Radical Redevelopment for the Future of Houses and Cities

Harvey M. Sachs, American Council for an Energy-Efficient Economy

ABSTRACT

The U.S. housing stock is generally poor in terms of energy use, location efficiency, and quality. Present "stick-built" approaches will not achieve national energy, climate, economic, and security goals. We propose an alternative that can start at a realistic size, but quickly scale to comparison with Haussmann's redevelopment of Paris (or the post-Sherman reconstruction of Atlanta).

Deep retrofits are inherently extremely labor-intensive because of stock variability, such as post construction *ad hoc* additions and modifications. Our houses may be large, but our households have grown smaller. Oversized, drafty houses with sub-par mechanical systems will increasingly have less value than the underlying land, particularly in cities and first-tier suburbs.

Land value is a key driver: We can release enormous market forces by "up zoning" to higher density. Although higher density has even greater potential, about 16 common-wall units/acre meet a threshold for "walkability" and mass transit frequency in some housing types (Condon 2010). Clearly, with higher densities, it becomes easier. Market forces and sound planning stimulate this in areas as far apart as Arlington, Virginia and British Columbia.

The major missing element is *mass customized* industrialized housing, based on advances in information technologies and new manufacturing processes. Factory-built panelized systems whose keying prevents incorrect assembly mean that quality and its byproduct, efficiency, can be built in, instead of inspected in.

Multi-year, increasing volume, declining cost procurement can launch new construction methods. The spillover would permanently change the industry, as is happening in other countries.

Introduction

American housing is a mess, from almost any perspective. Since 1950, median house size has more than doubled, while household size has declined. There is now far more space to be heated and cooled per person, in houses that are not well built. The housing price bubble has burst, leaving millions of homeowners owing more than the market value of the houses they live in. Interestingly, in many metropolitan areas the outlying suburbs have lost much more value than areas closer to the city core.

Commuting by car—and needing to use the car for all errands—makes household transportation energy use about as big as the energy used in the house for heating, cooling, hot water, and all the household amenities and services. In growing urban areas, congestion is overwhelming, while the civil infrastructure of roads, water, sewers, and communication services is obsolete and often decaying.

Many thoughtful people have addressed the challenges of "deep retrofits" to save half or more of the energy use in existing houses. The diversity of the housing stock, even within a single metropolitan area, along with the idiosyncrasies of site-built houses that have largely been spared the pride of craftsmanship in the face of demands for speed and price reductions, guarantee that lasting retrofits based on sound building science will remain labor-intensive and costly. In many housing types, really deep retrofits would require expensive envelope alterations that irrevocably change the appearance of houses and neighborhoods. Scaling up deep retrofits looks like it will require new financing models and new service delivery models: it can't be cost-effective with one-on-one sales like the replacement window industry.

Doing the same things over and over will not get us out of this quagmire: the resources and will are not there when the results promise to be so disappointing. Since we already plan in terms of decades for major infrastructure projects (highways, sewer system reconstruction), why not think in bolder terms about solutions that might address energy, environment, and community issues in urban areas, particularly if it can be financed by released land values?

This paper is a conceptual synthesis of one approach. It is a sketch, not a blueprint. For example, we do not treat questions of "embodied energy" in the housing stock. It represents one effort to begin a discussion about inventing a future. The fundamental elements proposed here are pretty simple and largely rely on bringing together things we know how to do already. These include:

- "Mass Customization." Use information technology and advanced industrial production methods to replace as much site labor as possible with construction components and systems *that can't be assembled wrong.* With modern production methods, such housing can be highly customized. Energy efficiency is extremely difficult to achieve by inspection but will be a no-cost byproduct of truly high quality assemblies.
- Use a long-term competitive acquisition system to launch the mass custom housing industry. As one route, competitive proposals would offer date certain for delivering completed houses of specific performance and capacity specifications. Over a five- to ten-year term, each year the contract would guarantee an increasing level of purchases, at declining unit prices as the manufacturing infrastructure is amortized and the production scale increases. We believe that this can be done in a way that the resulting high performance, high quality, moderate cost ($/sf) housing will be attractive for private sales in large numbers.
- Demolish and replace urban and close-in suburb neighborhoods that are near high-potential mass transit corridors. Starting with areas where the value of the lots is much greater than the houses now on them is one promising path. Such areas are frequently identifiable by the beginnings of tear-down construction of "McMansions" that replace post-war bungalows and ranchers, all but overflowing reasonable lots. We believe that the value released by replacing medium-lot-size housing with much higher density is so great that sellers and developers can profit, while buyers can move into new communities with higher amenities, real neighborhoods, new civil infrastructure, and competitive prices.

