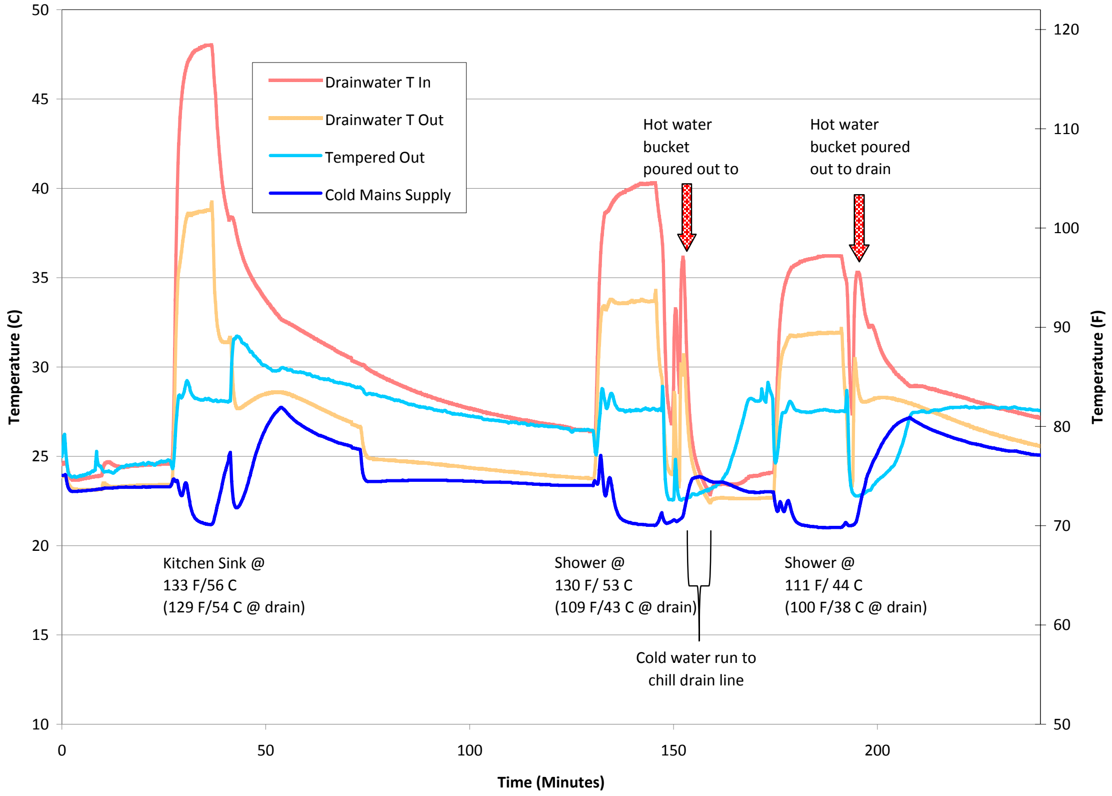


Figure 19: Temperature vs. time results for drainwater heat recovery measurements

Kitchen Sink Test

The kitchen sink portion illustrates the basic behavior of this drainwater heat recovery system. The water was supplied from the tap at 133° F, and was 129° F going down the drain.

This is then seen as a spike in the drainwater temperature: 115-118° F going in to the GFX (red), and 102° F leaving it (orange). Notice that the incoming drain water (Drainwater T in) gradually increases in temperature: it needs to warm up the drainpipes first. However, it reaches a steady state temperature in 5-6 minutes. This addresses one concern mentioned previously—that the thermal mass of the cast iron would "soak up" all of the heat before it went through the GFX.

This can be double-checked against physical properties of cast iron vs. water:

Material	Specific Heat c_p (kJ/kg·K)	Density ρ (kg/m^3)	Volumetric heat capacity (kJ/m^3·K)
Cast Iron	0.46	7300	3358
Water	4.186	1000	4186

Basically, this shows that water stores so much heat that the heat storage of water vs. cast iron is roughly equal on a **volume** basis. Therefore, the heat of a volume of water equal to the cast iron pipes' wall thickness/volume would bring the pipes to about the same temperature (this is an idealized case—in reality, reaching steady state is limited by the conduction through the cast iron pipe).

Once steady state conditions are reached, the fresh water comes out of the GFX is roughly 83° F (light blue). The incoming cold "mains" water (dark blue) drops in temperature to roughly 70° F—this is the temperature of the water main buried in the ground (as opposed to the water sitting in the cold water pipes, which is slightly warmer, at room temperature, 74° F).

The system was then allowed to cool naturally; the drainwater temperatures both fall slowly. However, the "tempered out" and "cold mains" temperatures rise: this is just the residual heat from the heat exchanger migrating to the cold water pipes.

Shower Tests

The results from the shower tests show similar patterns to the previous test, but the results are noticeably different. Each shower was allowed to run for 15 minutes, to reach steady-state conditions.

The first test was to run the shower as hot as possible, which was 130° F/53° C (comparable to the sink temperature). However, the temperature at the top of the GFX was much lower. Hand measurements of the water draining out of the shower (see Figure 18) showed that the water temperature drops from 130° F at the shower head to 109° F at the drain. This was very surprising at first; it is likely evaporation cooling of the small water droplets as they fall from the shower to the floor. Note that this temperature was taken after the shower had been running for a while, so it was not simply the effect of warming the shower floor. **This has the result of reducing the available heat to recover from the shower drain water.**

We then measured the flow rate out of the shower, using a bucket and a stopwatch; the results were a flow of 1.6 gallons per minute (0.10-0.12 liters/minute). Note that the graph shows the effect of pouring this bucket of hot water down the drain in one shot. That graph also shows why this GFX system can not be used for "batch" hot water drainage (e.g., bath, dishwasher, or washing machine): it will heat the "slug" of water in the wrapped pipe of the GFX, but it is a relatively small volume of water, resulting in little recovered heat.

Afterwards, we ran cold water down the shower drain, to cool the pipes back to a "baseline" condition, as shown by the rapid fall in temperatures.

This experiment was repeated with the shower at a more reasonable temperature (111° F); again, the water going down the drain was noticeably cooler (100° F), reducing the available energy. The flow rate was again tested, and was close to the same (1.6 GPM).

From these temperature measurements and the flow measurement, we can calculate the energy recovery of the GFX, as well as the fraction of the shower's water heating energy that it displaces.

Table 4: Heat recovery calculations of GFX for showering

130 F shower

104	T in
92.7	T out
1.6	GPM
8,987	Btu/hr recovered by GFX
Input required for shower @ 130	
69.8	T mains
130	Shower delivered T
47,709	Btu/hr required
19%	**saved by GFX**

111 F shower

97.2	T in
89.2	T out
1.6	GPM
6,277	Btu/hr recovered by GFX
Input required for shower @ 111	
69.8	T mains
111	Shower delivered T
32,651	Btu/hr required
19%	**saved by GFX**

These results are somewhat disappointing: earlier DOE results ("Heat Recovery from Wastewater Using a Gravity-Film Heat Exchanger," DOE/EE-0247 Revised, July 2005) had savings of roughly 40% for this plumbing configuration and temperature range. Possible reasons for this difference include:

- The DOE report assumes that the drainwater entering the GFX is only 12° F cooler than the shower setpoint. Our experiments showed temperature differences of 26° F (130° F shower), and 14° F (111° F shower). This is reinforced by calculating the recovery for the kitchen sink: with a much water drain temperature (129° F instead of 109° F), recovery was closer to 26%.
- The heat loss of the pipe might also play a factor: the water cools by 3-5° F (111° F and 130° F shower, respectively) going from the drain to the top of the GFX. This could be reduced by the use of pipe insulation. This is where the cast iron is hurting us: it has a thermal conductivity several hundred times higher than PVC (55 W/m·K vs. 0.147 W/m·K). If a non-metal pipe (PVC, ABS) cannot be used, pipe insulation would reduce this loss.
- Instrumentation might be introducing some error into these measurements, as discussed above. However, the magnitude of these errors is likely to be small, compared to a factor of two difference in energy savings seen in our measurements vs. the previous work.
- The system configuration is not an issue: the claimed 40% savings are based on simulations of a system plumbed identically to this one (unbalanced flow).
- One thought was that the relatively warm (70° F) ground water is reducing the efficiency of the GFX system—for instance, would results be better with a 60° F water mains temperature, as used in DOE test conditions? The greater ΔT would result in greater recovery of heat from the drainwater. However, at the same time, the water heater needs to put more heat into the water to heat it up to setpoint. As a ballpark calculation, it would come out to a net wash in overall effectiveness (~19%).

TED and Miscellaneous Loads

A TED (The Energy Detective) was installed for whole-house use, near the ee PC in the kitchen. It provides a real-time display of energy use, and a monthly history (similar to utility bills). We also looked at the phantom/standby loads for the house as it is currently operating; some of the "constant on" loads were isolated as follows:

- ee PC: 30-40W
- Router/cable modem: 20 W—all attached to power strip in mechanical room
- Remaining constant loads: 60 W—includes air handler transformer (10 W), the garage exhaust fan (18 W), the zTherm controller, smoke detectors, and any "phantom loads" (appliance standby condition loads).

Overall, these are not unreasonable "always on" loads, but of course, this house is not actually occupied, with associated phantom loads (cell phone chargers, television on standby, Tivo/DVR).

Figure 20: TED installed on kitchen counter

I would recommend that everyone working in the Lancaster unit keep an eye on the TED, just to get a feel for how electrical consumption varies over the course of the day. In addition, the TED stores monthly use (similar to utility bills); the manual should be on the counter or in a drawer, but it can be accessed by simultaneously pressing and holding the "►" and "MODE" buttons.

Air Source Heat Pump Water Heater

The air source heat pump water heater (AirGenerate AirTap) was only partially functional. As mentioned previously, airflow tests performed while we were on site showed that it was "choked" for airflow (due to the added ductwork), running at roughly 85 CFM, compared to its rated 160-180 CFM. In addition, according to the HVAC tech, there appear to be unsolvable problems due to the kinked refrigerant line where it enters the tank. A quick estimate of the efficiency was taken, based on a wattage draw (530 W; see Figure 22) and the volume and temperature of air going in and out of the ductwork (69.5° F vs. 55.5° F); it came out to an energy factor (EF) less than 1.0—i.e., worse than an electric resistance tank.

