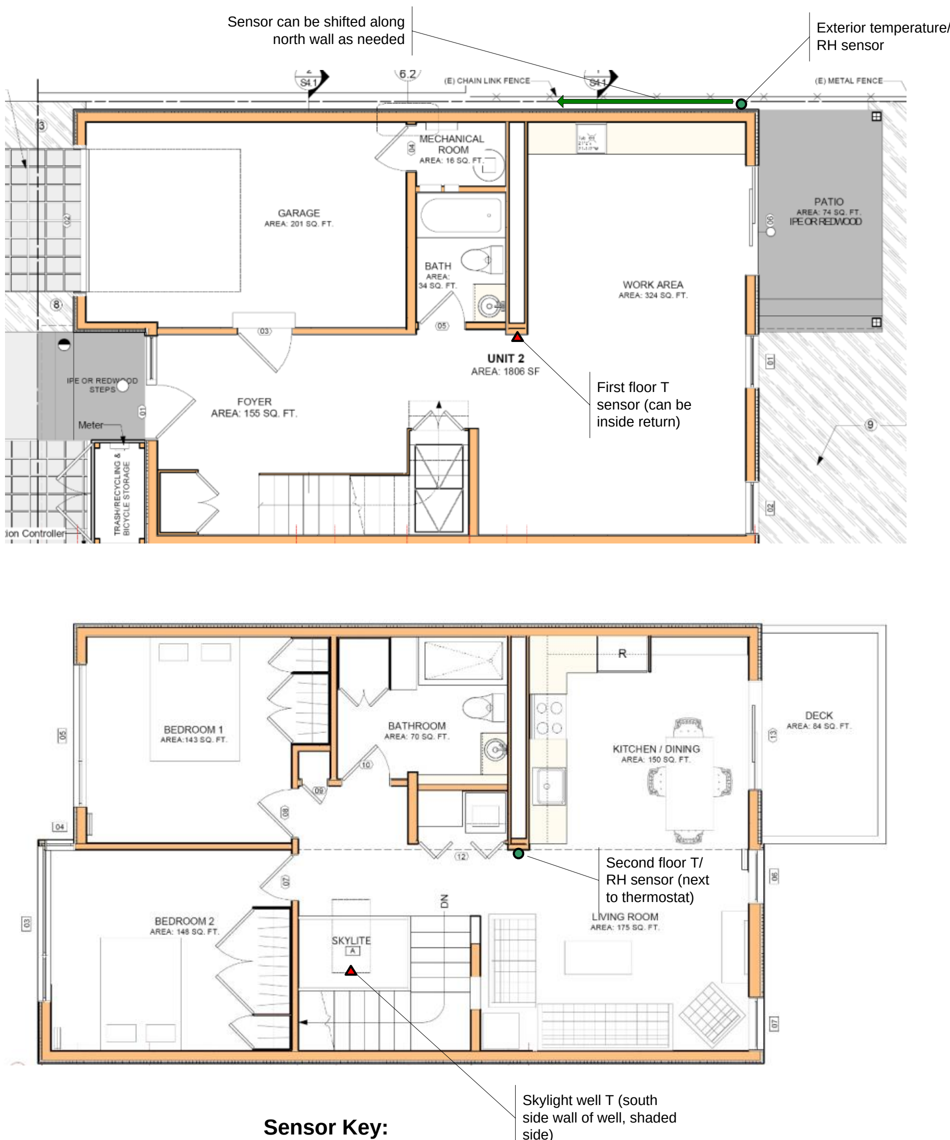
# **BUILDING AMERICA FIELD TEST PLAN**
# **DRAFT -- JUNE 8, 2009**

*NREL / Building Science Consortium*
*ZETA Communities*
*Oakland, California*
*Marine Climate Region, 40% Energy Savings Level*
*Gate 2: Prototype House Evaluation*
*Expected Test Dates: Mid-July 2009*

## **Description:**

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. ZETA is building a two-unit live-work townhouse in undeveloped space in Oakland, CA, near the Fruitvale public transit (BART) station. The first unit (V1) should be completed in mid-June, with the second unit (V2) completed at a later date. The townhouse is scheduled to undergo detailed performance testing by NREL once the second unit has been completed in mid-July. Building Science Corporation (BSC) will perform a number of short-term tests prior to that, and install some of the long-term monitoring equipment. An elevation drawing of the townhouse is shown in Figure 1, and the first and second floor plans are shown in Figures 2 and 3. The key specifications are listed in Table 1. The preliminary BSC analysis results are summarized in Tables 2 and 3, for a single-family detached design with similar energy features. Detailed simulations of the final Oakland design will be performed in the near future.


