

# ReFAB PreFAB: The Practice and Science of Prefabrication at the Cutting Edge

Questions + Answers from the March 11, 2013 Webinar

**Q:** I don't see any precedents from the long standing American modular, and manufactured housing industry. How could this obvious, well established, and mature industry not be included in your research? Yet you looked at things like the Lustron that failed spectacularly? [Gregory Lavardera]

**A:** Although our presentation omitted precedents from modular and mobile home industries, we have certainly studied them. They provide an excellent case study in the logistics and business model of traditional residential prefabrication.

This being said, we have made a conscious effort to distance ourselves from these industries. We feel that, by-and-large, both industries are akin to Walmart: they provide a product that prioritizes low price over other factors. Our ambition as architects is to leverage the savings made possible by prefabrication to provide a higher standard of design, a higher level of finishes, and an increased sense of livability (perhaps more in keeping with IKEA's model, to continue the big-box retail analogy). As such, we tend to position our project closer to the contemporary work of Keiran-Timbelake, Lake|Flato, Blu Homes and others.

**Q:** Have you looked at Eggrock prefabricated bathrooms and kitchens? If interested, go to <http://www.eggrockmodular.com>. [Phil Terzis]

**A:** We briefly looked at Eggrock and were connected with someone there. They were very helpful in sharing knowledge and may be a company to collaborate with in the future. Thanks for recommending them as well!

**Q:** What 3d modeling software did they use to model their designs? [Brad Ensz]

**A:** We used Rhinoceros 3D Version 5. While more a modeling program and not necessarily a drafting program, the newest version has features that allowed us to produce the drawing sets we needed both for our permits and shop drawings. This way all of our information was in one program, as opposed to doing 3D work in one program and 2D work in another. We contemplated other programs like Revit, however, at the time we had little experience as a group, where as we had proficient experience with Rhinoceros 3D.

**Q:** What happens if the water heater fails and needs to be replaced? [Eric Catellier]

**A:** While there is some difficulty in accessing the water heater, we have designed the mechanical closet to have a removable panel in the bathroom that allows for this possibility. In addition, there is a hinged door in this panel for more regular maintenance. The air handler can be serviced from here as well as from the return air chase.

**Q:** Is exhausting HVAC through roof efficient? [Naomi Deutsch]

**A:** We do not intend to provide any HVAC exhaust through the roof (sorry if our presentation or drawings made this unclear). As we understand the IRC, HVAC exhaust is not required; if we have misinterpreted the code or find that it changes in the future, we would attempt to exhaust through our exterior walls and would turn to the roof as a last possible resort.

Perhaps your confusion arose from our systems diagram, which did show HVAC ductwork above the InHouse OutHouse. In most cases, this would be a single plenum that supplies air to the four faces of the mechanical room

below the existing ceiling. In cases where the InHouse OutHouse is inserted into a larger home, the air handler could provide enough capacity to condition other rooms via attic routed ductwork.

The only vertical exhaust we show is for the plumbing stack vent. Our intent is to provide a chemical vent (Studor vent or similar) below the roof line where allowed by jurisdiction, and penetrate the roof only as a last resort.

**Q: Have you estimated this model vs traditional field assembly costs? [John Dugger]**

**A:** We worked with a local Houston contractor who was able to give us estimates for a field assembly version of what we were providing. Assuming that the appliances and fixtures would be the same in each type, based off of our estimates the InHouse OutHouse would save \$2,700 and more importantly 130 hours in on-site construction time allowing the home owner to move in quicker.

**Q: Why plumbing on an exterior wall for colder climates? [Robert Vagnieres]**

**A:** The current manifestation of the InHouse Outhouse is a product of Houston, TX; making it cold climate-friendly is a goal for the future.

**Q: Have you addressed the potential for freezing plumbing under the wc and the tub in northern climates?**

**Supplemental heat? [Peter Smith]**

**A:** This has not been addressed yet. While our long-term goal is to provide a universally deployable product, we have accepted that we will have to arrive there iteratively.