The Current Housing Stock

This paper focuses on the "light frame" housing stock. Single-family detached houses account for 63% of residential units (EIA 2009, Table HC2.1). Townhouses, low-rise condominiums, and similar attached-wall housing of similar construction are an additional 14% of the stock. Mobile homes are 6% of the stock. Although we expect this stock to face increasing competition from advanced industrialization, it is predominantly rural and urban edge, and thus will not have the same value proposition as "densifying" parts of the urban landscape.

Similarly, we do not treat the "heavy" multifamily stock, generally defined as four stories and higher, which is 17% of the stock. Such buildings differ fundamentally in construction materials (predominantly concrete and steel), scale, and HVAC systems. Present site-built construction methods for this stock are characterized by very long time scales. They are also amenable to change: Intensive use of factory prefabrication and exquisite control of logistics enabled site assembly of a 30-story hotel in 15 days in China—including the furnishings (CrazyEngineers.com 2012). Similar efforts are underway in the United States—for example, for schools. These approaches are not to be confused with the mass-produced concrete apartment "box" assemblies that characterized the former Soviet Union's efforts in post-war rebuilding, which yielded a vast sea of uniformity and low quality. That program simply did not have the information technologies and flexible manufacturing that are possible today. As with the mobile home stock, there may be huge possibilities for replacing multifamily stock in dense urban areas. In particular, where the value assigned to the land is much greater than the value assigned to the building, demolition and reconstruction could be profitable. However, this value proposition may require changing the use of the land—for example, from moderate-income housing to high-end retail, office, and condominiums. Because this housing stock is relatively small in the national picture, we do not treat it here.

Diversity is the most prominent characteristic of the single-family housing stock. Everything varies, but the *Residential Energy Consumption Survey* (EIA 2009) allows some generalizations:

- Eighty percent was built since 1949 (Table HC2.1).
- Median (and average) house sizes have grown substantially. The median new house size in 1973 was 1,525 sf, which grew to 2,277 sf at the 2007 peak (Census, undated). Going back further, the iconic Levittown house built for returning veterans was 750 sf (Rybczynski 1991), although the median for the 1950s was 2,055 sf (EIA 2009, Table HC 10.6).
- Forty percent are slab-on grade. About one-quarter of the houses have crawl spaces and over one-third have basements. This diversity has important ramifications for HVAC systems and their energy efficiency. In addition, half the basements are finished (EIA 2009, Table HC2.1). It is difficult and expensive to properly insulate finished basements.

During the post-war period, there was also a huge population shift from the "Rust Belt" to the "Sun Belt" of the Southeast, Southwest, and California. This shift brought several major changes in construction. In the Sunbelt, slab-on-grade predominated, with far fewer basements and crawl spaces. This forced the migration of HVAC and water heaters to new locations. Sometimes the equipment went into a closet, but more often it was exiled to space outside the thermal envelope, especially the attic or a garage wall adjacent to the living space.

Residential energy codes began in the 1970s. However, as built, post-war housing stocks are congenitally inefficient. "Features"[1] include:

[1] "Features" is the software marketer's term for what users call "bugs"—defects that the user must work around.

- HVAC systems
  - The earlier forced-air systems, with the furnace in the cellar or crawl space, had undersized ducts sized for heating only. The diameter is too small to move enough air with the smaller temperature contrast in air conditioning efficiently. And the role of return ducts was poorly understood. Most houses used unsealed interior wall stud spaces and panned-in joist spaces for their (undersized) return systems.
  - Later attic-based systems also had inadequate returns, with the additional feature of huge duct leakiness. And the attic is typically the coldest location in winter and the hottest in summer, but the equipment and ductwork had even less insulation than the ceiling.
- Shells
  - Almost universal use of 2x4 studs with poorly installed batt insulation (or none, into the 1960s in many regions), thermal bridges through studs without proper cladding or air barriers and drainage planes.
  - No or inadequate band joist or foundation insulation. No air seal at attic-living area to ceiling plane, leading to huge infiltration through gaps and areas with dropped ceilings.