There are two problems going on here:

- The kinked refrigerant line/heating coil (see Figure 21), and
- The restriction of airflow (85 CFM vs. 180 CFM). This item is very important, and might be the majority of the problem.

Figure 21: Kinked line fitting

Figure 22: Measurement of AirTap power use

Therefore, we talked about moving the heat pump water heater into the garage, thus eliminating the need for all of the ducting, the exhaust duct to outside, and the associated problems. The unit would simply recirculate garage air for domestic hot water. However, this raised the worry of whether this might cause problems: would the cooling caused by the heat pump result in the garage chilling down, frosting up the coils, the unit losing efficiency due to low temperatures, condensation on the walls, or other similar problems?

This will depend on a heat balance resulting from several factors:

- The garage has a continuously running exhaust fan (Panasonic WhisperWall, 98 CFM measured flow). Given the volume of the garage (2010 cubic feet), this is equal to 2.9 air changes per hour (i.e., volume of garage is replaced with outside air 2.9 times per hour).
- The garage faces west, so is heated by solar gain above outdoor temperatures (see Figure 23 below, for summertime data).

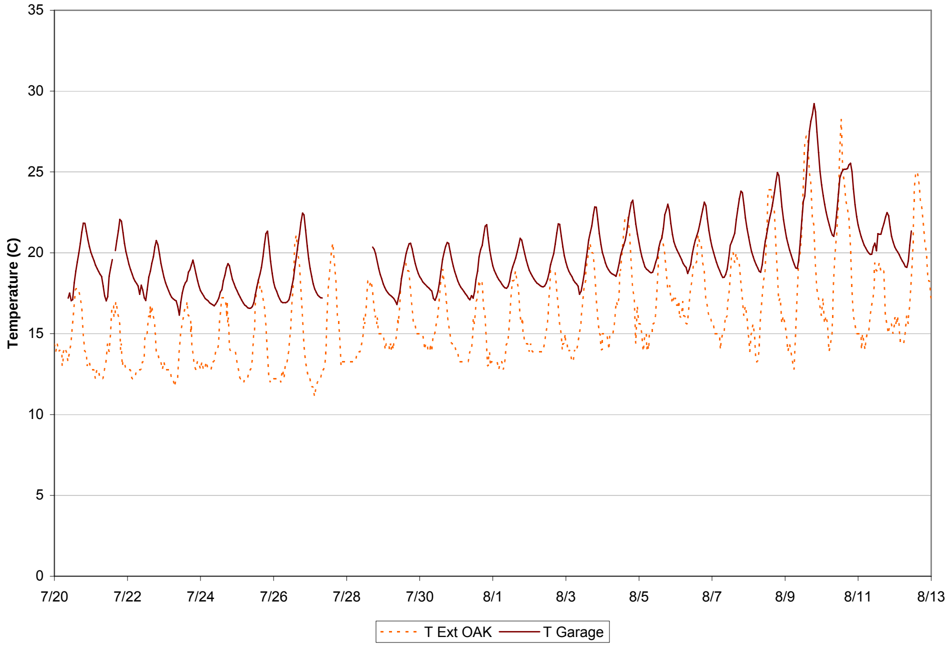


Figure 23: Outdoor temperature and garage temperature (July-August)

- The PV system inverter is located in the garage; weighted efficiencies are in the 95-96% range. This means that 5% of the energy coming from the PVs will be released as heat into the garage—reducing any "overcooling" issues.

  We ran some quick estimates; the amount of heat released would be equal to roughly 20% of the total energy demand of the water heater, which is a non-insignificant amount of heat.

Based on the ventilation rate and the garage temperatures, it appears that placing the heat pump water heater in the garage should work. However, we will continue to monitor the temperature of the garage with our data logger system; it will be critical during wintertime months. The worst case would be very large water draws during the worst wintertime conditions.

Finally, the AirGenerate installation directions state that the volume of the garage should be adequate for functioning:

> *The AirTap™ can only be placed indoors. If using the unit in an attic, garage or basement, the unit can be installed without any additional equipment. However, if using the device in a space with less than 1,000 cubic feet, an external vent will likely be necessary as well as ductwork to direct the cool air expelled from the unit. A duct kit can be purchased from AirGenerate.*

Your next question is probably, "Why can't we just leave the door to the mechanical room open to the garage?" The problem is that the walls, floor, and roof of the mechanical room are mostly (or completely) uninsulated (e.g., electrical panels, mechanical core), not to mention filled with all sorts of mechanical penetrations (see Figure 24 through Figure 26). We would be using the walls as the separation between inside and outside. This would result in many air barrier penetrations; our previous testing showed just how critical these leaks are (i.e., taping shut the mechanical room door).

This was the reason to begin with why we decided to move the thermal barrier (insulation and air barrier layer) from "wrapping" the mechanical room, to the wall between the mechanical room and the garage.

In addition, I am not sure how strong the AirTap's fan is: it is possible it will create a "pocket" of cold air; the volume of the mechanical room is only ~160 cubic feet.

Figure 25: Mechanical core from interior side, showing uninsulated mechanical core

Figure 24: Wall between mechanical room and bathroom, showing electrical panel and wires

Figure 26: Mechanical room-bathroom wall, showing electrical penetrations

Just to brainstorm out the idea, we considered the possibility of moving just the AirTap unit (the “box”) to the garage, and leaving the tank in the mechanical room. This should would work in theory, however, a large portion of the heating coil would be left outside of the water tank; this loss of heat exchange surface would result in a drop in efficiency. Therefore, this concept is not recommended.

As per previous correspondence, integrated heat pump water heater units are either available or will soon be available from General Electric and Rheem. If your experience with the AirTap has completely soured you on AirGenerate, you might consider those alternatives.

Action items: ZETA to look at option of moving water heater into garage (with associated plumbing and electrical connections, and support platform). BSC to continue to monitor garage temperatures, once heat pump water heater operation begins, for signs of problems.

Memo of Record

From:	Kohta Ueno, Building Science Corporation	Date:	March 17, 2009
To:	Steve Spademan, ZETA Communities; Dan Smith, DSA Architects	Re:	Data logger and control system preparation requirements

Hello Steve:

I wanted to send this document along, providing a more-exact description of the preparation requirements we will need for the data logger and control system at the ZETA Prototype (Lancaster Lofts Duplex) for our field visit in late April.

Thank you,

Kohta Ueno

-Kohta

Data Logger Location

At the data logger location (crawl space, probably near the air handler), we will require the following items:

- 120 V power outlet (for powering data logger), plus additional outlet for incidental uses (laptop computer, etc.) Quad box would be acceptable.
- 10BaseT network connection, **with static IP address**. Necessary for connection to Campbell NL100 Network Link Interface (http://www.campbellsci.com/nl100). Further information on the requirements for this network interface can be found in the NL100 documentation (also available on the Campbell website: http://www.campbellsci.com/documents/manuals/nl100.pdf).
- Lights (lights provided to crawl space should be adequate, if fixtures are close to logger location)
- ½” or ¾” plywood board roughly 2’ wide by 2’ tall, scrap 2x4s, saw. This will be used to mount our equipment; we will decide on-site where we are locating this board (most likely screwed to a floor joist). An example of a much larger installation (2 data loggers, 10 peripherals) is shown in Figure 1. Also, if you could have one of your carpenters or workers available/on call at the site during our field work, that has typically been very useful for our installations.
- Cable connections as described below, **clearly labeled**, and with adequate extra cable slack to allow routing to instruments.

Figure 1: Data logger/controller setup for large installation (much larger than ZETA)

Prepared Wiring Runs (Sensors)

The following wiring runs need to be installed prior to our work (and probably prior to closing the walls and setting the boxes). The layout can be seen in Figure 7.

- Outdoor temperature/RH sensor: wire runs from logger location to the **north side of house** (shaded location). 3 pair (6 conductor) telephone or network (Cat 3, Cat 5, or Cat 5e) cable. Can be terminated either hanging out of a hole, or alternately, coiled inside an exterior electrical box with cover (see Figure 2). Note that a smaller box (single gang) is fine in this application.
- Second floor/RH temperature sensor: wire runs from logger location to central location on second floor (near thermostat), out of direct sunlight. 3 pair (6 conductor) telephone or network (Cat 3, Cat 5, or Cat 5e) cable. Can be terminated using two options: (a) in an electrical box or a low voltage mounting bracket with blank plate (see Figure 3)—but **the sensor will be visible** in service, or (b) in a "fake thermostat" (see Figure 5 and Figure 6).
- Second floor temperature sensor in skylight well: identical description to second floor temperature sensor, but located on south (shaded) side of skylight well. Unused leads from this wire can be used to connect to rain sensor, if available.
- First floor temperature sensor: identical description to second floor temperature sensor: central location on first floor out of direct sunlight

The outdoor temperature sensor will be protected by a segment of pipe (see Figure 4); this will hopefully be unobtrusive enough.

The remaining temperature sensors (i.e., thermal basement, concrete slab temperatures) can be installed by our team while on-site.