**Figure 1: ZETA townhouse front elevation. (Courtesy of DSA Architects)**




**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 2. ZETA townhouse Unit V1 floor plan, indicating sensors to be installed by BSC.**

**Table 1: ZETA townhouse Unit V1 specifications.**

| **GENERAL** | |
|---|---|
| Floor Area | 1522 $ft^2$, including 457 $ft^2$ work space |
| Number of Bedrooms | 2 |
| Number of Stories | 2 |
| **ENCLOSURE** | |
| Ceiling | Low-slope roof, R-32 Icynene low-density foam sprayed cavity, R-22 Icynene (~6") in garage ceiling |
| Walls | 2x6 OVE R-19 cavity insulation + 1" XPS rigid insulation Icynene in most walls, cotton batt in long walls;<br>2x4 R-13 to garage (long wall) + R-5 XPS, no foam at 2x6 |
| Foundation | Sealed insulated crawl as thermal storage plenum R-7.5 |
| Windows | Serious Materials/ThermaProof Windows double w. film Series 725 High SG Typical: U=0.23 SHGC=0.42 |
| Infiltration | 2.5 $in^2$ leakage area per 100 $ft^2$ envelope, 1150 CFM 50 / 4.4 ACH 50 |
| **MECHANICAL SYSTEMS** | |
| Heating and Cooling | Goodman 16 SEER/9.5 HSPF air source heat pump (SSZ16) located in conditioned space (crawl space)<br>with Goodman/Amana MBE ECM modular blower interior |
| Domestic Hot Water | Electric tank water heater with attached air source heat pump unit, AirGenerate AirTap A7 (2.11 EF, 7000 Btu output), wastewater heat recovery, located in the garage, compact plumbing design |
| Air Distribution | R-4.2 flex duct runouts in conditioned crawlspace, no leakage to outside (5% or less), transfer grilles or jump ducts at bedrooms with central return (high) |
| Ventilation | Heat recovery ventilator (HRV) |
| **OTHER** | |
| Appliances | EnergyStar clothes washer, dishwasher, and refrigerator(??) |
| Lighting | 100% compact fluorescent lighting |
| Miscellaneous Electric Loads (MELS) | Greenbox Technologies smart meter (??) |
| PV System | SunPower 225 (225 W/panel) PVs; 24 panels, 5.4 kW array with Sunnyboy relabeled SunPower inverter |

**Table 2: Annual site energy analysis performed by BSC on similar, detached design.**

| | **Annual Site Energy** | | | |
|---|---|---|---|---|
| | **BA Benchmark** | | **BA Prototype** | |
| **End-Use** | kWh | therms | kWh | therms |
| Space Heating | 4018 | 0 | 2000 | 0 |
| Space Cooling | 1281 | 0 | 608 | 0 |

| | | | | |
|---|---|---|---|---|
| DHW | 3697 | 0 | 1076 | 0 |
| Lighting | 2047 | | 960 | |
| Appliances + Plug | 4458 | 0 | 4129 | 0 |
| OA Ventilation | 0 | | 0 | |
| *Total Usage* | *15,501* | *0* | *8773* | *0* |
| *Site Generation* | *0* | *0* | *6733* | *0* |
| *Net Energy Use* | *15,501* | | *2040* | *0* |

**Table 3: Annual source energy comparison predicted by BSC**

| | **Estimated Annual Source Energy** | | **Source Energy Savings** | |
|---|---|---|---|---|
| | | | **Percent of End-Use** | **Percent of Total** |
| | **Benchmark** | **Proto** | **Proto savings** | **Proto savings** |
| **End-Use** | $10^6$ BTU/yr | $10^6$ BTU/yr | | |
| Space Heating | 46 | 23 | 50% | 13% |
| Space Cooling | 15 | 7 | 53% | 4% |
| DHW | 42 | 12 | 71% | 17% |
| Lighting | 24 | 11 | 53% | 7% |
| Appliances + Plug | 51 | 47 | 7% | 2% |
| OA Ventilation | 0 | 0 | 0% | 0% |
| *Total Usage* | *178* | *101* | ***43%*** | ***43%*** |
| *Site Generation* | | *-69* | | *39%* |
| ***Net Energy Use*** | ***178*** | ***23*** | | ***82%*** |