Compounding these features were design characteristics that make efficiency harder to attain, including:

- Poorly ventilated hip roofs in southern climates. These serve as heat lenses, assuring that the attic is much hotter than ambient and forcing the attic HVAC and its incidental radiators (ducts) to work much harder.
- Two-story houses with atria or open staircases connecting the floors. Combined with inadequate returns and poor attic insulation, these design features assure that upper stories will be much hotter in summer than the ground floor.
- Really dumb plumbing architecture, with hot water fixtures widely dispersed but served by a water heater at one extremity or the other—convenient to the chimney. For slab-on-grade houses, under-slab routing guarantees that the hot water lines won't freeze but will dissipate residual heat quickly.

On the other hand, houses are "organic" adapting to the needs of successive owners with remodeling and additions. In bad years for new construction, the remodeling industry has as much revenue as new construction, so it is significant. Remodelers sell space and amenity; we believe that few stress efficiency. Because remodelers must discover the surprises in the walls, high costs are inherent and *ad hoc* solutions to problems such as joining a new wall to the existing house are required daily.

The resulting house is often a composite of different construction styles. This is important because figuring everything out and designing a shell retrofit requires matching methods to construction. Diversity adds time and cost to the process. Thus, there are major technical challenges to establishing and scaling up "deep retrofit" programs. There have been impressive efforts, and Building America has turned attention to these issues. However, if the country commits to large-scale deep retrofits, it may require "re-cladding" or adding a new envelope (with new windows) to many kinds of existing buildings. This is characteristic of "Passivhaus" retrofits in Germany (e.g., Waltjen et al. 2009). The cost of these extensive changes is likely to exceed current and expected house values in many parts of the country.

A second barrier is emotional attachment to the house as home. We're promising greater comfort and much lower energy bills, but deep retrofits will cause some disruption and leave the owner with a house that might look quite different from the outside—and looking through the windows. It's a hard sell and leads us to consider alternative processes with different barriers.

In addition, there are major institutional issues. One is that we don't know how to organize deep retrofits for low-cost service delivery, so we can efficiently do an entire neighborhood on a production basis. We need new institutional arrangements that respect individual freedom of owners and yet minimize transaction costs that make replacement window sales, remodeling, and similar individual transactions so expensive—from sales through finance.

Notes on Land and Location Efficiency

As noted in the Introduction, typical households use about as much energy for transportation as for operating the house and its accouterments. Conventional wisdom in the real estate industry is that prices in a given metro area for equivalent houses fall in proportion to distance to the city center. As a consequence, many families have accepted the trade-off of longer commutes for more house. However, gasoline price increases have greatly affected cash flow and affordability in outlying areas. Thus, outlying suburbs have suffered much higher fractional losses of value since 2008 and have higher fraction of foreclosures and houses "underwater"—that is, worth less than the mortgage obligation.

This implies that closer-in suburbs will have increasing relative value if energy (or even just gasoline) prices remain high. For example, in relatively desirable suburbs in the D.C. area, lots less than one-half acre are worth \$750,000, whether or not the existing house has been demolished. Today, that desirability is yielding a crop of teardowns and oversized McMansions. With rezoning at higher density and with a mechanism for assembling large "parcels," enormous value could be released by redeveloping with new civil infrastructure. This need not be high-rise: experience in British Columbia and elsewhere suggests that attached housing in the range of 16 units/acre can be extremely desirable (Condon 2010). And, even at this low density, one can assure easy walks to frequent mass transit and shopping, at least in "gridded" cities. This begins to sound like a "value proposition:" If the land value of an acre is \$1.5 million (two lots @ \$750,000 each), and if we can put 15 units on that acre (including access roads), then the underlying value of the land is only \$100,000/household.

