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INhouse

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Abstract

This paper will describe the *process* and *product* of Cal Poly's U.S. Department of Energy's Solar Decathlon 2015 entry. The Solar Decathlon is a biennial competition in which teams of faculty and students work to design, build, and compete with solar powered residences. There are ten individual contests involved in the Decathlon, including measured as well as juried tasks. The team from Cal Poly [called "Solar Cal Poly"] included faculty and students predominantly from architecture and engineering but also included members from four colleges and over ten disciplines (involving over 100 students over the 2 year project). The hands-on nature of this design/build/operate competition offers faculty an opportunity to work in tandem with students in an attempt to put their ecological ideals (as they relate to the build environment) into action.

Keywords: *climatic responsive design, Solar Decathlon, design/build*

1. INhouse: An Idea

INhouse is a net-zero residence designed in response to the U.S. Department of Energy Solar Decathlon 2015 challenge, a home intelligently designed to respond to the conditions of the climate in coastal California, such that the majority of its needs for heating, cooling and lighting were addressed architecturally. The supplemental systems necessary for the remaining space conditioning, lighting, and power needs are efficient and effective. The public and private wings are serviced by an active core that contains the home's mechanical, electrical, plumbing, and monitoring systems. The private wing includes a master bedroom and a flexible space which may serve as a library, office, or secondary bedroom space. The public wing incorporates entertainment and dining spaces with thoughtful linkages to the exterior spaces and the views beyond.

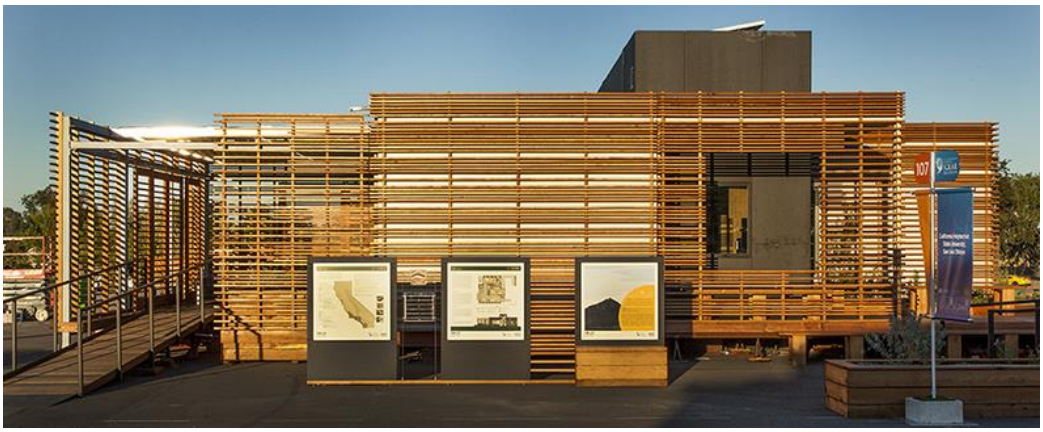

Fig. 1: INhouse [east facade]

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2. Climate and Place

The design of INhouse was driven by climate and place.

- **organize:** facing south with east/west elongation; designed around a "core" that houses the systems of the house, flanked by the passive "wings."
- **insulate:** tight envelope with R 30.5 walls + roof; R 24 floor
- **shade:** shaded southern openings [utilizing bifacial solar panels that simultaneously shade, shape space, and generate power] and tuned envelope shading based on thermal mapping of incident solar radiation.
- **ventilate:** operable windows for cross and stack ventilation
- **stabilize:** use of phase change material to dampen temperature swings, applied both internally as well as decoratively (exposed so residents can view performance).
- **collect**: sun and water: net zero energy (solar power); water collection and grey water recycling.

