BUILDING AMERICA FIELD TEST PLAN
DRAFT – OCTOBER 4, 2006

NREL / Building Science Consortium
Burlingame Community
City of Aspen, CO / Shaw Construction
Severe Cold Climate Region, 50% Energy Savings Level
Expected Test Date: Late November 2006

Description: The City of Aspen is building a development of affordable attached multi-family homes, designed with building durability and energy efficiency in mind. The homes are expected to reach approximately 51% source energy savings versus the 2005 Building America Benchmark through the use of air-tight spray foam insulation, low-E windows, and high efficiency mechanical equipment. The specifications for these homes are provided in Table 1.

Figure 1: Progress underway at Burlingame Building F-1

Table 1. As-Designed specifications for Burlingame Building F-1.

Burlingame Specifications	As-Designed
Building	F1 (4 units)
Bedrooms	One 1-BR, one 2-BR, two 3-BR
Floor area	~ 5300 ft^2 total
Building envelope	
Ceiling	combination of cathedralized unvented attics and flat roofs R-50 high density foam at sloped roof, R-38 at flat roofs
Walls	2x6 with 3.5" of high density foam (R-24)
Slab	2" XPS perimeter insulation extending 2' below grade
Frame Floors	R-24 high density foam
Foundation	1.5" polyiso insulation where heated units are below grade
Windows	Milgard, U=0.37, SHGC=0.33
Infiltration	2.5 sq inches per 100 sf envelope area (to outside)
Mechanical systems	
Heat	93% AFUE Condensing boiler (central system) in mechanical room hot water baseboard heating, all plumbing in conditioned space
Cooling	none
DHW	120 gallon indirect tank off of boiler in mech room, domestic recirculation system
SHW	120 gallon solar preheat tank in mechanical room, 92 sf solar panel per building
Ducts	only for ventilation system; in conditioned space
Leakage	5%
Ventilation	Carrier HRVCCSVU (60% efficient), 62.2 rate for each unit supply to bedroom and living, exhaust from bathrooms
Other	electric heating at roof edges to prevent ice dams

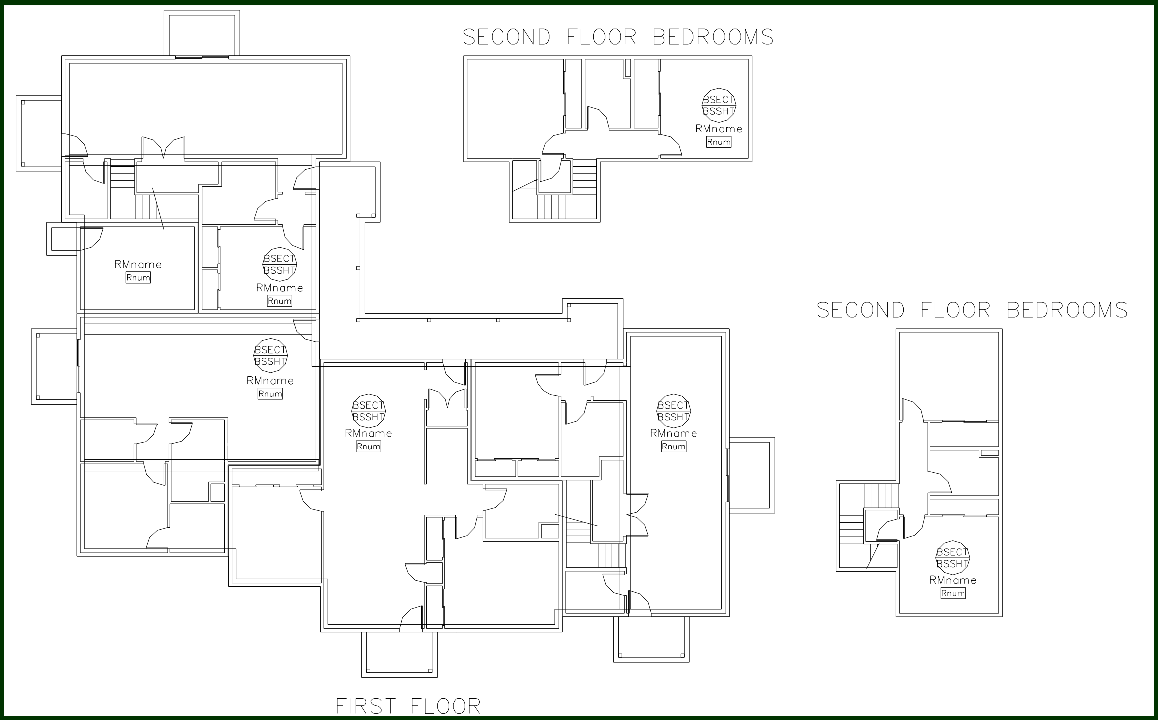

Figure 2: Floor plan for Building F-1

Research Questions

The following research questions will be addressed by NREL and BSC:

1. What is the effective leakage area of each unit as measured with a blower door? How does the leakage area change when adjacent units are also pressurized? (short-term testing)
2. What is the hourly air change rate of each unit with and without the HRV running as measured with a tracer gas? Does operation of the kitchen or bathroom exhaust fans in adjacent units result in higher air flow between the units? (short-term testing)
3. What are the supply and exhaust ventilation rates of the HRVs? How balanced are the flows? What is the resulting change in pressure for each unit when the HRVs are operating? (short-term testing)
4. How much energy do the DHW re-circulation systems lose assuming Benchmark event schedules? What fraction is regained as useful space heating energy? What volume of water must be drawn before the most remote hot water fixtures in each unit meet the minimum useful temperature of 115ºF, before and after operation of the re-circulation system? (short-term testing and simulation)
5. What is the actual efficiency of the condensing boiler? How does the predicted annual space heating energy for the centralized baseboard heating system compare to individual 92% AFUE condensing furnaces? (short-term testing and simulation)
6. What are the DHW and space heating loads for individual units? Are these loads affected by the use of gas bills averaged across all units? (long-term monitoring and occupant interviews)
7. What is the power consumption of the electric heaters used for ice dam prevention? What is the expected annual energy use for these heaters? (short-term testing and long-term monitoring)

8. What is the measured HRV sensible efficiency? What is the HRV electricity use? How does the energy use of the HRV compare to a continuous exhaust fan or central-fan integrated supply ventilation system? (short-term testing and simulation)
9. How are the HRVs operated by the occupants in each unit compared to the recommended 50% duty cycle? (long-term monitoring)
10. What are the heating temperature settings within each unit? (long-term monitoring)
11. How many hours per year are above the cooling setpoint of 76ºF? (simulation and long-term monitoring)
12. What are the predicted annual energy savings and fraction of annual hot water energy use met by the solar hot water system? How does the energy savings for the solar system differ for this central, multifamily system when compared to individual single-family systems? What is the estimated cost-effectiveness of the solar hot water system? (Short-term testing, simulation, and long-term monitoring)
13. What is the estimated annual source energy use of each unit compared to the BA Benchmark and Regional Standard Practice? (Short-term testing and simulation)
14. How does actual monitored energy use compare to that predicted by the simulation after occupancy? Are major differences (if any) caused by unexpected occupant behavior, building system performance, simulation errors, or a combination? (Long-term monitoring, simulation, and occupant interviews)

Preliminary Time Frame: The building should be ready for testing in late November 2006.

Day #1 (TBD)	Arrive at site and meet with City of Aspen representative for keys to house. Transport equipment from NREL to test building.
Day #2	Meet with HERS rater to conduct blower door tests
Days #2-7	TBD testing of the units.
Day #7	End test and transport equipment back to NREL.

Requested Action Items for Team and Builder

1. Ask homebuyers to sign agreement form with NREL to allow long-term monitoring and access to utility bills.
2. Let NREL know with as much advance notice as possible when this building will be available for testing.
3. Install flow meters in DHW and space heating loops (specific locations to be determined).
4. Have the house fully finished prior to testing if possible.
5. Have any building commissioning activities deemed necessary by the team performed prior to testing (i.e., balance air distribution system).
6. Inform NREL test engineer if builder or sales personnel require access to the house while testing is underway.

Directions
Jobsite: Burlingame Ranch, Aspen, CO

Contacts

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Appendix A. BSC Simulation Report on Burlingame Ranch

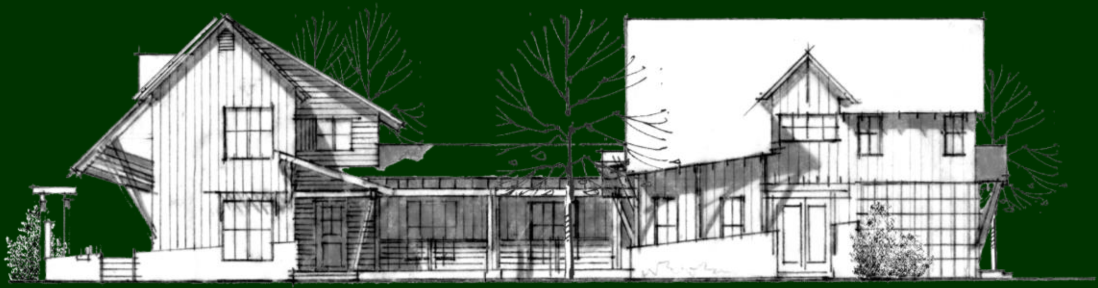

Figure 2: Front elevation, Burlingame Ranch building F(1)
(image courtesy Poss Architecture + Planning).