Given the modular construction, these lines must be spliced together when the boxes are assembled. We recommend the use of "3M™ Scotchlok™ IDC Butt Connector UY" to complete these splices (see http://solutions.3m.com/wps/portal/3M/en_US/Telecom/Home/Products/Products/?PC_7_RJH9U5230GE3E02LECIE20O4M7_nid=NZW3RHPDRDbeDP16W8FB2Ngl) No stripping of wires is necessary for these splices. These connectors are available in small packs at home centers, or in larger packs at any telecommunications supply store (e.g., Graybar)

Figure 2: Outdoor electrical box with sensor as example

Figure 4: T/RH sensor protected by pipe segment (indoor application shown; will be used for outdoor sensor)

Figure 3: Low voltage mounting bracket

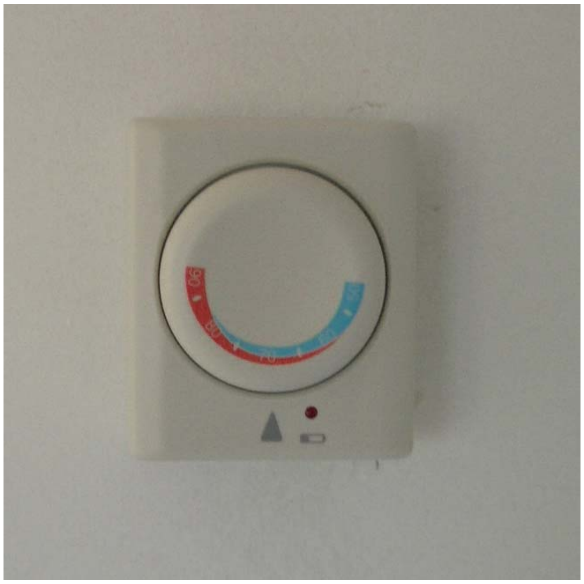


Figure 5: Fake thermostat temperature sensor

Figure 6: Fake thermostat temperature sensor

Sensor can be shifted along north wall as needed

Exterior temperature/ RH sensor

First floor T sensor (can be inside return)

Second floor T/ RH sensor (next to thermostat)

Skylight well T (south side wall of well, shaded side)

Sensor Key:
▲ Temperature
● Relative humidity/temperature

● ▲▲ ▲

Crawl space list: T/RH, T in crawl slab (x2), T in first slab (x1, drilled from below) (to be installed by BSC)

Figure 7: Sensor layout schematic

Wiring Runs (Controls)

One wiring run for controls will be need to be installed before our site work:

- Control line for skylight (from skylight control to logger location). ZETA must provide specifications/interface information for controlling the Velux VSE Series Skylight, including what signal/voltage are required for opening and closing of the skylight (5V/24V/120V; switch closure or energize). It is our understanding that the Velux WLF 111 controller operates by having a switch closure for "open" signal, and a switch closure for "close" signal. This must be verified before BSC's field work.

The remaining wiring runs will be required to control the mechanical equipment. It is likely that we can run these cables, but if they can be completed prior to our arrival, they will save us time.

- Thermostat control cable from large motorized damper (outside air 14x8) to logger location
- Thermostat control cable from small motorized damper (outside air 6" round) to logger location
- Thermostat control cable from air handler to logger location

As a reminder, a motorized damper is required for both of the outside air ducts: the large "free cooling" duct and the small "ventilation" duct.

Campbell Order Clarification

This discussion informs which Campbell equipment is and is not necessary. Items that are no longer necessary are greyed out. This supersedes my previous email on this topic (February 24, 2009 "Re: FW: Quote on Campbell Scientific Instrumentation"):

- 1 ENC12/14 WEATHER-RESISTANT 12 X 14 INCH ENCLOSURE1 ENC MOUNTS TRIPOD MAST **NOT NEEDED**
- 1 SUB ENC12/14 W/2 CONDUITS FOR CABLES **NOT NEEDED**
- 1 PS100 PTO 12V POWER SUPPLY W/CHARGING REGULATOR & 7AHR SEALED RECHARGEABLE BATTERY
- 1 POWER WALL ADAPTER AC/AC 110VAC TO 18VAC 1.2A, 6FT CABLE
- 1 CR1000 PTO MEASUREMENT & CONTROL MODULE W/CR1000WP
- 3 107-L TEMPERATURE PROBE (-35 TO +50C) (EACH SENSOR WILL HAVE A 25 FOOT CABLE) **WRONG SENSOR: THIS IS TEMPERATURE ONLY (NOT TEMPERATURE/RH) REPLACE WITH PRODUCT BELOW**
- 1 HMP50-L VAISALA TEMPERATURE AND RH SENSOR. ORDER WITH MINIMUM LEAD LENGTH; IT WILL BE SPLICED AT OUTDOOR BOX (SEE Figure 2) **MUST BE ADDED TO ORDER**
- 75 CABLE 22 AWG 1 TWISTED PAIR SHIELDED W/DRAIN SANTOPRENE **NOT NEEDED: CABLE WILL BE SPLICED AT OUTDOOR BOX**
- 3 41303-5A RM YOUNG 6-PLATE GILL SOLAR RADIATION SHIELD **NOT NEEDED**
- 1 LOGGERNET DATALOGGER SUPPORT SOFTWARE

Photovoltaic Output Logging

The Campbell CR1000 will have pulse counter ports available with the logging package described below. These can be used to log photovoltaic system output, if provisions have not been already made to do so. If this is required, two options are presented:

- A kWh meter that produces pulse outputs (e.g., IMS Blue Series 1000 1 or 2 Phase Three Wire (2 Element) kWh Meter) must be provided; a kWh meter probably runs roughly $300-500.
- Alternately, it is possible that the PV inverter has some metering output available. The availability of the signal and type of signal must be verified by ZETA.

Sensor List

This is mostly for our own records and preparation; it is a list of sensors to be provided. Note that not all of these sensors are required for the final controller: they are being used for our research that examines the behavior of this house.

- T/RH exterior (north side of building) (Campbell HMP50-L Vaisala)
- T/RH second floor
- T (only) skylight well (south side/shaded)
- T (only) first floor
- T/RH thermal basement
- T x2 thermal basement concrete surface/mid-slab
- T first floor concrete slab (drilled from below)
- Current sensor switch on indoor HVAC unit (air handler) for runtime
- Current sensor switch on outdoor HVAC unit (condenser) for runtime

Sensor count = 8 T + 3 RH + 2 switch closures = 13 channels (16 available)

Controls List

This is mostly for our own records and preparation; it is a list of control ports to be used.

- Air handler (low speed)
- Air handler (high speed, for heating and cooling)
- Heating
- Cooling
- Outside air ("free cooling") damper
- Ventilation damper (and/or control by AirCycler FR-V)
- Skylight open (switch closure)
- Skylight close (switch closure)

Control list count = 8 (8 ports available; pulse counts occupy C ports as well)

June 2, 2009

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ATTN: Bob Hendron, Ed Hancock

Pacific Gas & Electric
ATTN: Lee Cooper, Nicholas Rajkovich, Anna M LaRue

Re: ZETA Lancaster Prototype (V1) Testing and Monitoring Plan

Dear Ms. Sankaran:

The following document describes Building Science Corporation's current plans for short term testing and long-term monitoring at the ZETA Lancaster Prototype in Oakland, CA. The two phases described here are as follows:

- Short-term commissioning testing, which is slated to be accomplished during BSC's field visit of the week of June 15th, 2009. There may be some items on that list which will not be completed at that time; those items will be accomplished during future visits.
- Long-term monitoring, which will be used to determine the performance of the house and its systems.

If you have any questions, you can reach me as per the contact information below, or at kohta@buildingscience.com.

Thank you,

Kohta Ueno

Cc: John Straube, Ph.D., P.Eng., Aaron Grin; Building Science Corporation

1. Short Term Commissioning Testing

Most of the fundamental testing is required as per the provisions of BSC's Building America Program Performance Criteria, as described here:

http://www.buildingscienceconsulting.com/buildingamerica/targets.htm

This includes targets for air leakage, duct leakage, mechanical equipment installation, and room pressurization. It is divided into requirements and recommendations. The information typically required for testing is recorded in BSC's SNAPSHOT ("Short, Non-destructive Approach to Provide Significant House Operation Thresholds") form:

http://www.buildingscience.com/documents/reports/rr-0413b-snapshot-form
http://www.buildingscience.com/documents/reports/rr-0413-the-snapshot2014a-quick-description

Some of the major testing procedures are described below.

Infiltration (Blower Door) Testing

Blower door testing of the unit will be completed to measure airtightness.

Target: less than 2.5 square inches/100 square feet surface area leakage ratio; equal to 1154 CFM 50 (air flow needed to generate 50 Pa of pressure difference).

We will also complete additional tests beyond the required Building America regimen, for our research purposes:

- Air leakage of crawl space alone, using nulling (pressure equalization) methods and Duct Blaster fan
- Zone pressure diagnostic testing, to determine relative leakage of spaces such as the crawl space, mechanical room, and garage (see http://www.energyconservatory.com/products/products8.htm, under Free ZPD Calculation Utility)
- When second unit (V2) is set, nulling blower door testing to determine leakage between units/interconnectivity and compartmentalization
- A combination of visual inspection and possibly smoke testing, to determine the location of remaining air leakage points, if significant

Mechanical/Ductwork Leakage and System Testing

The ductwork system will be tested for leakage using fan depressurization testing.

Target: Less than five percent of the total air handling system rated air flow at high speed (nominal 400 CFM per ton) determined by pressurization testing at 25 Pa. Target for 2 ton nominal system is 40 CFM 25.

This target is for duct leakage to the outside, to be determined with combined blower door/duct blaster testing. Total system leakage (to inside plus outside) will also be tested. In addition, these further tests will be run:

- An examination of leakage at the "free cooling" (economizer) damper, to determine if excess leakage to the outside is occurring at this location
- Airflow measurements at HVAC duct registers, via balometer/flow hood. Adjust flows with dampers if required relative to Manual J calculations.

- Standard SNAPSHOT test items, including room pressurization checks (under 3 Pa target), and recording equipment model numbers.
- Test of temperature vs. time while in heating mode at thermal basement, supply plenum, first floor register, second floor register (temperature HOBOs at short interval), to measure supply temperature response with and without thermal mass coupling.

Mechanical System: Ventilation (Heat Recovery Ventilator)

[Note: requires HRV to be powered up, ducted, and all grilles/hoods installed.]

- Flow hood measurement of supply and exhaust sides of heat recovery ventilator
- Wattage measurement (Kill-A-Watt) of HRV, to determine CFM/W efficiency, and compare to manufacturer's specifications. Determine if defrost setting might cause continuous phantom load.