**Q: In the first project example (i.e. prefab bath / kitchen unit) how do you obtain adequate maintenance access to the water heater? I've never lived in a house where I didn't have to replace the water heater at least once. [Robert Smith]**

**A:** While there is some difficulty in accessing the water heater, we have designed the mechanical closet to have a removable panel in the bathroom that allows for this possibility. In addition, there is a hinged door in this panel for more regular maintenance. The air handler can be serviced from here as well as from the return air chase.

**Q: Is under cabinet lighting anticipated? Would the entire module be UL rated as a single appliance? [Peter Smith]**

**A:** Under cabinet lighting was included. There are LED puck lights under each cabinet and LED strip lights above the kitchen sink and above the desk. In terms of UL rating, this is not something we anticipate pursuing, though we appreciate the suggestion and will definitely investigate its implications.

**Q: Appears to be std.30/40 gal HW heater. Annual flushing, servicing and replacement of HW heater appears to be difficult at best due to location. How is access for these accomplished? Also, describe regular serving of furnace. [Chuck Sullivan]**

**A:** After constructing the prototype, we are seriously considering relocating the water heater in future iterations, potentially moving towards a tankless water heater. The prototype does provide service access to the entire mechanical closet, which is separated from the bathroom with a "wall" of removable panels. The HVAC unit we used only requires front service access, which we provide just outside and adjacent to the bathroom door; we expect this will remain unchanged in future iterations.

**Q: The windows next to the toilet and tub offer a great view for the neighbors when the occupants "drop trou". Does**

the water that comes out of the frozen water pipes on the outside wall fall directly through the floor and get diverted to the flower beds? [Curt Juergens]

A: Although it may not have been clear in our presentation, the windows in the bathroom are intended to be frosted or otherwise translucent. There is ample precedent in bathrooms for enjoying natural light while “dropping trou” (think glass block, clerestory windows, etc). In fact, we consider the light that fills the bathroom as result of these windows to be one of the prototype’s most successful design moves.

The issue of frozen pipes and the suitability of the prototype for cold climate has come up repeatedly. Thankfully, we have thus far only build a single prototype that will spend its entire life in humid subtropical Houston, TX. We are the first to admit that our prototype is the first of many iterations that will be necessary to perfect a core that has more universal climate suitability.

Q: Does the floor of the insert unit duplicate the existing floor? [Tom Hirsch]

A: Only a small portion of the InHouse OutHouse has a floor: the ~18” that projects beyond the existing exterior wall (i.e. below the wall hung toilet and the tub drain). The rest of the unit has no floor and instead takes advantage of the existing floor.

Q: Why a water heater rather than "instantaneous" (i.e. tankless) heater(s)? [Barry Parks]

A: Very early in the process, we considered a tankless water heater and ultimately moved away from it for several reasons. We wanted to avoid having to vent any gas equipment through the roof, which would have meant locating the tankless heater on the outside of the core. Throughout our design process, we (for better or worse) fetishized the portion of the InHouse OutHouse that protrudes from the existing house and made every effort to keep it as clean and pure as possible. Having built our first prototype, we are reconsidering the purity of the projected volume are a strongly leaning towards an exterior mounted tankless water heater for future iterations.

Q: It looks like you are trying to stick these bathroom/kitchen units right where the living room would be in these bungalows. How does that make sense? Does it actually cost less than a stick built bathroom and kitchen of such modest size? [Neil P Hoffmann]

A: Our research shows that this not only costs less but also saves a great deal of time which is important to renovation clients. In terms of your question about the bungalows, we used the maps as rough diagrams and would obviously need to investigate the plan of each house more specifically. If you mean the prototype itself, the intention was to place it in the middle of the row house to allow for a living/dining space towards the front of the house and a bedroom in the back. The OutHouse unit acts as the divider between the two spaces with a 3’ corridor.