## Research Questions:

1. What are the voltage-current characteristics of the PV system under various weather conditions? How do the performance characteristics of the PV system compare to the published values? What is the predicted annual electricity supplied by the PV system assuming TMY3 weather conditions? What is the predicted annual effect on electricity production of positioning the PV system on a shallow angle because of the low-slope roof compared to the optimal orientation? (Simulation – Greg)
2. What is the hourly natural air infiltration rate of Unit V1 measured using a tracer gas during typical summer weather conditions? With the air handler operating? With the economizer open? With the HRV operating? With the crawlspace sealed off? With the economizer damper sealed off? (Short term testing)
3. What are the natural air distribution characteristics of the house based on multi-zone, single tracer gas testing? How is air distribution affected by operation of the HRV? How is air distribution affected by operation of the AirCycler 5 minutes every half hour? Are the decay curves sufficiently stable to accurately calculate reciprocal age-of-air? If guarded blower door tests indicate that the leakage area of the attached wall is significant, what is the leakage rate through the attached wall under natural conditions? (Short-term testing)

4. What is the heat transfer coefficient between the thermal mass and the supply air? What is the temperature of the thermal mass over the course of a day with and without operation of the zTherm controller? Is the supply air temperature exiting the crawlspace acceptable from a comfort standpoint (TBD°F)? How much heat can be stored in the thermal mass at night using a controlled heat source to maintain a constant 80°F indoor temperature, if the thermal mass has been pre-cooled to 71F°? What is the difference in daily energy usage for the heat pump as measured on alternating days with either the system as designed, or with the economizer disabled and the supply air directed to the first floor through hard ducts? (Short term testing)
5. What is the maximum potential energy savings and peak load reduction for the zTherm system, economizer, and crawlspace thermal mass under optimal conditions? (Short term testing, TBD method) If the system demonstrates significant potential energy savings, what it the predicted annual energy savings and peak load reduction for the zTherm controller using each of the control strategies being considered by BSC? Are there additional strategies that have greater energy savings potential? What is the expected effect on comfort in different rooms throughout the house under different control strategies throughout the year? (room-to-room temperature difference, hours below minimum comfortable temperature per ASHRAE Standard 55, etc.) (Simulation – Jeff)
6. What is the installed COP of the air source heat pump under typical summer weather conditions with a simulated cooling load? (Short term testing)
7. What would be the energy savings for an economizer, without the zTherm controller and thermal mass interaction? (Simulation – Jeff)
8. What is the temperature response of the house if the thermostat setting is raised to 84°F at 4 pm, following a pre-cooling period at where the house is set to 74°F from 10am to 4pm, simulating peak load shifting from the utility? (Short term testing) What amount of pre-cooling would be necessary to maintain comfort throughout such periods? (Simulation – Jeff)
9. What is the predicted average hourly electricity profile for each month based on the as-built design? What would be the predicted effect on hourly electricity profiles if peak load shifting was applied (postponing space cooling, water heating, and clothes dryer operation on hot afternoons)? What would be the effect on energy use? (Simulation – Jeff)
10. What is the difference in electricity use for alternating periods with and without the homeowner feedback system? (Long term testing)
11. What is the difference in electricity use for the space conditioning system during alternating periods with and without peak load shifting using a remote thermostat controller operated by NREL? (Long term testing)
12. What is the predicted effect of the special work area on whole-building energy use? On peak electricity use? (Simulation – Jeff)
13. What is the predicted energy savings of the HRV compared to an efficient continuous exhaust ventilation system? (Simulation – Jeff)
14. Does the delivered hot water temperature at the shower change over time? (Short-term testing) What is the projected fraction of total hot water load met by the waste-water heat recovery system? (Simulation - Greg) What is the actual fraction? (Long-term monitoring) What is the predicted annual energy savings for the waste water heat recovery system? (Simulation - Greg)
15. What is the installed average efficiency of the heat pump water heater, with the load measured by starting from a cold tank, heating the water to its setpoint, then measuring the

transient water temperature as it is drained from the tank? What is the level of noise from the unit in dB? (Short-term testing) What is the difference in annual energy use for the installed heat pump hot water system compared to a typical stand-alone tankless electric water heater using Benchmark operating conditions and weather? Compared to an electric storage tank water heater? What is the predicted effect on space conditioning load? What would be the effect on whole-house energy savings if the system was inside conditioned space instead of in the garage? (Simulation – Greg)