Mechanical: Air handler System

[Note: requires AHU to be powered up, ducted, and all grilles/registers installed. To measure COP, outdoor unit must be installed and powered, refrigerant charge set.]

- HVAC system static pressures (under 125 Pa/0.5 IWC target)
- Air handler power draw at various speeds & modes, using Kill-A-Watt or The Energy Detective (TED) if hard-wired or two-phase power. Include test of economizer damper open; resistance of system should go down
- Air handler airflows at various speeds &modes; use concurrent power measurements to determine air handler fan efficiency (CFM/W); compare to previous work.
- Test of coefficient of performance (COP) of unit operation (at a single point exterior temperature)—Vaisala T/RH meter for plenum conditions ($\Delta T/\Delta W$), airflow measurements, and draw of indoor and outdoor unit; TED or WattNode installation required for outside unit power draw

Mechanical: Domestic Hot Water (DHW) System

[Note: requires AirTap to be installed, connected, ducted, and powered up, as well as supply water availability.]

- Airflow through duct of AirTap system, relative to the rated 180 to 160 CFM. Or is the ductwork system too restrictive? Delta T across system if possible, to determine instantaneous Btu input
- Infrared surface temperature meter; estimate jacket losses through tank sides; is it worthwhile to add additional insulation?
- Short-term testing of the drainwater heat recovery system—connect thermistors, determine heat stored in cast iron drain pipe system; is this a significant detriment to performance or not? Use flow measurement (shunt line) to determine overall Btu/hr exchange of drainwater heat recovery system.

Enclosure/Other

- Window Low E/film coating—grab image of laser thickness meter showing two panes + film of Serious Material 725 Series

2. Long Term Monitoring

In order to determine the long-term energy performance of this house and the functioning of the zTherm thermal mass/thermal comfort/energy optimization controller, a data logger (Campbell Scientific CR1000) will be installed to collect a variety of data points. Some initial discussions on the monitoring plan can be found in the document "2009-03-17 Instrumentation Preparation Work" which has been submitted to Steve Spademan, John Paddock, and Jeremy Fisher.

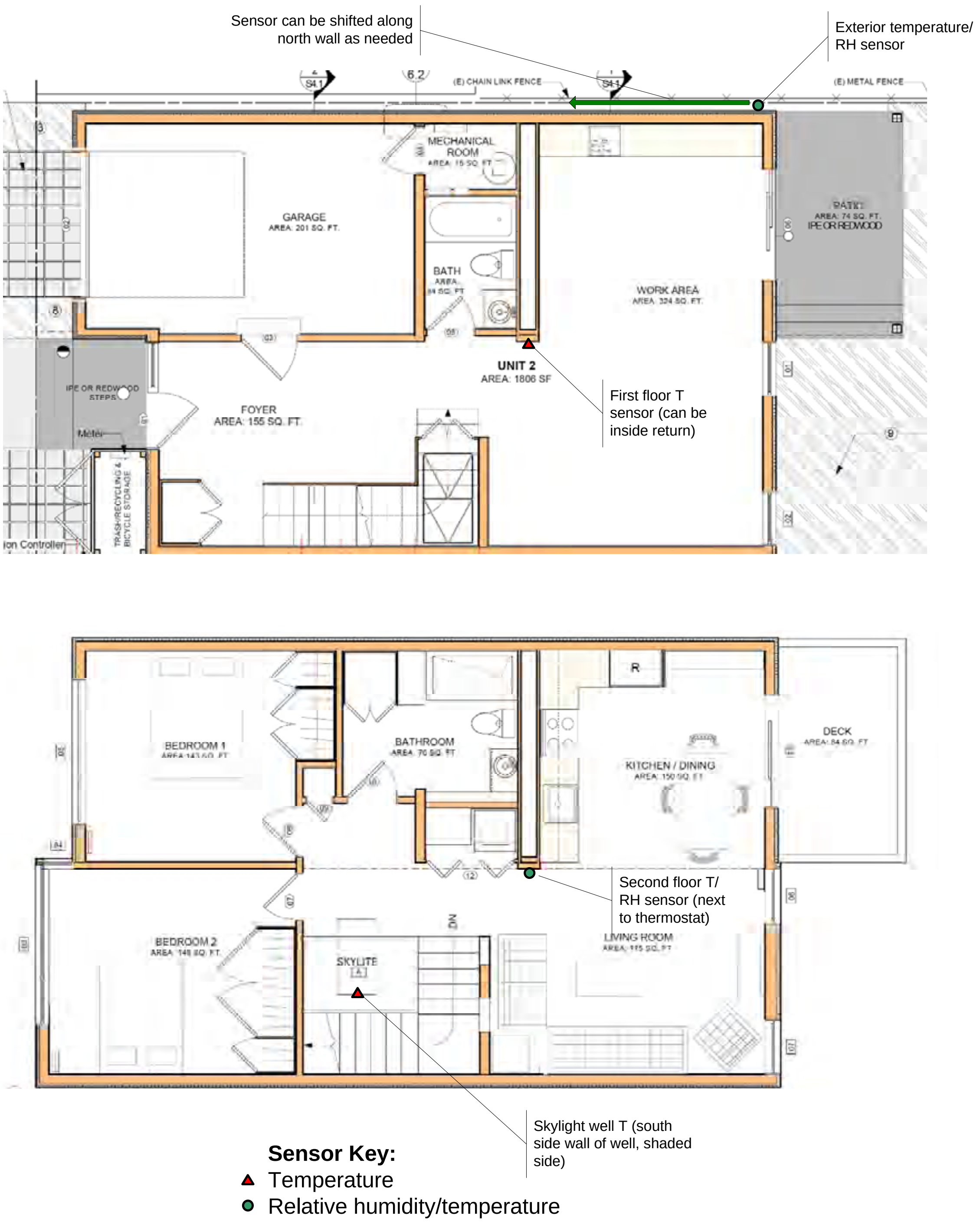
Our goal would be to leave this equipment installed and recording data for at least a year, and potentially longer if useful data can still be gained. For instance, modifications to systems over the course of the year could be evaluated in a before/after comparison of the same season (winter 2008-2009 vs. winter 2009-2010).

Campbell Logger Connected Channels

All data from the Campbell logger will be recorded hourly, and kept in on-board memory. This data will be used to evaluate the effectiveness of the zTherm control algorithms, and potentially used to optimize these algorithms.

A network interface (Campbell NL120 Ethernet Module) will be used to download data remotely; this will require a network connection at the logger, as, described in "2009-03-17 Instrumentation Preparation Work." The planned channels are as follows; they are also illustrated in Figure 1.

- T/RH exterior (north side of building) (Campbell HMP50-L Vaisala)
- T/RH second floor
- T (only) skylight well (south side/shaded)
- T (only) first floor
- T/RH thermal basement
- T x2 thermal basement concrete surface/mid-slab
- T first floor concrete slab (drilled from below)
- Current sensor switch or relay on indoor HVAC unit (air handler) for runtime.
- WattNode watt hour meter; measuring hourly consumption of outdoor (condenser) unit. Connected to pulse count channel
- Horizontal solar radiation



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Crawl space list: T/RH, T in crawl slab (x2), T in first slab (x1, drilled from below) (to be installed by BSC)

Figure 1: Sensor layout schematic

Domestic Hot Water Long Term Testing

The AirGenerate AirTap A7 system is of particular interest; it has the promise of making domestic hot water at an all-electric site far more efficient than resistance heating; however, there are some concerns due to the overall output (7000 Btu/hour) and its ability to keep up with domestic hot water demands. The plan is to measure equipment runtime and monthly power draw of the AirTap unit. If the electric resistance element is connected as a backup, runtime will be monitored. Therefore, the monthly contribution of domestic hot water to the monthly (utility bill) use can be disaggregated. The logged channels will include the following:

- Monthly electrical consumption of AirTap (heat pump) using Energy Detective (TED).
- State logger (on/off) of AirTap, to provide runtime patterns
- State logger of electric resistance element, if connected
- Temperature of garage (source of air for heat pump water heater); electricity usage can be estimated from manufacturer's stated COP curve. Also, actual garage temperature data would be useful, given that only estimates were previously available for this input condition for the AirTap.

Measurement of water tank temperature would be interesting; however, it would be difficult for several reasons. For one, an immersion temperature sensor (e.g., thermocouple in well) would be required for tank temperatures. Second, high/low temperature sensors would provide the best resolution of the response of tank temperature to DHW draws and heating. Third, sub-hourly time steps would be required to have useful data on temperature recovery times; hourly measurements will provide relatively poor resolution. Having a tighter timestep would increase the amount of data, and require greater data logger storage, and conflict with the hourly timestep used for other data collection.

Drainwater heat recovery system short-term testing

As discussed earlier, the drainwater heat recovery system will be tested during the commissioning testing trip. The current plan is to temporarily connect the four temperature channels (thermistors) to the CR1000 data logger, and run a short term program to record temperatures at a short timestep. The shower water temperature will be recorded manually with a handheld thermocouple (both coming out of the shower head, and at the drain).

- T incoming supply water (T mains)
- T outgoing supply water (T tempered)
- T incoming grey water
- T outgoing grey water

August 14, 2009

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Re: ZETA Lancaster Lofts V1 Testing Action Items

ZETA Team:

This letter covers the immediate action items for the ZETA Communities V1 Prototype at 612 Lancaster Street, Oakland, CA 94601, based on BSC's testing and instrumentation visit of August 10-12, 2009

A summary of the action item is shown in **bold/red**, at the beginning of each heading.

Several items in the list below reference Andy Wahl's "Zeta Follow-up Items August 4, 2009," which are a list of items to be completed before an additional site visit from him; they are shown in *italics*. I wanted to point them out, because some items coincide with BSC's list, and should be completed before his visit. You should probably forward this report on to him, to let him know what is being worked on, and in what manner.