Q: So what was the problem with the existing infrastructure you are trying to replace with this unit? What is the motivation to stick one of these into an existing house? [Robert Tieni]

A: The existing house was wired in the 1950s. Additionally the plumbing was over 30 years old. The house was in desperate need of service upgrades. We provided an electrical panel that was a major upgrade, modern plumbing fixtures, and modern kitchen appliances that the house did not have before. Additionally, in this case, the prototype house was being used more as a workshop for an artist rather than a house. The house shell was in great shape (despite a lack of insulation) but the livability was questionable. With an OutHouse unit, the house is completely

reborn.

**Q: If the units are inserted on the street side they would seem to prevent visual connection from living space to the street; which is critical for neighborhood engagement. [Peter Smith]**

**A:** If you are referring to our neighborhood studies, yes this would be a concern for houses that have very little street exposure. However, in most of those instances, there is also a shared communal space in the back of the houses. If the house is wide enough there would be a window on either side of the unit or two on one side. Additionally if there is enough space between houses, this will help with neighborhood engagement. To be clear, it is not our preference to put the units in the front of the house. Our intention is that they are on the side or less ideal in the back. If we can avoid putting them in the front we absolutely will specifically for the reasons you mentioned as well as many others.

**Q: What about insulating the outer walls particularly at the base of the bath and toilet area? [Celeste Novak]**

**A:** Insulation is key the the long term success of the InHouse OutHouse in any climate, hot or cold. We have always intended to use sprayed foam insulation on all walls, interior and exterior. We need to continue to refine the location and routing of the plumbing waste; once this is more successful, we will take a closer look at wall thickness to provide enough cavity depth for insulation throughout the height of the units.

**Q: Did you consider sustainability of materials, construction process? [Celeste Novak]**

**A:** Among the many advantages of factory-based construction/fabrication is dramatically increased material efficiency. In typical site/stick built construction, 10-20% material waste is common; in a factory setting, that can be reduced as low as 2% waste. For the construction of the prototype, material selection was largely driven by what was easily available and not necessarily on the material's sustainable credentials; if/when we begin to produce the InHouse OutHouse in large quantities, we will begin to place much more emphasis on sustainability.

**Q: This is somewhat reminiscent to the inserted modular motel rooms used at the Contemporary Hotel at Walt Disney World. There a steel frame awaited the delivery of individual rooms on truck loading beds. Upon arrival, these were lifted and slit into position. At that point, room utilities where connected into the building system utilities. [Barry Parks]**

**A:** There are a number of compelling commercial projects that we took on as precedents and inspiration (specifically the McMurtry College dormitory bathrooms at Rice University by Hopkins Architects with Hanbury, Evans, Wright, Vlattas + Company). However, we noticed that the commercial applications completely dominated the market place leaving an avenue of opportunity open in the residential market. We're hoping to attack that niche both in terms of renovation and new construction applications. Thanks for the suggestion of the Disney project!

**Q: How access to the mechanical units achieved?... as the diagrams don't quite illustrate that detail and the space within the bathroom seems to be fairly tight. [Gerrod Winston]**

**A:** After constructing the prototype, we are seriously considering relocating the water heater in future iterations, potentially moving towards a tankless water heater. The prototype does provide service access to the entire mechanical closet, which is separated from the bathroom with a "wall" of removable panels. The HVAC unit we used only requires front service access, which we provide just outside and adjacent to the bathroom door; we expect this

will remain unchanged in future iteration. During the course of constructing and inserting the prototype we had, for various logistical reasons, to remove and reinsert the water heater several times. After it is drained it is entirely manageable for two people to maneuver.

**Q: Did you consider handicap accessibility implications in the size of the unit? [Barry Parks]**

**A:** To date, we have not considered handicapped accessibility (ADA, Texas Accesibility Standards, etc). We view the InHouse OutHouse as one manifestation of an innovative delivery system that is prefabricated, has no floor, and can be inserted into existing homes. A nearly limitless number of configurations are possible, and we hope to incorporate universal accesibility in future models.

**Q: Where does overhead and profit fit into your bar charts? [Paul Adams]**

**A:** In a round about way, profit and overhead is embedded in our case study. We based all of our analysis on a detailed estimate from a local contractor, and we folded overhead into each category. In the process of extrapolating this information to our reasonable goals for future production, the profit and overhead came along for the ride. That being said, we realize that we need to take a much closer look at both if our project is going to have longterm success.