16. What is the predicted whole-house energy savings for the compact hot water distribution system compared to a typical trunk-and-branch design consistent with the BA Benchmark? (Simulation – Greg)
17. What is the projected annual energy savings of the test house compared to the Benchmark, and the minimum requirements of Title 24? (Simulation - Jeff)
18. What is the energy use of the test house under occupied conditions? (Long term monitoring) How does the actual energy use compare to the simulations when actual weather and operating conditions are used? What is the explanation for any major differences? (Simulation – Jeff/Greg)

**Preliminary Time Frame:** Unit V1 should be available for testing in July, with completion of Unit V2 sometime later.

| | |
|---|---|
| Day #1 (July TBD) | Arrive at site and meet with builder representative for keys to house. Transport test equipment to the house. |
| Days #1-10 | Short-term testing. Long-term monitoring installation. |
| Day #10 (July TBD) | End test and transport equipment back to NREL. |

**Requested Action Items for Team and Builder:**

1. Let NREL know with as much advance notice as possible when this house will be available for testing.
2. Have the house fully finished prior to testing if possible.
3. Have any building commissioning activities deemed necessary by the team performed prior to testing (i.e., balance air distribution system).
4. Conduct full battery of quality assurance tests, including blower door, duct blaster, HVAC static pressures, register flows, and ventilation measurements.
5. Inform NREL test engineer if builder or sales personnel require access to the house while testing is underway.

Table 4. Locations of instrumentation for long-term monitoring.

**Directions**

Jobsite: 612 Lancaster Street, Oakland, CA. (See Figure 7)

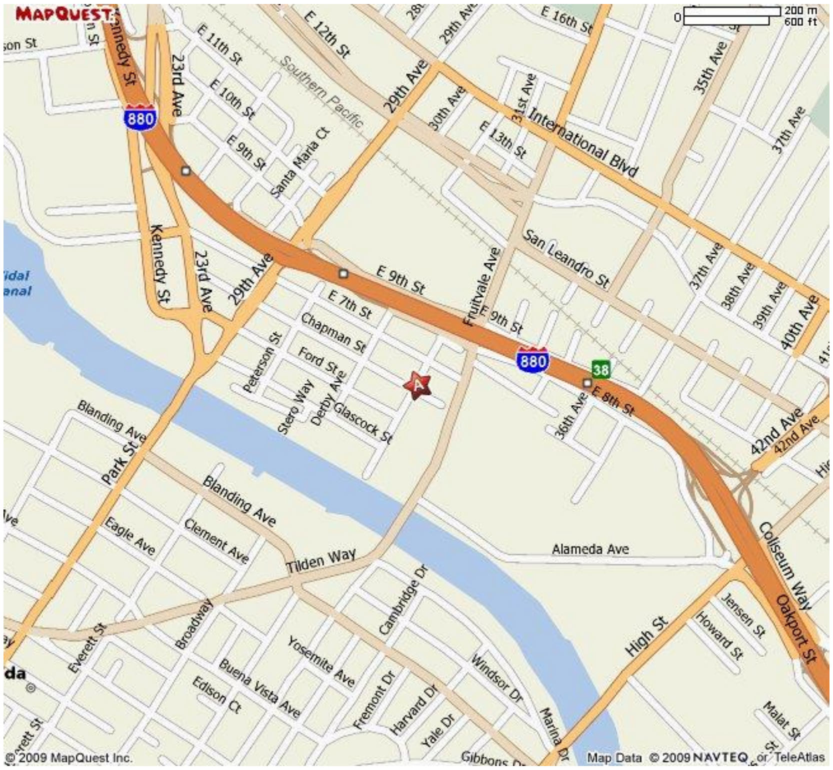



**Figure 7: ZETA Townhouse Site Location**

## Contacts:

| | | |
|---|---|---|
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| BSC | Kohta Ueno (Lead) | 617-863-5276, office<br>617-849-0888, cell |
| NREL | Bob Hendron (Lead) | 303-384-7454, office<br>720-331-3537, cell |
| | Ed Hancock | 303-517-8238, cell |
| | Greg Barker | 303-775-7646, cell |
| | Jeff Thornton | 608-274-2577, office |

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|---|---|
| Development Web Site | To Be Announced |
| Builder Web Site | http://www.zetacommunities.com/ |