If you have any questions or comments about this report, please contact Kohta Ueno of Building Science Corporation (kohta@buildingscience.com), or as per contact information shown. However, I will be out of the office from August 15th through August 25th (inclusive);

Sincerely,

Kohta Ueno

Cc: John Straube, Ph.D., P.Eng., Aaron Grin (Building Science Corporation)

Encl: Fantech FR Inline Fan Excerpt

Action Items

Air Handler Filtration

Replace current filter with 4" MERV 13 filter

The filter provided with the filter housing was a MERV 8, 4" unit. MERV 13 is required for a LEED point.

- EQ7:** MERV 8 filter installed.* ***Zeta to install MERV 13 and Andy to check during next site visit.

Although a MERV 13 filter was provided to BSC on site, it is a 2" pleated media filter. Using a 2" filter will increase static pressure (i.e., burn more electricity at the fan motor), reduce airflow, and have a shorter lifespan than a 4" filter.

An example of a reasonable MERV 13 4" filter is:

- 20x25x5 MERV 13 Honeywell Replacement Filter (2 Pack)
  http://www.amazon.com/20x25x5-MERV-Honeywell-Replacement-Filter/dp/B000V2LN58
  Nominal size 20 x 25 x 5/ Actual size 20 x 24 3/4 x 4 3/8

The actual dimensions of current 4" filter (ICP MERV 8) is 24-3/4" x 19-7/8" x 4-1/4", so the Honeywell filter listed above should fit.

Figure 1: MERV 13 2" filter vs. MERV 8 4"

Figure 2: Removal of return grille filters

Incidentally, when the HVAC contractor bid the job of installing the 4" filter box, was it in his contract to provide a MERV 13 filter? Or was it not specified? Just something you might be able to get as a callback item.

In addition, BSC removed the return grille filters, which are now redundant, and would end up increasing system pressures/reducing airflows (see Figure 2).

Duct Leakage

Remove slumped mastic from second floor return.

The HVAC contractor came by while we were testing to perform retrofit sealing on the ducts. He applied mastic to the first and second floor returns; however, Aaron Grin noticed that the heavy layer he put on the second floor return had slumped to the bottom of the return.

Figure 3:Slumped mastic at upstairs return

It is our understanding that the supply boots were sealed to the floor, and the toe kick register was sealed prior to our trip, but after Andy Wahl's testing. BSC needed to remove the blue masking tape sealing the air handler, in order to perform testing on this trip; the air handler itself is typically a substantial portion of the total leakage (50+ CFM 25).

- EA1/IAP 4.2: Duct Leakage Test: Duct leakage total is 266 cfm (36% leakage), leakage to the outside is 59 cfm (7.4% leakage). Duct test requires <6% of total duct leakage. This fails.-----Supply boots not sealed to floor, return duct has building framing showing. All ducts are required to be approved duct material. ***Zeta to correct ducts. Andy Wahl to then conduct additional site visit.***

Economizer/"Free Cooling" Damper

Check damper gaskets; possibly replace power open/power closed economizer damper with power open/spring closed damper.

The economizer duct system was replaced as per BSC's directions, from a 10" round to a 12" round. The HVAC system was run with the damper in the closed position, and the leakage past the damper was measured with a flow capture hood.

Figure 4: Measurement of economizer flow

Figure 5: Manually tightening damper seal

The leakage was measured at:

- 39 CFM (to exterior) as found
- 19 CFM (to exterior) manually rotating the damper against the gasket (see Figure 5)

This is significant duct leakage to outside, and has a substantial energy penalty. For further illustration, see the effect of the leakage on a piece of paper below:

Figure 6: Outside economizer damper; HVAC system running

Figure 7: Suction at economizer damper due to leakage past damper

BSC did not disassemble the damper to check the gaskets on this trip; this should be the first thing checked. It is possible that the gasket is not set up to make a very good seal against the damper.

However, more importantly, the damper installed is a "Power Open/Power Closed" damper (apply power to one set of terminals to open, and to another set to close). Instead, a "power open spring return" damper would use its spring force to compress the gasket. Also, it is much simpler to control (power open = damper open). This is BSC's typical damper for these applications.

Somebody should verify with John Stockton as to what type of damper system he has set up his controls for (power open/power closed damper vs. power open/spring return damper).

Domestic Hot Water

Team needs to decide whether to continue to attempt repairs on AirTap, or replace with a different model. Further simulation required to determine whether garage location can be used to eliminate ducting and associated problems.

The air source heat pump water heater (AirGenerate AirTap) was only partially functional. Problems were earlier reported with condensation on the sheet metal exhaust duct through the plumbing core, when operating the unit. Preliminary tests showed that it was "choked" for airflow (due to the added ductwork), running at roughly 85 CFM, compared to its rated 160-180 CFM. In addition, according to the HVAC tech, there appear to be unsolvable problems due to the kinked refrigerant line where it enters the tank. A quick estimate of the efficiency was taken, based on a wattage draw (530 W) and the volume and temperature of air going in and out of the ductwork (69.5° F vs. 55.5° F); it came out to an energy factor (EF) less than 1.0—i.e., worse than an electric resistance tank.

Figure 8: Kinked line fitting

Figure 9: Measurement of AirTap power use

Instead of trying to add a fix to a fix to a fix, we want to step back and look at our options. First, some type of heat pump water heater is necessary to achieve the efficiency levels required for Building America, if electricity is being used as a fuel source for domestic hot water. In other words, it's not something that we can just drop.

One suggestion was to move the water heater into the garage, which would eliminate the ducting issues discussed above. Moving the water heater would require moving the cold/hot piping connections, and the 240 V electrical connection. However, pulling heat out of the garage and putting it into the water tank will chill down the garage—and it might become colder and colder during hot water draws. On the other hand, there is a continuously running exhaust fan (98 CFM) to provide air change to the garage.

A preliminary simulation showed that moving the AirTap to the garage, even with the exhaust fan, might result in temperatures down in the 30s in wintertime, and closer to the 40s or 50s in summertime. However, this is only a preliminary model, and should be adjusted.

For information's sake, General Electric is coming out with a heat pump water heater ("GE Hybrid Electric Water Heater"); it is expected out in the fourth quarter of 2009, and will be priced in the range of $1,200 to $1,500.

- http://www.geconsumerproducts.com/pressroom/press_releases/appliances/energy_efficient_products/doetanklesshybrid.htm
- http://blogs.consumerreports.org/home/2009/01/ge-hybrid-electric-water-heater.html

Heat Recovery Ventilator

Install Fantech inline fan on exhaust port of HRV, replacing existing exhaust fan (lower left hand side).

The controls for the HRV are now correctly set up; pressing the button in either bathroom will provide 20 minutes of runtime at high speed to exhaust the bathrooms. In addition, the control functions as a central ventilation system, turning on the system ~15 minutes every hour; this setting is controlled by the slider on the Fantech Ventech VT20 switch (see Figure 12); this can be changed by removing the switch plate cover and moving the slider.

The HRV was originally set up with the exhaust system connected backward (supplying air into the bathrooms, instead of exhausting). I disassembled the HRV, in order to swap the fan to the correct direction (see Figure 10), and then measured the exhaust flows from the bathrooms:

- Upstairs bathroom: 47 CFM
- Downstairs bathroom: 36 CFM

Unfortunately, both of these measurements are below the 50 CFM required for Builders Challenge, LEED, and ASHRAE 62.2. Therefore, we need to somehow increase flow through the exhaust ducts, when this system is activated.

Dan Smith originally suggested adding a Fantech inline ("tube") fan, replacing the HRV fan, in order to increase the flow. Based on the fan curves, a model FR 150 should provide adequate flows to both bathrooms. Note that it must be wired in to high voltage (120 V) switched red out of the metal flex conduit (i.e., not the DC outputs from the silver box inside the HRV). I do not have many good suggestions on the fan location: space will be very tight (see Figure 11). The FR 150 is 6-3/4" long x 11-3/4" diameter.

Figure 10: Removal of HRV exhaust side fan for reversal of flow direction

Figure 11: Available space on left hand side of HRV installation

Figure 12: Fantech Ventech switch; note left hand slider (60 to 0)—minutes runtime/hour

- EQ4.3: Need to conduct 3rd party performance testing of ventilation system. This was not completed due to Zeta party afternoon of visit. ***Andy Wahl to conduct additional site visit to perform test.***

zTherm Controller

Install solar radiation shield on outdoor temperature sensor.

The display on the zTherm controller was showing temperatures of 105° exterior T, when actual conditions were closer to 73° F. This is likely due to solar radiation hitting the outdoor temperature sensor, which results in higher readings than air temperature. The solution to this problem is to use a radiation shield, which has a white (non absorbing) surface, but has enough air ventilation to carry away most excess heat. An example is shown below in Figure 15. Having accurate outdoor temperature readings is vital for effective functioning of the various zTherm control mechanisms.

- RM Young Multi-Plate Radiation Shield Model 41003
  http://www.youngusa.com/products/2/11.html

Note that this unit can take a temperature sensor up to 1" diameter.

Figure 13: Display showing 105.5° F outdoors


Inside Temp 78.9

Inside RH% 48.8%

Set Point 75.0

Outside Temp 05.5

Outside RH% 37.7%

Basement Temp 70.8

Basement RH% 63.8%

Relay State 11

Figure 14: Display showing 105.5° outdoors

Figure 15: RM Young Radiation Shield

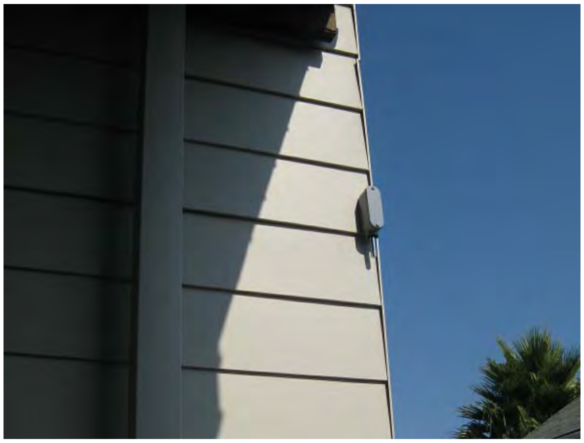

Figure 16: BSC outdoor T/RH sensor

BSC's temperature sensor on the rear of the house is exposed (Figure 16), and suffers from similar problems, but aesthetic considerations prevented us from using a radiation shield at this location. We can also rely on airport data to correct our temperatures later.