Aspen, Colorado has one of the most expensive real estate markets in the United States. The mountains around Aspen provide beautiful views, skiing, and small-town seclusion, but they also limit the space available for the city to grow. In 2000, the Aspen Area Community Plan called for affordable housing projects based on the goal of housing at least 60% of the city employees within the city limits. The Burlingame Ranch project is one major step towards achieving this goal.

In 2004 an architectural design competition was held to select a design/build team, and the Aspen city council selected the development team consisting of Shaw Construction, Bill Poss Architects, and DHM Design. This team's design features a "ranch vernacular" style of architecture, and provides 236 units of condominium-style housing in approximately 30 buildings and 265,000 square feet of living area. Additional single-family homes sites will be sold to individuals. The development features a bus route to downtown (less than ¼ mile away), pedestrian and bike trails, and a commons building, where a small market is available to eliminate the need for last-minute trips to the grocery store.

Energy Analysis

The Poss Architects proposal for the Burlingame project included ten different multifamily building designs. Each design may have multiple variants. Building type F(1) was selected as a representative example of the building designs. Although the building designs are different, all will fall into the same range of energy savings, since they are to be built with the same attributes. During the design process, building designs have changed; however building F(1) is still a representative example of the range of buildings in the project.

Description of Building F(1)

Building type F(1) includes four units: one 1-bedroom unit, one 2-bedroom unit, and two 3-bedroom units. The building includes about 5300 square feet of living space. The last report (July, 2005) included the energy modeling done for building F(1). Since then, minor changes have been made to the building design; however only one change needed to be made to the prototype model in order to bring it up to date. Table 2 describes the four units in the building.

Table 1: Burlingame Building F(1) Unit Attributes

Number	Bedrooms	Category	Living area (sq ft)
1	1	1&2	877
1	2	3&4	1149
2	3	3&4	1622