The value proposition improves with denser housing and mixed-use development. Although the advanced construction materials and methods for high- and medium-rise buildings differ from those for free-standing and common-wall single-family housing, there are similar opportunities for massive reductions in time to completion through precision off-site prefabrication of "modules" that can be assembled quickly and whose "arteries" and "nervous systems" (HVAC, plumbing, power, and communications) are precisely enough located within modules to be quickly linked to the building "backbone." One example is a 30-story hotel that took 15 days to assemble—including finishes and furnishings—with claims of unusually low energy consumption, too (CrazyEngineers.com 2012).

Of course, this assumes that the housing built on such sites is attractive to consumers, who are assumed to aspire now to McMansions, even if they are built cheek-by-jowl on tiny lots. Given that household size continues its downward trend, many observers see a reversal of the trend to grandiosity and a shift toward valuing easy maintenance, lower operating costs, and even actual neighborhoods. The scheme we propose could reinforce these trends with high value but moderate cost houses.

To summarize, our underlying premise can be stated succinctly: Rather than renovating car-centered inner suburbs one house at a time, let's buy the properties, "replat" with new civil infrastructure,[2] and rebuild with much higher density to meet the needs and aspirations of the next century. It's a lot easier to do a thousand housing units at once, even with very varied plans and features, than to redo a thousand units one at a time, leaving all their inherent problems. After all, this was part of the drive for "green field" developments such as the Levittowns and waves of California development.

But, the approach we suggest requires a means to provide houses and communities that people will want to live in, and to do it profitably.

Scale

Many successful innovations start small, stay small for a long period, and rapidly transform the market. Some remain niche solutions for decades, as exemplified by both Structural Insulated Panel construction (SIP) and residential "geothermal" (ground-source) heat pumps. To some extent, both suffer similar problems: very high costs at small sales volumes, when the support infrastructure just doesn't exist. That essential infrastructure includes knowledgeable consumers, contractors, and code officials—and a large enough industry to have competitive markets (and competing suppliers of components) in key areas.

SIPs are an industrial alternative to stud-wall (stick-built) construction, but have not been able to establish a competitive advantage yet. We believe that multiple factors are interacting here. One of the most important seems to be that present manufacturers are not making enough panels to cost-effectively make real "kits." By this we include panels that are keyed so they can't be put together wrong; windows, wiring and plumbing that are largely factory installed; and prefinished walls. Today, just air sealing SIP panels for a house requires cases of caulk, hand-applied. At best, the labor content required reminds one why cars are no longer hand-painted.

Instead, we need to think of integrating information technologies—including BIM[3]—with mass production. One conceptual route would involve "continuous casting" of panels that are cut to length, fitted with interlocking joints, and prewired and pre-plumbed, with windows installed—then stacked in sequence for shipment on a flat-bed truck for field assembly. Ideally, each housing unit would be clear-span, with no interior structural elements other than a plumbing and utility core. That feature would allow reconfigurable interior partitions for "remodeling" at much lower cost, without risks of damage to the building.

One illustration of the importance of scale and customizability is the need for different construction for common walls of town or row houses from true exterior walls. Common walls must meet high fire protection standards and should offer high sound attenuation. On the other

---

[2] Water, sewer, communications, power (often built around distributed generation with district heating and cooling).

[3] BIM is "Building Information Modeling," a new basis for three-dimensional modeling that automates dimensioning of components, creates bills of materials, and finds interferences for re-design (Conover et al. 2009).

hand, they may not need as rigorous thermal insulation, and they have no windows or other openings. We believe that a factory would need to "blend" at least two types of panels, and that they might have different thicknesses.[4]

We guess that basic plant capacity should be at least 10,000 houses, and that a suitable facility would be about the size of a small automobile assembly plant—of which there are numerous surplus ones today.[5]

There may not be a market for 10,000 similarly constructed houses per year in the United States. Thus, we stress the importance of information technology and advanced, flexible manufacturing. Today, a customer can order a new car from the factory with exactly the features he wants, at least for some lines. Imagine being able to do this for a house, in a setting with full three-dimensional simulation for virtual house tours—and pricing done dynamically for all alternatives desired. With proper IT integration, that highly customized and completely finished house could be delivered for assembly within weeks and assembled in days. If you can assemble a 30-story hotel in 15 days, surely we don't need months for single-family and similar attached housing.