Other Items

The mechanical room door should be weatherstripped; there is an excellent door sweep in place, but no weatherstripping on the jambs and head.

We would like a network connection to our data logger; please install a cable from an open port on the router to our data logger in the basement.

Figure 17: Router, showing open ports

Figure 18: Data logger, showing network connection port

The sump has one output pipe connected; the other is currently open to the subslab area. It should either be used and connected, or capped off to air seal the thermal basement from the subslab conditions.

Figure 19: Sump pit cover

Figure 20: Open port on sump pit

- EA1, GPR F3--Thermal Bypass Checklist & Qii: needs followup on electric main, sewer main, radon pipe, sump pipes at final. ***Andy Wahl to conduct additional site visit to follow-up.***

Informational Items

The tests run by BSC on this trip are described below; they will be fully analyzed and described in a later report.

- Air handler airflow: one issue from the previous report was that the wrong air handler was installed (3-5 ton system), which provided excessive airflows, and therefore high system pressures. I found that I could provide a bypass jumper to run the air handler at “fan on” speed (~750 CFM), instead of cooling/heating speed, providing a better match to target airflows. Note that it is documented inside the air handler cabinet, and can be reversed if necessary (snap-in connectors).

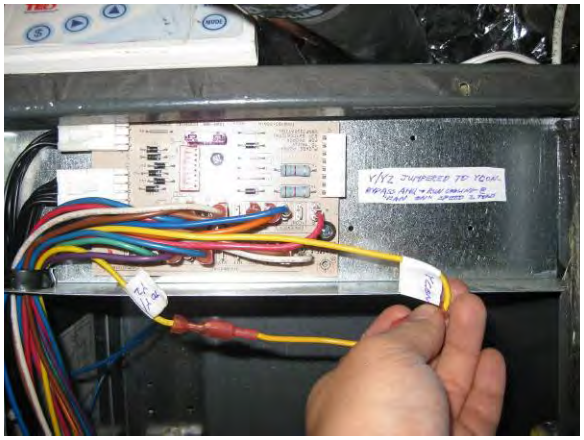

Figure 21: Bypass jumper at air handler

- Room airflows and pressurization were measured; all numbers looked reasonable.
- We examined airflow delivery temperature vs. time, testing the response of the thermal basement in cooling and heating modes.
- The drainwater heat recovery system is now plumbed properly, and a preliminary look at the tests shows that it is functioning correctly. BSC will write up the results in a later test report.
- A TED (Energy Detective) was installed for whole-house use, near the ee PC in the kitchen. It provides a real-time display of energy use, and a monthly history (similar to utility bills). We also looked at the phantom/standby loads for the house as it is currently operating; it was 60 W after we had turned off the ee PC, the router/cable modem, and everything that can be switched. The remaining loads includes the air handler transformer (10 W), the garage exhaust fan (18 W), the zTherm controller, smoke detectors, and any “phantom loads” (appliance standby condition loads).

Figure 22: TED installed at kitchen counter

- A TED has also been installed to log power for the heat pump water heater; it might need to be moved, depending on the unit's final location.

Figure 23: TED for heat pump water heater logging

- The photovoltaic array was noticeably dirty, after several months of exposure.

Figure 24: Photovoltaic array condition

ZETA Lancaster V1 Monitoring Data Check

From:	Kohta Ueno, Building Science Corporation	Date:	August 28, 2009
To:	John Straube, Ph.D., P.Eng., Aaron Grin, ZETA Team	Re:	ZETA Lancaster V1 Monitoring Data Check

All—

I have taken an initial look at the data collected by the Campbell CR1000 data logger system installed at the ZETA Lancaster V1 prototype, to ensure proper functioning (see 2009-06-02 ZETA Testing and Monitoring Plan and 2009-07-03 ZETA Lancaster Testing Report for monitoring details).

Note that there is not much data of significance, given that the zTherm controller and HVAC system are not yet in operation. Therefore, the only data is with the house "floating" in temperature. However, the following points were noted:

- All sensors are returning reasonable data
- The outdoor T/RH sensor is hit by solar radiation in the morning, and shows higher readings than air temperature (as measured at the airport). A radiation shield is recommended
- Second floor temperatures track higher than first floor, as would be expected given the geometry of the building.
- Skylight temperature peaks are in the 35-40° C range (95-104° F). However, we can not eliminate the possibility that the sensor is seeing some direct solar radiation for some periods, which would result in measurements higher than air temperature. Temperatures are lower, though, at other periods (likely skylight open).
- Slab temperatures seem to respond relatively quickly to HVAC runtime influences.
- Relative humidity measurements show that the conditions in the thermal basement are not conducive to mold growth.

If you have any questions, you can reach me as per the contact information below, or at kohta@buildingscience.com.

Thank you,

Kohta Ueno

Exterior Temperature

The exterior T/RH sensor results were compared with the results from Oakland Airport weather data (KOAK). There were relatively large daytime spikes in temperatures in the BSC data; these were noted to be much higher than highs for OAK data. If a radiation shield can be installed at the rear deck, this would result in more accurate air temperatures (i.e., without solar effects).

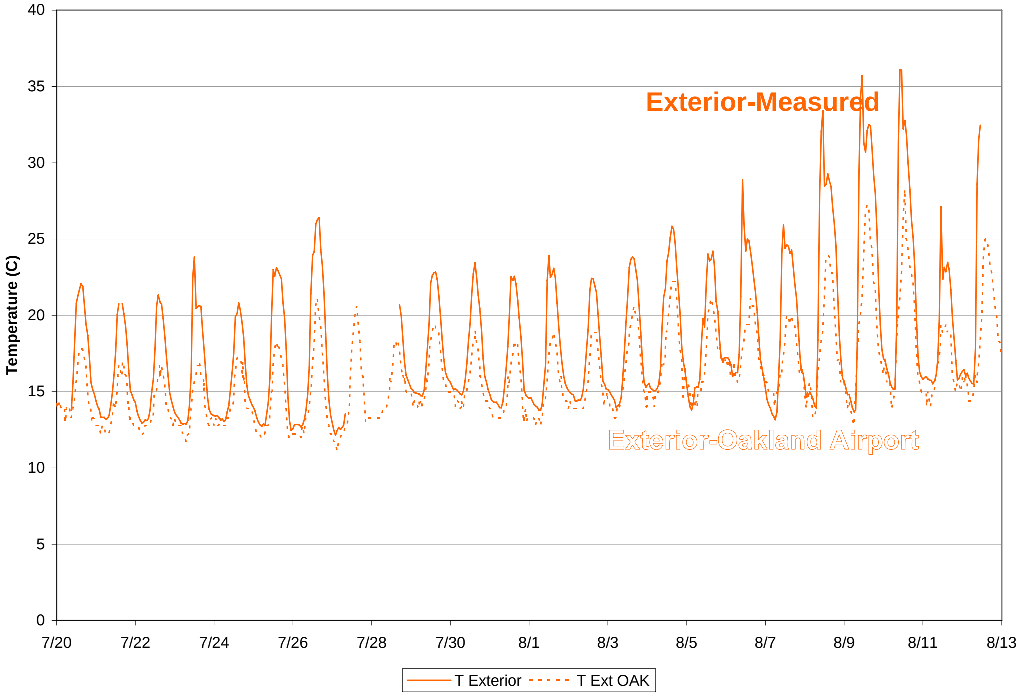

Figure 1: Exterior temperature and KOAK airport temperatures

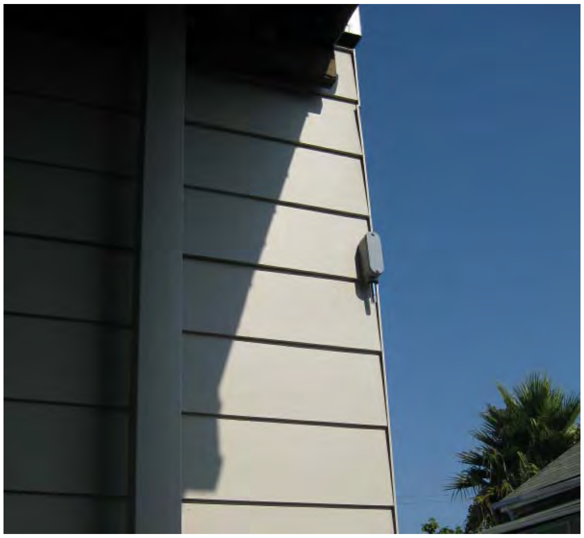

Figure 2: Exterior temperature sensor

Figure 3: RM Young Radiation Shield

Interior Temperatures

Interior temperatures were measured at the basement (air), first floor, second floor (main), and the two front bedrooms.