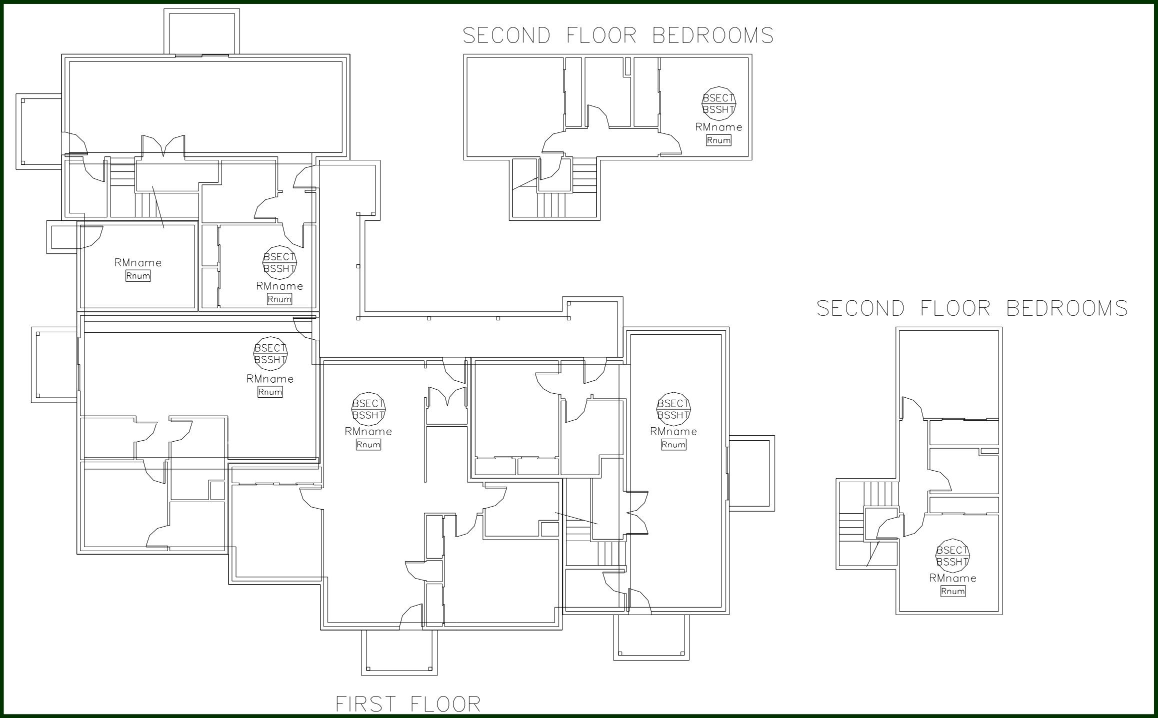

Figure 3: Building F(1) Floor Plan

Description of the Benchmark and Proposed Design

The Building F(1) Benchmark is based on a building meeting the 1995 Model Energy Code (MEC) in Eagle, Colorado (the location closest to Aspen with available weather data), with additional characteristics for hot water use, lights & appliances, etc. Table 3 describes the relevant attributes of both the Benchmark and the Prototype, with the red text indicating changes in the design since the last deliverable.

Table 2: Burlingame Benchmark and Prototype Specs

	Building F(1) Benchmark	Prototype
Building envelope		
Ceiling	R-36	R-48
Walls	U=0.076 (approximately R-15) 2x4, 16" o.c.	R-24 2x6, 24" o.c.
Slab Edge	R-7	R-10
Windows	U=0.35, SHGC=0.32 WWR=19% no exterior shading	Milgard Vinyl Classic Series Double glazed LoE U=0.36, SHGC=0.32 WWR=11%
Infiltration	5.7 sq in leakage area per 100 sf envelope area 0.46 ACH	2.5 sq in leakage area per 100 sf envelope area 0.20 ACH
Mechanical systems		
Heat	Central boiler system, 80% efficiency	Central boiler system, 90% efficiency
Cooling	Individual 10 SEER AC units	No cooling, modeled as individual 10 SEER AC units
DHW	Individual standard HWHs, EF=0.56 120°F setpoint, 260 gpd	central system with boiler backup (EF=0.66), 192 sf solar panel w/ 250 gallon tank 120°F setpoint, 195 gpd
Ducts	ducts in unconditioned attic 15% duct leakage	no ducts no duct leakage
Ventilation	150 cfm continuous no energy recovery	150 cfm continuous HRV (60% efficient)
Lights & Appliances		
Lighting	86% incandescent, 14% fluorescent	10% incandescent, 90% fluorescent
Appliances	standard appliances	Energy Star appliances

Energy Modeling Procedure

The energy modeling was performed using EnergyGauge USA version 2.42. The analysis procedure was as follows: (1) model the Building F Benchmark and determine annual energy usage; (2) make an incremental improvement to the model (upgrade insulation, add solar panels, etc) and determine the effect of the improvement; (3) repeat, until all the improvements are incorporated into the computer model. At the end of this process EnergyGauge USA predicts the overall energy use of the proposed design. Figure 5 describes the order in which improvements were incorporated.