**Q: How was the existing bathroom and kitchen handled? Was the outhouse located in the same place in the floor plan? [Mathew Albores]**

**A:** The existing kitchen was in the back of the house. The original house was a typical row house plan with two rooms up front and a kitchen in the back. The back porch was closed in to house a bathroom. After Project Row Houses acquired the property, the interior partitions of the front two rooms were removed to allow for a work space. We removed the kitchen partition and allowed the OutHouse unit to act as the divider between living and sleeping spaces. The existing kitchen was demolished and the existing bathroom will be turned into a large storage closet.

**Q: What does local building code (AHJ) adapting this? [Duc-Huy Huynh]**

**A:** The InHouse OutHouse as designed and built in the prototype conforms to the 2006 IRC, the code currently in effect in Houston, TX. Further refinements may be necessary to meet more up-to-date code. In the long term, we plan to obtain a license from the state to operate like a mobile/modular home manufacturer. While this would not change our obligation to the IRC, it would shift much of the burden of inspection from the site (i.e. the local building authority) to the factory (i.e. an inspection regimen that we maintain).

**Q: Have you studied the works of John Habraken from the Netherlands? Also Japanese unit baths, unit toilets, unit bathrooms, etc. There is a large variety and the quality ranges from basic to fairly high end. Totally unitized. [Richard Skorick]**

**A:** We are not currently familiar with the work of John Habraken and will certainly learn more. In a way, we have embraced the surface of the Japanese modular units, in that we aim to achieve a big impact with a small package. As we advance the project, we hope to adopt some of the high-tech/innovative/creative uses of space that appear in many of the Japanese projects. That being said, we also want to make sure that we keep the American user (our clients) in mind to provide a design that achieve a high degree of livability (and not get lost in novelty).

**Q: Did you eliminate a floor to avoid ADA issues? [Paul Scoville]**

**A:** Not directly. Changing floor elevation would be awkward for anyone, regardless of how able-bodied. Our goal was to make the InHouse OutHouse integrate as seamlessly as possible into the existing house. We still have a long way to go to meet ADA guidelines (maneuvering space will be hardest for us to achieve), but thankfully the floor is not an issue we will have to solve along the way.

**Q: Did the costs listed include the cost of appliances? [Kate Svoboda-Spanbock]**

**A:** The overall cost includes the appliances. We obviously used very high end appliances for the prototype since we had generous donors and partners. The grade of the appliances would likely be reduced, but remain above bottom line. In terms of the price comparison between on-site and prefabrication, we did NOT include the cost of appliances as we considered these to be fixed variables between the two options.

**Q: Why not a window in the kitchen if you have the wing wall? Better than a bath window? [Fay Suelztz]**

**A:** This is a great suggestion. We're working out what the wing wall actually entails at the moment. We think that we will be moving the electrical panel to the interior and adding the meter on-site. This would allow a window into the kitchen. However, we do like the idea of the double window in the bathroom and while a shower window may be frowned upon for construction and privacy issues, we felt it important as an issue to add daylight to the bathroom for a more enjoyable space to be in.

**Q: Weight of unit vs. weight limit of the Lull (fork lift)? [Robert Coolidge]**

**A:** This is something we discussed at length with the company we rented the forklift from. They provided us with extension forks as well as helped us to figure out which unit would serve our purposes best. The OutHouse weighs roughly 5,000 pounds and we used an 8,000 pound forklift.

**Q: What's the different if we just prefab the parts & assemble it on site? [Duc-Huy Huynh]**

**A:** Good question. The major difference is the OutHouse is a completely finished-out unit that merely needs to be mated with the existing house and have services connected. The on-site work is minimal due to the efficient design. If the project were broken up into wall components, site work would increase sharply. Additionally, there would not be much savings in terms of shipping volume as the OutHouse is very efficient in terms of shipping dimensions as we were very careful to specifically design to USDOT regulations and standards.