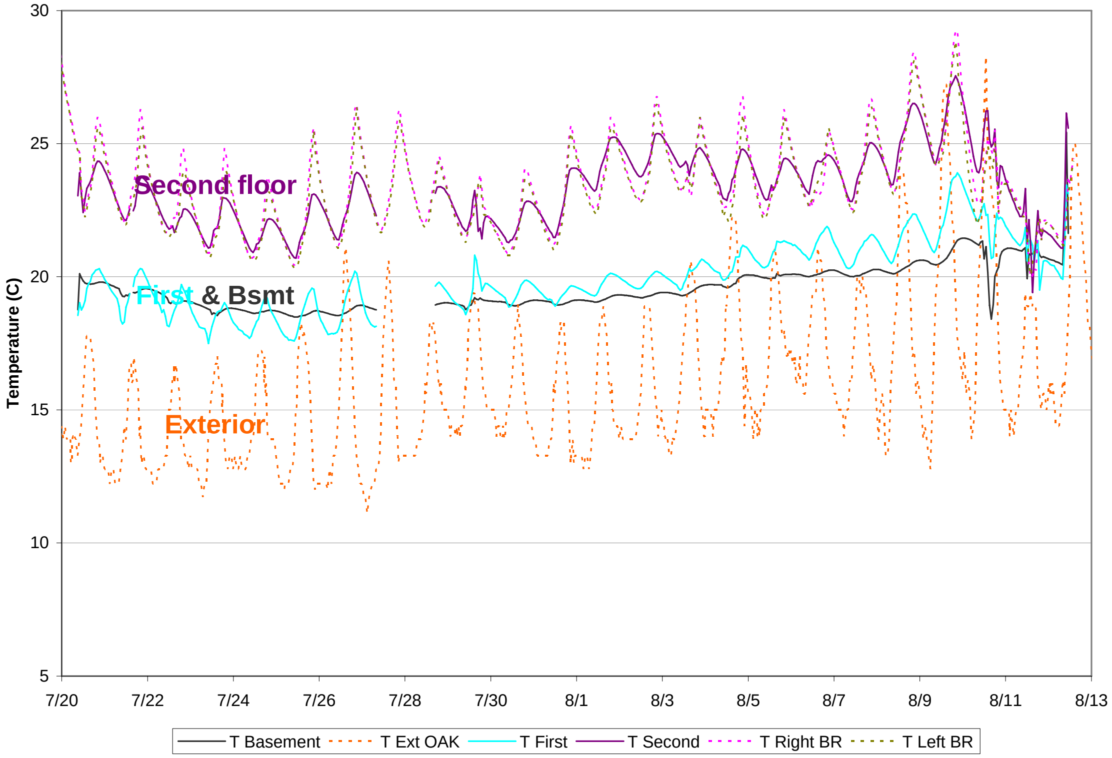

Figure 4: Interior temperatures (with exterior T)

The data demonstrates, that when the house temperatures are "floating" (no HVAC operation):

- The second floor tracks warmer than the first floor; this is probably obvious to everyone who has been in the house. This is a function of the physical layout and glazing of the house: first floor has almost no afternoon solar exposure and substantial thermal mass (slab floor), while the second floor is made warmer by thermal stack effect (warm air rising), roof exposure, a skylight, and most importantly, a highly glazed west-facing façade.
- The front bedrooms are noticeably warmer in the afternoon than the main second floor, as would be expected due to the glazing. The temperatures in the two bedrooms are similar—I was expecting more of a difference, given the difference in glazing ratios. Note that these sensors are not in direct sun; they are hidden behind the entry door of each room.
- The front bedrooms have nighttime temperatures lower than the second floor hallway; this might just be due to window area (worse insulation value than walls), or possibly due to windows being left open for ventilation.
- The thermal basement shows less temperature variation than the above-grade floors, as expected due to its ground contact, thermal mass, and lack of glazing. It follows a general trend following exterior temperatures, but with a phase shift.

- Interior temperatures are consistently "phase shifted" from outdoor temperatures: daytime outdoor peaks occur around 3-5 PM, while interior peaks occur at 8-10 PM. It should be noted that sunset at this time of year is in the 8:15-8:30 PM range.

Interior Relative Humidity and Slab/Mold Risks

There are several temperature/relative humidity sensors measuring interior and exterior conditions. Raw relative humidity data is not necessary useful for moisture comparisons (see Interior Dewpoints, below); however, it can be used to gauge the risks of mold and microbial growth. One consistent worry among the design team was the risk of mold growth in the thermal basement, due to condensation risks.

The raw relative humidity data is shown below; exterior conditions bounce from ~50-90% on a diurnal cycle; interior conditions are relatively stable. They range from 50-60% (first floor), to 40-50% (second floor—warmer conditions, lower RH), and 60-70% in the basement.

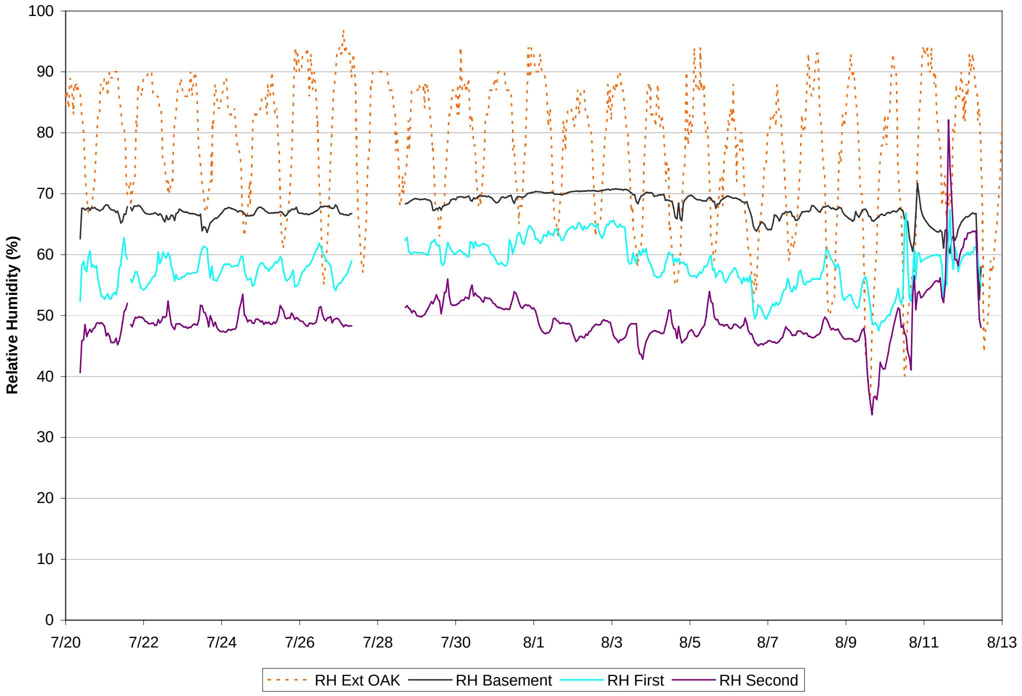

Figure 5: Relative humidity (exterior and interior conditions)

The basement RH conditions can be compared with slab temperatures, to calculate a "surface relative humidity"—the humidity that would be occurring at the surface, which is one of the governing factors for mold growth.

Measured data shows an average surface RH of 69%, ranging from 60-75%. This is well within the safe range, especially considering the substrate of concrete (able to absorb water without damage, no nutritive value for mold).

Interior Dewpoints

The raw relative humidity data for various spaces is not necessary useful comparison, as it does not show absolute moisture conditions—temperature conditions are required to normalize it to that metric. Therefore, T and RH data were converted to dewpoint (absolute moisture content—the temperature at which that air would condense on a surface), as plotted below.

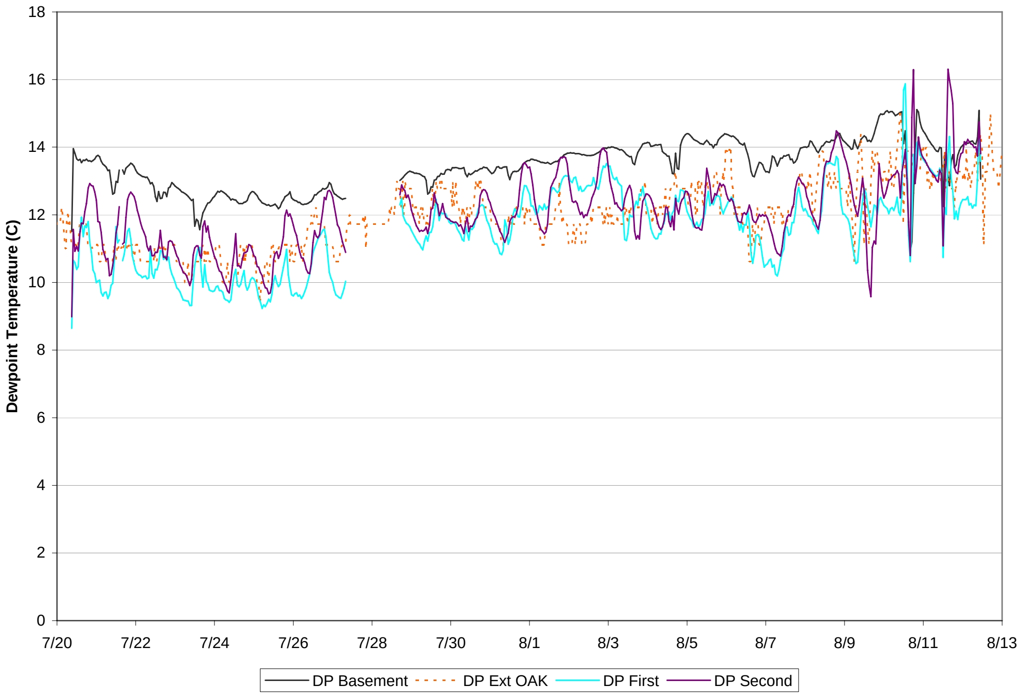

Figure 6: Dewpoint temperatures for basement, first, second, and exterior

Interior conditions are almost indistinguishable from exterior conditions; this is expected, given that the HVAC system was not active, so moisture removal due to cooling would not have occurred. However, there is some lag between interior and exterior conditions, probably due to adsorption and desorption of moisture from interior finishes. The period around 8/3-8/4 had slightly elevated dewpoints; it seems possible some moisture-generating activity (painting, washing, or high occupancy) occurred then.

The thermal basement dewpoint is elevated above the interior conditions; this is expected, given the large volume of water contained in concrete. This concrete will continue to dry for a long period—several years at least, but probably longer. As discussed above, this does not appear to be a risk factor for mold growth.