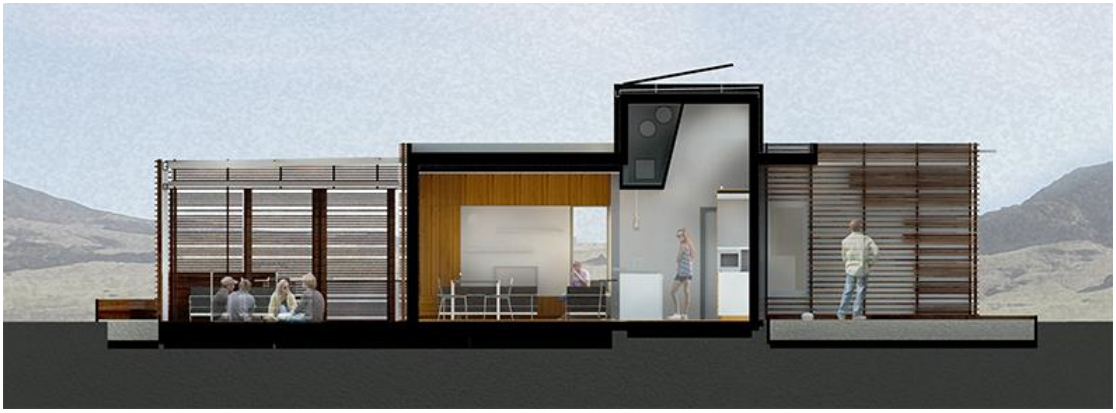

Fig. 2: INhouse [north|south section]

3. Intuitive, Interactive, Integrated

INhouse is designed to inspire its residents to take control of their personal environment. Intuitive, interactive, integrated: the team's interpretation of net-zero, a new way of interpreting a contemporary California home. INhouse explores the link between system and resident, with the goal of making operation and management intuitive, energy affordable, and waste minimal.

3.1 Intuitive

Through a precisely designed envelope and passive systems, INhouse is crafted to maximize the thermal and luminous comfort of its residents. Residents can easily learn how to operate the passive systems of the house - sliding screens, sliding glass walls, operable windows - in order to maintain their daily and seasonal comfort. Through a straightforward control system, residents can optimize their luminous and thermal comfort by communicating on site or remotely with the supplemental systems of the house, which include heating, cooling, and lighting systems. The operation of the INhouse systems does not require any rigorous training; the design of these systems is intended to be intuitive. By actively engaging with INhouse, residents can save energy, reduce costs and maximize comfort. Over time, residents will learn that small changes in their daily habits can result in a reliably comfortable living environment - one that not only elicits sensory delight but also realizes real energy efficiency.

3.2 Interactive

INhouse provides an environment that enables the resident to adjust the house to meet changing needs. Interaction with the house is based on the resident's senses and aims at enhancing each experience. When the

weather is nice, s/he can open the folding glass wall between the living module and the outdoor solar bifacial room. When the sun is least harsh or views are too good to pass up, the resident can push open sliding screens along the southern edge of the bifacial room. By enjoying the bifacial room itself, the resident is directly interacting with one of the home's methods of energy production. Meanwhile, real-time feedback informs residents about energy use and production, allowing them to appropriately respond to this information. The interactive features of the home allow a fully customizable experience that can be tuned to the needs of the occupants.

3.3 Integrated

The home is designed around a core that contains its active intelligence - mechanical, electrical, plumbing, and monitoring systems. INhouse aims to unify all of the home's components into a coherent whole - from passive to active, indoor to outdoor, and architecture to engineering. All systems are integrated, creating an efficient home that is simultaneously delightful as well as user friendly. The resident dwells between the core and the wings, in open and comfortable spaces where thoughtful architectural design and mechanical systems meet.

4. Holistic Design

INhouse represents a collaborative team effort, a cohesion of architecture and engineering in which the sum of the parts result in a larger cohesive and delightful whole. The team's design combines materials and systems to create a modern California aesthetic.

4.1 Passive | Active

Designing INhouse to minimize environmental impact and maximize climate responsiveness and comfort begins at the most basic level - building shape and placement. The home's spaces are thoughtfully arranged with solar orientation in mind.