**Q: Does the wall inside the bathroom need to be removed to change the furnace air filters? [Curt Juergens]**

**A:** No. The return air filter is accessible just outside the bathroom via a very standard return air access grille. If other service to the air handler was ever required, the manufacturer's required service access is also provided adjacent to the bathroom via a service access panel. As a last resort, the wall between bathroom and mechanical closet is actually a large removable panel that provides unfettered access to the air handler and water heater.

**Q: Is the "inhouse" accessible? Are the floors at the same level as the existing house? [Don Woodruff]**

**A:** The OutHouse does not have a floor of its own, so to answer your question, yes they are at the same level. The

walls of the OutHouse slide in on the existing floor thus there is no need for a step up. Having a floor for the OutHouse was an issue that came up early in the process that we recognized was not feasible so we engineered all of the plumbing through the walls thus removing the necessity for a floor for the unit itself.

**Q: How serviceable are the components in the out-house (in the event of renovations or plumbing/electrical failures)? [Aric Abblitt]**

**A:** The majority of the plumbing and electrical are run behind the lower cabinets which are removable. This is easier to accomplish earlier in construction to facilitate inspections. It becomes more difficult once finish and trim work is complete, but can be accomplished in the event of this area needing servicing or renovation. The transformers for all the lighting are located in the mechanical closet and can be accessed at on of the removable panels inside the bathroom.

**Q: Have you investigated 2 and 3-story applications? [Edward Acker]**

**A:** While we have not fully explored the issues associated with these applications, it is definitely on our radar as something to explore and investigate. The main issue would seem to be what to do with all of the pipes and lines coming into the unit from the utility companies. This might be a major problem to deal with but may be one that can be worked with through some keen problem solving. It's something we still need to work out, but for now we are focused on one story applications.

**Q: Can you recommend bim software that is used most often by prefab companies and architects? [Debra Coleman]**

**A:** To our knowledge, most prefab companies are using Revit to coordinate efforts. This way the factory can have the same model as the design office. Architecture offices are increasingly using Revit to coordinate with trades. However, CATIA and SketchUp have both made strides in their ability to provide BIM information as well.

**Q: What are the building code and inspection issues? [Steve Riden]**

**A:** For the prototype all of the inspections were able to be completed at the site of assembly. For future applications we plan to work toward establishing certification for manufacturing standards once these were being produced in any volume.

**Q: Did you include comparison of design and coordination cost premium for the OutHouse vs analog? [Travis Campbell]**

**A:** No, and we should have. In a scenario where we build the InHouse OurHouse in small quantities, these cost are unsustainable. Once we reach larger scales of production, this cost can be distributed across a larger number of units.

**Q: Any thoughts about incorporating a composting toilet or other off the grid fixtures? What challenges would these types of fixtures pose? [Michael Kilkelly]**

**A:** I really love this suggestion. It's an incredibly intriguing one that would be interesting to study. I think part of the challenge with a composting toilet would be making sure the house receiving an OutHouse unit had a basement or at least sufficient crawlspace for the composting tank as well as clearances to access and service it. However, we are aware of other units which have built in tanks and are looking into this as a possibility. In terms of other off grid

techniques, we attempted to incorporate solar technologies, however this would require quite a great deal of battery space which we felt we did not have. Part of the reason for choosing a large water heater was the potential ability to adapt the project for solar hot water, however, we don't view this as a standard option. I think the interest in affordability may limit our potential on some of these technologies, yet they are definitely worth pursuing.

**Q: Was the removal of existing bathrooms and kitchens included in the cost of using one of these units in an existing home? [James Gooden]**

**A:** We did not consider the cost of demolition, however, similar to how we addressed the appliances, we assumed these as equal costs between site built and our prefabricated alternative. Assuming a renovation would take place, the demolition costs are a given. The question brings up a good point that we should address this cost as a line item in our findings.