Skylight Temperatures

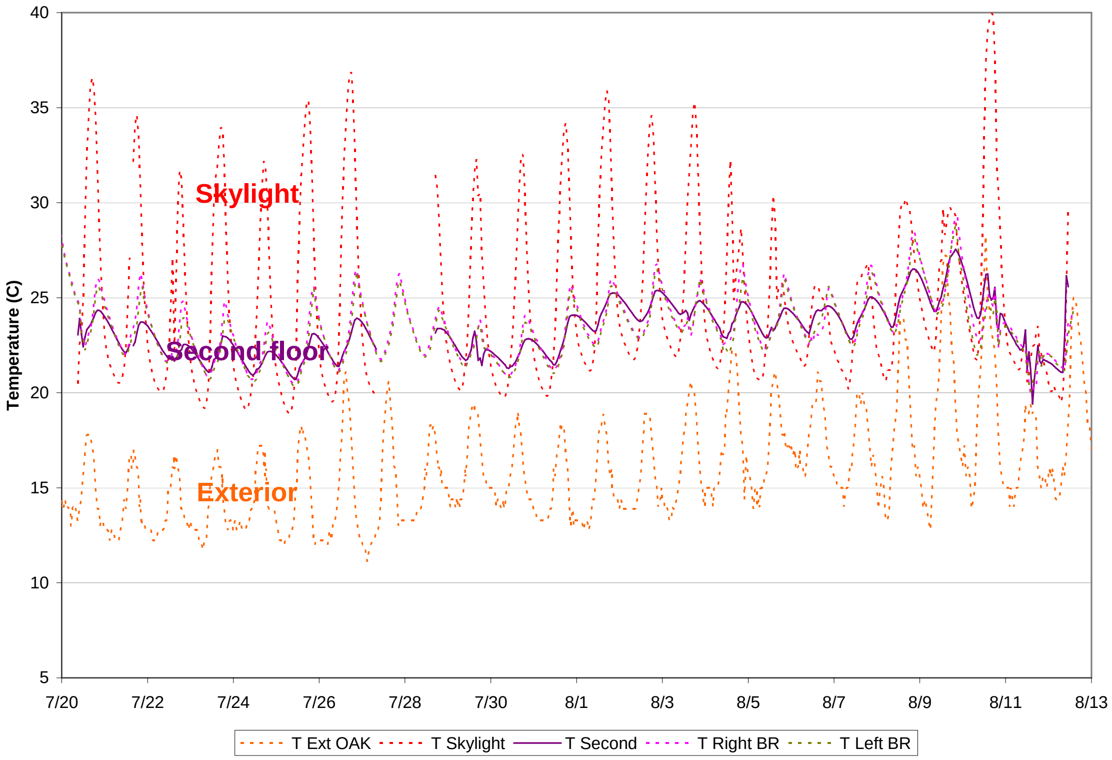

Figure 7: Skylight temperatures, relative to second floor Ts

The skylight temperatures are sometimes very high, with peaks in the 35-40° C range (95-104° F). However, I can not eliminate the possibility that the sensor is seeing some direct solar radiation for some periods, which would result in measurements higher than air temperature.

The temperatures are roughly in phase with outdoor temperatures.

There are several days when the temperature is much lower (close to second floor temperature); this may be due to opening of the skylight. For instance, when we arrived on August 10th, the skylight was open; we closed it in order to do our blower door tests; this matches measured patterns.

Slab Temperatures

Figure 8: Concrete basement slab surface T (front of basement)

Figure 9: First floor slab temperature sensor (installed before casting slab)

The thermal basement surface temperatures (front and rear) and first floor slab temperature (bottom of slab at subfloor) were compared with air temperatures.

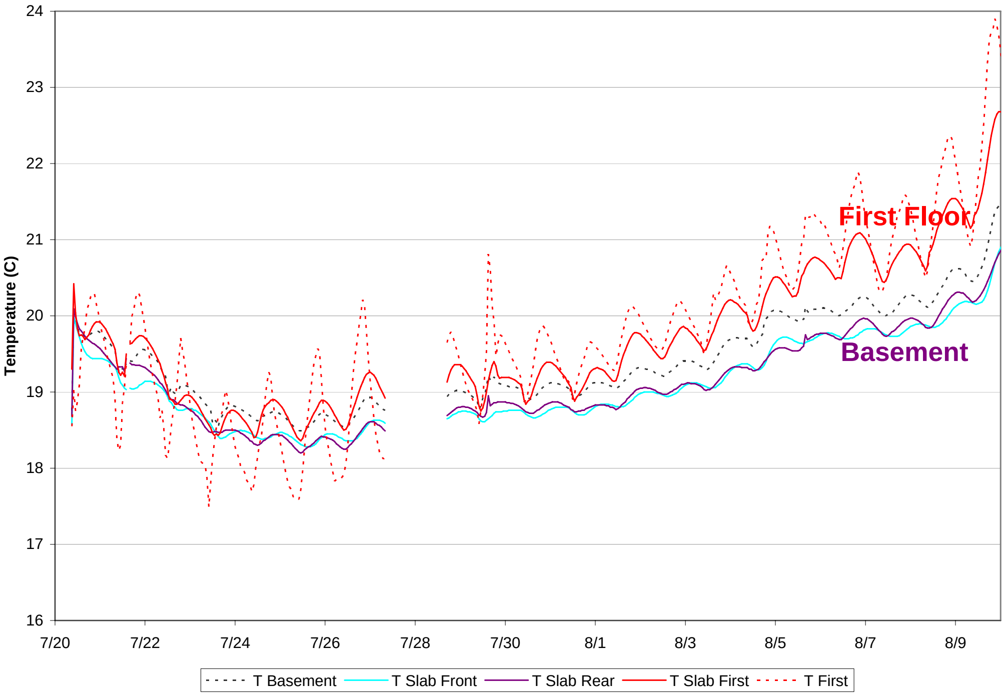

Figure 10: Slab and associated interior air temperatures

- The thermal basement slab temperatures are cooler than the basement air temperature, with a consistent offset; this is expected behavior.
- The first floor slab operates at a temperature both warmer and colder than the first floor; in addition, there are some days when it shows a significant phase shift relative to outdoor temperature. Note, of course, that this temperature sensor is "deeper" into the slab (bottom instead of top surface), which could explain this "lag" response. However, it is exposed **on both sides** (basement and first) to interior conditions—it remains between basement and first floor air temperatures, for the most part.

HVAC Operation

The HVAC was operated briefly on the days while we were testing (8/10-8/12). This behavior might inform the overall operation (including the zTherm controller); having a grasp of the interaction between HVAC system operation and slab thermal storage will be useful for determining algorithms for the controller.

The operation of the HVAC system (in cooling, heating, or fan-on mode) is noted by the shaded blue, red, or grey bars. The following points were noted:

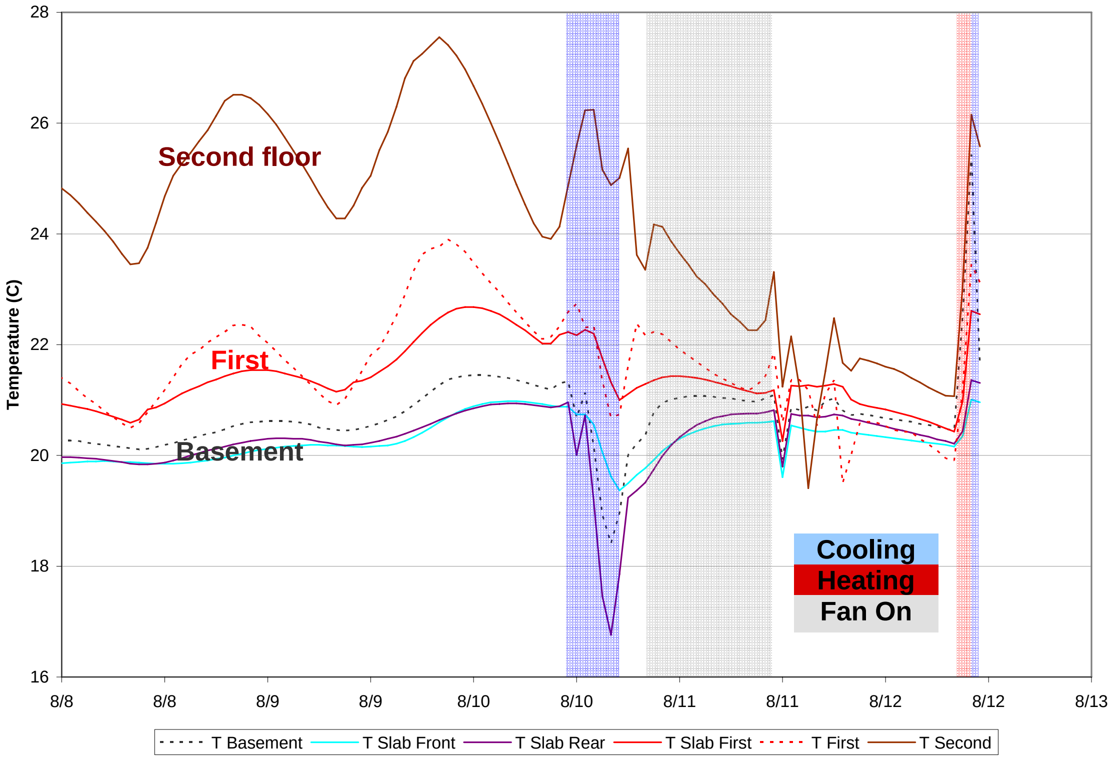

Figure 11: Slab and interior air temperatures with HVAC operation (shaded bars)

- 8/10: During the first cooling operation, all temperatures were pulled down. The basement (air and slab) seem to have the fastest response—there is a large airflow to that space, which is "bled" to the first floor with transfer grilles. Note that the rear slab cools more quickly than air temperature; there is likely an open duct relatively close to the sensor. The second floor remains warmer than the first floor (24-26° C, or 75-79° F).
- 8/11: The HVAC fan was left running overnight, to determine its effect on interior temperatures. It ran from 8 PM to 11 AM the next morning. Note how all of the temperatures "converge," due to this forced mixing of interior air. The first floor and basement are within 1° C at the end of this run; the second floor is slightly higher.
- 8/12: This was some final runtime in heating and cooling mode, which was done for temperature-time responses in the registers. The system was run for roughly 2 hours in heating, and 1 hour in cooling. It can be noted that the slab temperatures do seem to respond relatively quickly to this runtime.