In a temperate climate such as San Luis Obispo, California, with near equilibrium between heating and cooling degree days, the design of INhouse utilizes these elements to achieve comfort balance. The team's climate analysis led to six primary climatic design priorities: organize, insulate, shade, ventilate, stabilize, collect. To organize, the house is elongated on its east-west access and the interior is zoned for maximized comfort. The public day use spaces are on the south, and the private predominantly night use spaces are on the north. To insulate, the 8 1/4" structural insulated panels [SIPs] in the walls and ceiling provide an R value of 30.5. The SIPs combined with the R 24 floor results in excellent insulation values and a tight envelope, an appropriate design approach for our target climate zone. To shade, the house uses multiple strategies, including both the bifacial room on the south as well as the redwood screen on the wings. To ventilate, all the windows are operable, including the north-facing clerestories in the taller core, which are designed to promote stack ventilation. To stabilize, a phase change material duct runs the length of the core, dampening temperature swings on the interior. To collect, the team specified both monofacial as well as bifacial photovoltaic panels for a combined rated power output of 9.3 kW [the house also powers an electric car].

Fig. 3: Bifacial Room [with bifacial photovoltaic panels

4.2 Core | Wings

INhouse includes two wings - one public and one private - linked to an active core. On the exterior, the core and the wings are formally and materially differentiated through volume as well as materials. The passive wings are lower, more porous, and are defined by a redwood screen designed to shade the envelope as well as to highlight the origin of our project, the central coast of California. The taller active core is more sleekly designed, using panelized construction, and enclosing the home's comfort systems.

On the interior, the core and wing organization creates a separation of space that allows for an open floor plan for the public spaces, while maintaining the option of privacy. In addition, purpose-specific casework is integrated along the short ends of the wings, creating a "bookend" effect that minimizes clutter and defines space. These bookends are also an example of the project's overall holistic design. The bookends act as thermal buffers through their east/west orientation, acting as additional indicators of the project's climate responsiveness. They also provide spatial organization as well as material and textural interest to their adjacent spaces.

4.3 Inside | Outside

Connected by a 15 foot NanaWall®, the public wing seamlessly connects to a generous outdoor area, emphasizing the outdoor living potential afforded by the coastal California climate and doubling the home's public space. The outdoor decks provide residents with additional square footage that is essential for an otherwise modest house footprint. This outdoor space is adaptable through operable shading screens that allows user–defined comfort in response to the changing seasons. In the bifacial room, shading with bifacial PV panels not only offers refuge from the harsh southern sun but also provides additional power for the house. This includes some power gained through reflected light, one of the attributes of bifacial technology.

The constructed wetlands are an additional indicator of holistic design. In drought stricken California, progressive thinking about water use is essential. Greywater from INhouse is captured and channeled into the wetlands, transforming a resource that was once considered waste into a precious resource that provides a touch of natural delight for the inhabitants. Additionally, the other planters located around the walls of the house collect the rainwater from the roof. These small rain gardens are planted with local vegetation which become dormant in the off season.

5. In Pursuit of Quality

In order to realize the design intent of INhouse, Solar Cal Poly established a goal of selecting materials of superior performance and quality. The team selected materials based on thermal and environmental performance as well as durability. Many of the materials selected for the project come from the West Coast.

However, material performance alone is insufficient for delightful design; quality is essential to achieve delight. For the team, this translated into choosing materials not only for their aesthetic potential but also for their longevity.

With these filters established, the rationale behind the material selections for INhouse becomes clear. The envelope is predominantly constructed of structural insulated panels, which combine structure and insulation into one component, resulting in higher R-values, faster construction times, and a tight envelope.