We've already outlined the benefits of selling these as part of community restructuring: buying up entire "obsolete" neighborhoods at market prices, demolishing the houses and roads, and replacing them with higher-valued property. This has precedents, particularly in replacing older but well-located residential areas with high-value commercial high-rises.[6]

What's missing is how to create enough demand to capitalize the manufacturing systems. One approach would use competitive solicitations in which the government (military, public housing, graduate student apartments, etc.) guarantees a large enough initial market (say, five years) to justify the product design, design for manufacture, process R&D, market research, etc. These competitions might only guarantee sales of 5,000 units per year, or other such number to be determined. And, the manufacturer would only be paid per unit delivered successfully.[7] The goal is market discipline: requiring real business plans from credible, bondable firms that make it possible to build products on the same line that are attractive to private buyers as well as institutions. That's where the profits lie.

This concept is not completely novel. For one example, DARPA, NASA, and other agencies are increasingly using competitions as an alternative to government-funded research to solve "hard" problems. In a real estate example, during the late 1980's, New Jersey stimulated redevelopment in some urban cores by issuing RFPs for new office space in these neighborhoods. The RFPs were structured to commit the state to leasing *most,* but not all of the office space, and to require retail on ground level. It was clear to bidders that they might cover most costs on the state leases, but profit would require adding commercial tenants for the remaining space. In short, the state lease guarantee provided the foundation for a solid business plan, but not the whole revenue stream. We're proposing something similar: a guaranteed market that will largely cover capital costs, but which will require making an attractive, cost-effective, product that will draw additional private sales.

---

[4] This need was pointed out by a reviewer.

[5] Burton Goldberg outlined an early version of these concepts in his 1998 paper at NAHB and stimulated much of my thinking.

[6] Possible examples are found near I-285 US 19 (Roswell Rd) on the north side of Atlanta.

[7] In this, we follow the model of the wind energy tax credit, which is based on delivered energy (c/kWh), rather than investment. This imposes much greater discipline on the market.

Discussion

"Up zoning" to higher development density seems to occur almost as a "natural" response to opportunity. As one example, the D.C. Metro Orange line (heavy rail) runs through Arlington, Virginia. When the line was planned and constructed, the Arlington County government succeeded in getting a string of four stations within walking distance of each other. This corridor has redeveloped with entertainment, office, hotel, and higher density residential, with maximum access to the Metro line (Ehrenhalt 2012). We're only proposing that this process be made more aggressive where there is a lot of value to be created through redevelopment.[8]

By now, there is a fair amount of agreement on major features of sustainable communities. Condon's (2010) *Seven Rules* typify some requirements: Enough density for streetcar-type mass transit; interconnected street systems; quick (five minute) access to transportation and services; good jobs near good housing; diverse housing types; linked parks and natural areas; and better infrastructure. We argue that the mix of advanced construction, large-scale quick redevelopment, and a value proposition based on value created through densification can meet all of these needs.

Of course, there are counter-arguments, some rooted in history. One highly relevant example is the "Lustrum House" (Reickert undated). This was an early post-WW II effort to mass produce and sell prefabricated houses based on porcelain-coated steel construction. The program received federal funding and built 2,498 units before bankruptcy. There were many factors in its failure, including pricing about 25–50% higher than competitive structures from large-scale, industrialized site-built firms like Levitt. Available technologies did not permit "mass customization," and a single 5-room, single-bath design was offered. The units were sold individually, rather than in a large-scale redevelopment project, so there were no economies of development scale.

However, the example does show the importance of firm, if contingent, agreements: Payment for performance, but solid contracts for payment over time for each unit under the program. As alluded to above, it is important that these contracts be structured to assure a break-even market (government), and to achieve the "mass customization" capability that will form part of the value added for private sector construction.