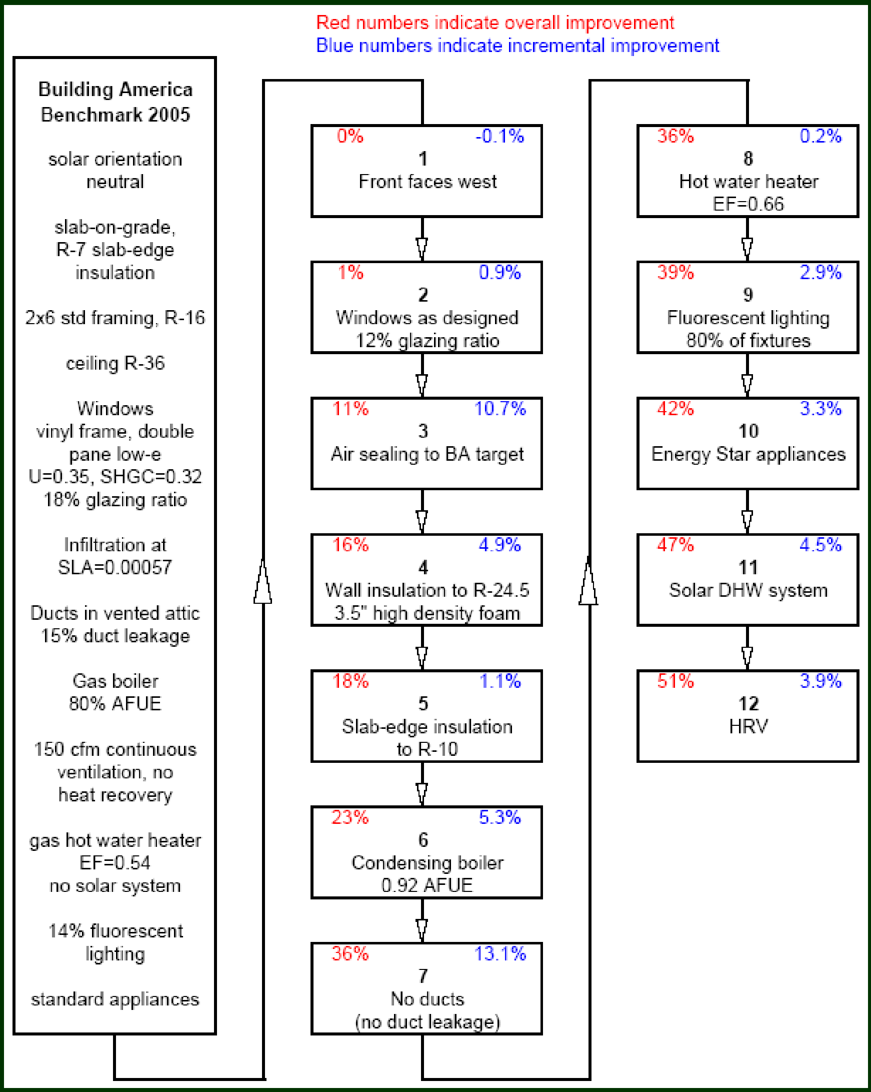

Figure 4: Flow chart describing incremental improvements

Energy Modeling Results

Figure 6 illustrates the reduction in annual source energy use with each step in the analysis. The first bar on the left is the annual source energy usage, in millions of Btu, of the Building F Benchmark. Each bar to the right of the first bar represents the annual source energy usage of one of the improvement steps.

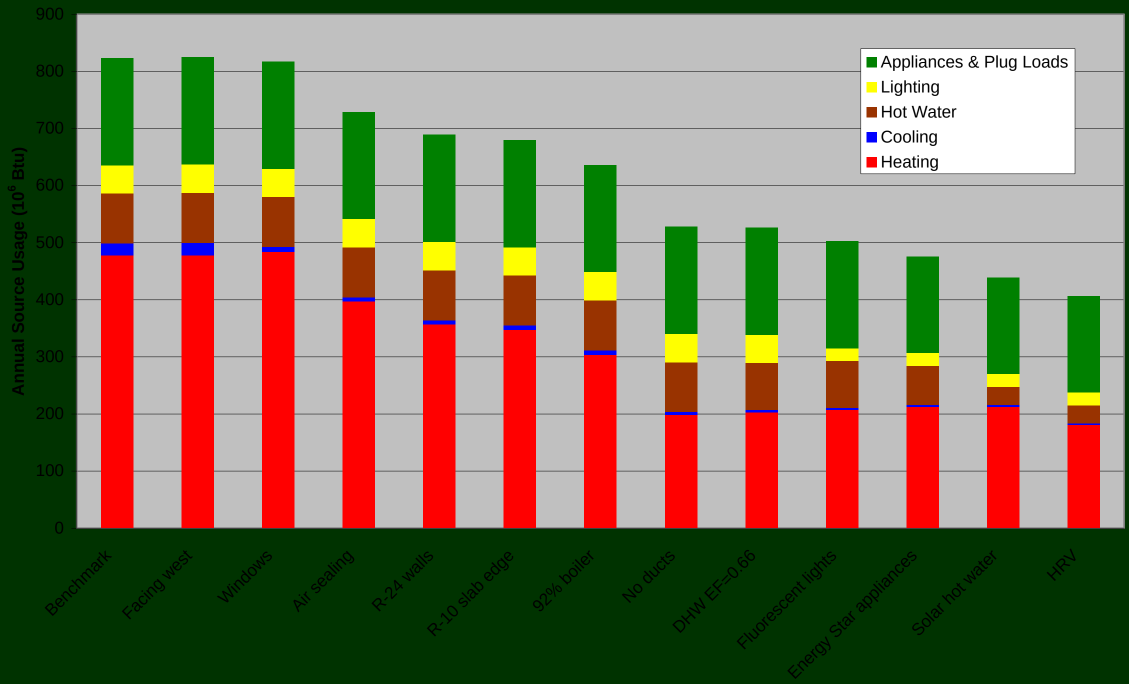

Figure 5: Burlingame Effect of Incremental Improvement Steps

The results of the energy consumption analyses are highlighted below.