On the exterior, the core and wings are materially differentiated from one another. The core utilizes a panelized material made with FSC® certified and post consumer waste paper content; it also requires no additional treatment. The wings are predominantly screened with locally sourced FSC® certified redwood. For performance, the redwood screen shades the envelope and is patterned as a solar thermal map of the house, with the denser areas indicating zones of higher solar intensity [Fig. 4]. For quality, the redwood identifies the project as a product of its region (coastal California) detailed and crafted to create a modern California aesthetic. On the south, the screen continues past the limits of the envelope to shade the exterior, providing privacy and creating a comfortable outdoor room.

Fig. 4: Redwood screen: as modeled (left) and as built (right)

On the interior, INhouse's contemporary aesthetic draws on a blend of light colors and wood to create comfortable and delightful spaces. The light walls are intended to work in concert with the architectural lighting to create an expansive feeling in the relatively small spaces. The flooring and bookends are intended as a gentle contrast, using the warmth of FSC® certified bamboo flooring and cabinet faces as a material counterpoint.

Also within INhouse is a material that is mostly hidden: phase change material [PCM]. Following good passive design principles means that INhouse needs thermal mass in order to dampen temperature swings and to better maintain thermal comfort. Most of this material is out of view, located in the phase change duct that runs the length of the core. In order to educate inhabitants, the team chose to display some PCM material through the more interactive art piece along the south wall.

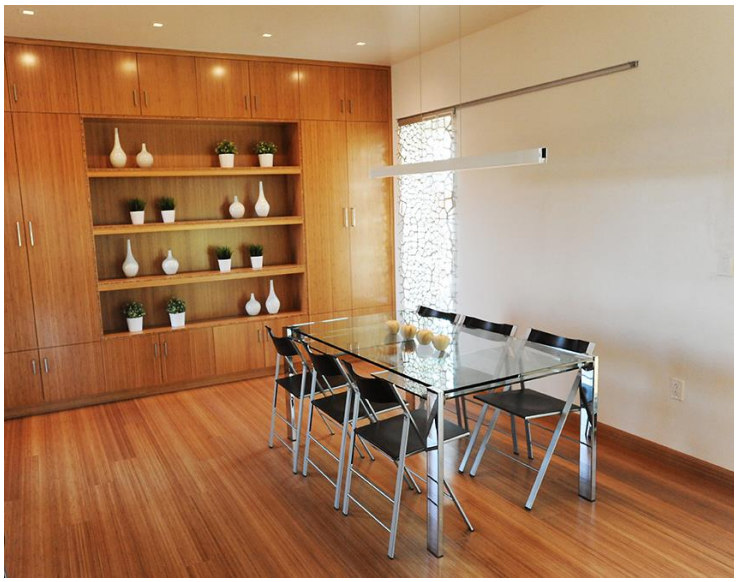

Fig. 5: INhouse interior [dining room]

6. Conclusion: INnovation

Differentiating between the active core and the more passive wings exemplifies an aspect of INhouse's design ingenuity. Locating the active systems in a central core allows for more design freedom in the wings and thus presents an opportunity for replication without duplication. If replicated, the number of wings might be different, or in a different configuration. The core itself could be prefabricated and mass-produced. Either of these components could be fabricated for high-end or more modest clientele.

Creative use and expression of material was also a goal for INhouse. The use of PCM as a thermal moderator is one example. The use of the redwood as an expression of thermal shading and solar thermal mapping is another. Each of these represents an emerging chapter in the design professions, as we employ our parametric design tools to help us simultaneously achieve superior performance as well as delightful aesthetics.

Perhaps the Solar Cal Poly team could have designed a house that operates entirely independent of its residents, but a "smart home" is of less value to society than a "smart resident." This holistic approach stems from the shared vision and close collaboration between the many disciplines involved in creating INhouse. Residents of INhouse will be encouraged to learn how to live net-zero, and the house itself will be the vehicle of their education.

The Solar Cal Poly team presents a new standard of "in" by creating a notion of ecological living that is enticing as well as achievable. INhouse is an approach to living well, while still living within our ecological means.

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Photo credits: Thomas Kelsey/U.S. Department of Energy Solar Decathlon and Josef Kasperovich/Cal Poly