**Q: Have you thought about integrating this module with the PassivHaus system? [Margot Fehrenbacher]**

**A:** This is a really good question. Ultimately, we don't necessarily view this project as a "performance project". While all projects at this point need to have sustainable considerations as well as energy efficient ones, our focus was more on quality design, compactability, and efficiency in terms of space. With that said, we chose a low flush toilet, low flow fixtures, LED lighting, energy efficient appliances, and added insulation to the prototype house which had absolutely none. We are still working through other ways to find energy efficient techniques to add to the project and I think the PassivHaus system is a great suggestion.

**Q: How thick is the wall on the proto-type to support the wall hung WC? [Michael Engel]**

**A:** The wall for the wall hung toilet is a 6" deep wall. We framed the wall specifically for the in-wall tank and doubled our plywood "studs" as necessary to allow for more structural stability. The toilet uses the steel frame of the in-wall tank as its structure.

**Q: How to address a two bath unit plus kitchen where at least one bath needs to be adjacent to a bedroom i.e. a master suite? [Fernando Zuniga-Pflucker]**

**A:** This is a great question and one we have looked at in a number of ways. We imagine that a second unit could be used in a house that has 2-3 bedrooms. We consider this OutHouse 2.0 where the kitchen would be replaced by storage or an office and the mechanical closet would be replaced by a washer and dryer. We're still developing this as a design idea, and hope to potentially work with this down the road. However, our focus at the moment is the single unit.

**Q: When you are building a modular unit as an all encompassing solution, you need to accommodate specifically, the Fair Housing Act and not ADA requirements for accessibility. Your bathrooms are not and you cannot market this for projects of four or more units. Your kitchen design really needs to consider the what is important in a compact cooking unit, dishwasher, high research on kitchen cabs for max storage such as roll-out shelves, a second level of cabs above the cabs after installation. The cost of plumbing in the kitchen is negligible, consider a sink in the island and make that triangle between the range sink and refrigerator. You cannot replace the HW heater or service the heater. [Douglas Korves]**

**A:** Your comments about the Fair Housing Act are very useful, and frankly something that we have not considered in great detail.

We struggled throughout the process with what to attach to the InHouse OutHouse and what to leave for the site. We ultimately came to the conclusion that an island in the kitchen would be necessary for deployments in larger homes. That being said, we were pleasantly surprised by how functional the current kitchen layout is, even if the wrap-around countertop is a bit unconventional.

The mechanical closet is one of the least successful areas of the prototype. The entire "wall" between bathroom and mechanical is actually a series of removable panels that provide access to water heater and air handler. The air handler also has manufacturer/code required service access from just outside and adjacent to the bathroom door. Despite our best intentions, these access details turned out fussy and labor intensive, and we are studying a variety of better strategies.

**Q: What software have you used? Rhino was mentioned? Links to CNC? [Robert Coolidge]**

**A:** We used Rhinoceros 3D Version 5. While more a modeling program and not necessarily a drafting program, the newest version has features that allowed us to produce the drawing sets we needed both for our permits and shop drawings. This way all of our information was in one program, as opposed to doing 3D work in one program and 2D work in another. We contemplated other programs like Revit, however, at the time we had little experience as a group, whereas we had proficient experience with Rhinoceros 3D. We used RhinoCAM to export our files for CNC fabrication working first with a 3-axis router at Rice University and later with a local cabinet shop who had proprietary software for their series of CNC machines. I think in the future, we will likely partner with a company to do all of our routing if we do not do it ourselves in a factory setting.

**Q: It is imperative that all architects understand that the accessibility safeharbor for 4 units or more is the Fair Housing Standards not the local or ADA requirements. NYC City has had an accessibility code approved by the Justice Dept for 20 years and does not meet FHA. [Douglas Korves]**

**A:** We could not agree more that architects and others often undervalue the importance of universal accessibility. Sadly, we have thus far fallen into that category.

On the bright side, we view our work to date as investigating the feasibility of a system that reimagines the way architecture is delivered (literally). Our prototype has proved the viability of this system, and we are excited to begin refining the manifestation of that system into something that is better designed and more universally inclusive than the prototype.