Table 3: Burlingame Building F(1) BA Benchmark Performance Report

Table 1. Summary of End-Use Site-Energy

	Annual Site Energy			
	BA Benchmark		Prototype 1	
End-Use	kWh	therms	kWh	therms
Space Heating	1573	3921	1288	1422
Space Cooling	2073	0	332	0
DHW	0	742	190	252
Lighting*	4853		2164	
Appliances + Plug	14097	366	12573	341
OA Ventilation**				
Total Usage	22596	5029	16547	2015
Site Generation	0	0	0	0
Net Energy Use	22596	5029	16547	2015

Table 2. Summary of End-Use Source-Energy and Savings

			Source Energy Savings	
	Estimated Annual Source Energy		Percent of End-Use	Percent of Total
	BA Benchmark	Prototype 1	Prototype 1 savings	Prototype 1 savings
End-Use	106 BTU/yr	106 BTU/yr		
Space Heating	477	180	**62%**	**36%**
Space Cooling	21	3	**84%**	**2%**
DHW	87	32	**64%**	**7%**
Lighting*	50	22	**55%**	**3%**
Appliances + Plug	188	169	**10%**	**2%**
OA Ventilation**	0	0	**0%**	**0%**
Total Usage	823	407	**51%**	**51%**
Site Generation	0	0		**0%**
Net Energy Use	823	407	**51%**	**51%**

*Lighting end-use includes both interior and exterior lighting
**In EGUSA there are currently no hooks to disaggregate OA Ventilation

Energy and Building Science Consulting

In 2005, BSC worked with the development team and the City of Aspen to design the energy efficiency measures, including high-density spray foam insulation; a tight envelope; 90+% furnaces; baseboard hot water radiators; efficient domestic hot-water systems including a solar hot water system; heat recovery ventilators; a fluorescent lighting package; and Energy Star appliances.

In 2006, BSC is continuing to work with the development team to finalize the solar hot water system design, review third-party energy code compliance reports, and provide support through the bulk of the construction phase.

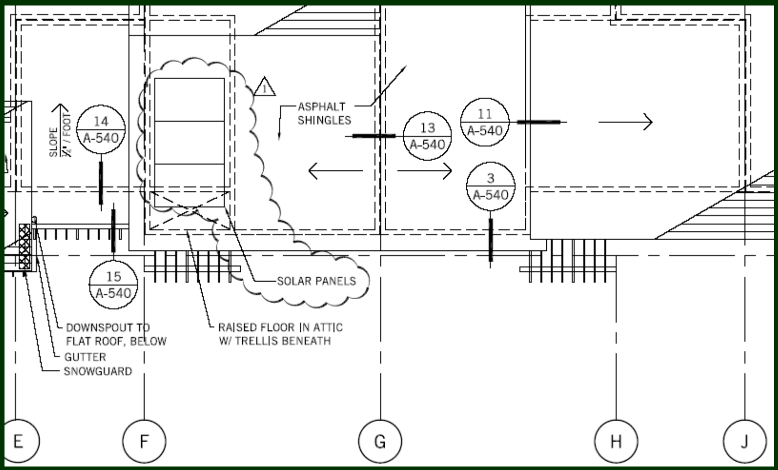

Figure 6: Recommended location of the solar hot water panels

BSC will continue to provide advice and guidance to the architect and builder team. This guidance will include energy details, by providing guidance for solar panel placement and piping, and reviewing building science details, such as water management in the roof, wall, and foundation assemblies.

Current Status

As of March 2006, construction is well underway. The first two buildings (designated G1 and F2) are in the MEP rough-in stage. These buildings are completely framed and the roof underlayment installed; the roofing will be installed before the end of March. The third building (H1) is in the final framing stages; the fourth building (C1) is in the initial framing stages; and the foundation for the fifth building (E1) has been poured. Occupancy of the first building is scheduled for September 2006, and completion of the first set of 16 buildings is scheduled for January 2007; however the construction schedule is currently about three months behind. Final build-out of Phase 1 is scheduled for late 2007.

Figure 7: Building G1 as of February 13, 2006.

Figure 8: Building F2 as of February 13, 2006