We also believe that the present residential construction model is obsolete. For 30 years, we have relied on inspection (augmented by magical tools like blower doors and infrared cameras) to put fear in the hearts of builders so they would avoid insulation gaps, leaky ducts, and other sins of omission and commission. The automobile and other industries learned decades ago that quality is much less expensive when designed into the process instead of relying on post-assembly inspection and testing. It's time to supplant low-bid subcontractors with challenging work-force issues with a new system based on tightly controlled factory processes. Indeed, I assert that *energy efficiency is just a side benefit of quality,* when designed in from the start.

We believe that flexible factories and changes in the marketing model can lead to housing that makes for customized, amenity-rich, quiet, comfortable, and energy-efficient homes, at

[8] The legal basis for land condemnation for "private" redevelopment is being litigated as this is written, but eminent domain may not be necessary.

prices much lower than we pay today. And the rebuilt neighborhoods can become communities, with great reductions in transportation energy for commuting, school transportation, and shopping.

The only problem is that this approach requires commitment to immediately get to scale. Quickly reaching profitable production and sales volumes will require commitments from government—for zoning, and as early adopter and guarantor of a sustaining product for high quality products, and also from the private sector, rising to the challenge of inventing both a high quality product and efficient processes for making it. It will be hard, but all the alternatives look much less desirable.

Acknowledgements

My journey to this conceptual paper merges lessons learned from many mentors and colleagues. Feather O'Connor Houstoun, when Treasurer of New Jersey, showed the power of state leases of *parts* of new office buildings in urban cores to stimulate new private sector investment that brought in commercial office and retail tenants. The state gained cost-effective office space—and the tax revenues from the private sector tenants who helped revitalize the targeted urban areas. Randy Swisher, AWEA, helped me develop the concept of declining-cost, increasing volume resource acquisition (for wind power). Burton Goldberg, NAHB, first illuminated the potential of "mass customization" when we served together in a strategic planning process for ARI; Thomas Kenney, NAHB, helped me locate a key paper. Eric Mackres, ACEEE, introduced me to Condon's work, which focused prior experiences observing redevelopment. Current ACEEE work on "intelligent efficiency" has been background music. The paper has been vastly improved by Panel 13 reviewers. Finally, I'm grateful for all the factories and construction sites I've been able to visit, and all the experts who've shared their knowledge so freely. But, there's much more to be done.

References

Census. undated. Median and Average Square Feet of Floor Area in New Single-Family Houses Completed by Location. www.census.gov/const/C25Ann/sftotalmedavgsqft.pdf

Condon, Patrick M. 2010. *Seven Rules for Sustainable Communities.* Washington, D.C.: Island Press.

Conover, David, et al. 2009. *An Introduction to Building Information Modeling (BIM): A Guide for ASHRAE Members.* Atlanta, Ga.: ASHRAE.

CrazyEngineers.com**.** 2012. **"**30 Storey Building Constructed In 15 Days! Broad Group's Timelapse Video**."** http://www.crazyengineers.com/30-storey-building-constructed-in-15-days-broad-groups-timelapse-video-1628/**.** CrazyEngineers Technologies Pvt. Ltd.

Ehrenhalt, Alan, 2012. The Great Inversion and the Future of the American City. New York, Alfred Knoph.

[EIA] U.S. Energy Information Administration. 2009. *2009 Residential Energy Consumption Survey*. http://205.254.135.7/consumption/residential/ Washington, D.C.: U.S. Department of Energy.

Goldberg, Burt, D. Dacquisto, and L. Fischer (authors not named on report). 1998. *Factory and Site-Built Housing: A Comparison for the 21st Century.* Report No. 2606. Upper Marlboro, Md.: NAHB Research Center.

Reickert, Judy. undated. The Story of Lustron Homes. http://www.lustronconnection.org/whatislustron.html.

Rybczynski, Witold. 1991. "When Houses Bulked Out (Part 2)." *Atlantic Monthly* 91:02. http://www.theatlantic.com/past/issues/91feb/9102house2.htm

Waltjen, Tobias, Walter Pokorny and Thomas Zelger. 2009. *Passivhaus-Bauteilkatalog | Details for Passive Houses.* Vienna and New York: Springer.