1

Free and Clear

If you were driving through the small town of Townsend, Massachusetts, along Highland Street in the spring of 2011, you would have passed the future of building just off the side of the road. You *would* have passed it, too, because at thirty miles an hour the small new development looks the same as any other small middle-class neighborhood you'd see in New England.

The nearly two dozen houses already built and occupied are a typical collection of robin egg blue, canary yellow, warbler gray and cardinal red single- and two-story clapboard homes with steep gabled roofs. Had you taken a right, though, on to Coppersmith Way, the development's single road, you'd have seen almost immediately one of the rarest of sights in any single community.

All but one of the homes have solar panels — visibly darker and shinier than the gabled roofs they cover on one side. Towards the end of the lane, you would have seen a nearly completed house that on close inspection had some other uncommon features: unusually deep walls and windows that are noticeably wider than most windows.

You might have wondered whether what you'd see inside the house or any of the existing homes would be different too, then shrug and think

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TRANSFORMATIONS, INC.

Townsend, Massachusetts home with solar panels facing south.

maybe not any more than the little you'd seen so far. You'd be right, and that's just the point.

The future of building is not about any radical change in the way houses and other buildings look. It goes deeper, to the way they work, and here the change is nothing short of revolutionary. Put simply, these are houses that will produce as much energy as they use. This balance is summed up in the name they are known by: zero energy or net zero energy homes.

It doesn't stop there, though. The spirit, if not the letter, of zero energy homes requires that the energy produced must be from completely natural renewable energy sources — typically solar, but possibly wind too — converted into electricity on the property. What isn't used at the time it's produced is fed into the local utility grid. Any energy consumed when the sun isn't shining or the wind blowing is also electricity, supplied to the home by traditional fossil fuel-burning power plants. Eventually, however, those plants will be replaced by solar, wind, geothermal and ocean wave power facilities — as they have been in a few communities to some degree today — when coal, oil, propane and natural gas supplies start running

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out or become more expensive than the renewable sources. (And nuclear facilities become untenable.)

Also, a zero energy home consumes very little energy. The amount should be at least two-thirds, and hopefully as much as ninety percent, less than consumed by a standard house the same size. Smaller houses trump larger too — the better to reduce the amount of energy used.

Inside the house, it's mostly a story about the many ways — small, unseen, out of the way or uncommon — that make up the structure and components of the house that will separate the future from the present and the past. It's a revolution about doing nothing less than changing the way we live — without, as contradictory as it may seem, reinventing the way homes are built. That's because everything it takes to build the house of tomorrow is for sale today, bought off the shelf or from the Internet.

Some of the features and ways of doing things will be new to most homes, though much of what makes up a zero energy house will just be more efficient versions of what's already in them. In the package of features that make up a zero energy home there can be heat or energy recovery ventilator systems, tankless hot water heaters, heat pumps, fiberglass doors, low-flow showerheads, Energy Star top-freezer refrigerators, front-loading clothes washers, LED lighting and cellulose and foam insulation, as well as triple-pane gas-filled windows and solar electric panels.

Finally, a zero energy home *must* be priced within the means of the average homebuyer.

All the houses on Coppersmith Way were built with the goal of reaching zero energy, coming close or at least being far more energy efficient than any standard home. They use many of the features noted above and depend on electricity for nearly all their energy. A few use nothing else and a number of the houses are well below the average house size. (The one house without solar was too close to protected wetlands and the trees there would block the sun from reaching a photovoltaic system.)

Ideally, zero energy homeowners would wind up paying nothing for the electricity they consumed over the course of the year. For the owners of a typical American house, eliminating the entire bill in an all-electric zero energy home could be a savings of about $2,200 annually (2009 figures). It can also mean more money in the pocket later, when the house is sold.

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In a study appearing in *The Appraisal Journal,* a home's value was said to increase an average of $20 for each $1 decrease in the annual utility bill.

A higher quality of life — by a number of different measures — is another advantage of living in a zero energy home. The homes are quieter, maintain temperature settings better, allow more natural light, have better air quality and may stand up to storms better than traditional homes. But as welcome as these advantages are, they don't speak to the reason why zero energy homes are — many people would say must be — the housing of the future.

In the United States, buildings, both residential and commercial, account for roughly 40 percent of energy use and carbon emissions, more than either of the other two main sectors of the economy, industry and transportation. Throw in construction and demolition, and it increases to 50 percent.

Governments have seized upon the idea of developing zero energy buildings as a key strategy for cutting down on both energy consumption and pollution as part of worldwide efforts to end global warming. If they are not successful in the next decade or two, it will be fair to question whether there will be a future as we have always thought of it — a time better than what preceded it — for housing or anything else.

New single-family homes have been their prime focus. Existing homes, multifamily residences and industrial and commercial buildings are also targets for efficiency makeovers and on-site solar production, but new single-family homes make a great lead-in. Their impact is relatively small, but they're the easiest to develop and can provide a field lab and a set of standards for all buildings.

This strategy began to take shape in the nineties based on what was already well known. In theory, anyone could build a zero energy building. All it took was enough money to lay out solar panels and/or wind turbines on a property to offset any amount of electricity use. Yet, to do so would likely be beyond the financial reach of most families because of the high cost of solar equipment. Big solar layouts tended to come with big, well-stocked houses that require a lot of energy to run. A family of four in a two-bedroom cottage with a single bathroom and a leaky oil furnace might use less energy than a zero energy home that was larger and didn't maximize energy efficiency.

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Another way of developing a zero energy home would be to have a house that was not connected to the grid, which would mean it had to produce all the electricity it used. The problem with those homes, however, was that they were not easily duplicated or desirable in a mostly urban, utility-connected society that over time would need the renewable energy that millions of homes could feed the grid.

They were also of dubious environmental value. They counted on storing electricity in toxic lead acid batteries the size of small refrigerators that would be an eternal nightmare once their useful life was over. (California is looking for ways to use safe lithium-ion batteries, but a cost-effective solution is many years away.)

What was needed instead was, in the words of the US Department of Energy, "marketable zero energy homes" — the kind of zero energy homes that the average American home buyer could shop for on Sunday outings as they would for any other home. It became the job of DOE's Building America program, established in 1995, to make that idea a reality by 2020 and there were soon a few concrete signs. Within five to ten years, a number of private homes that looked much like any other, but that were far more energy efficient and that had solar installations on their roofs were built under the program.

In 2007, California stepped up an aggressive campaign, using tougher and far more encompassing language. The state's Public Utility Commission said in 2008 that "all new residential construction [in California] will be zero net energy by 2020." The European Union chose a variation on the same theme over a similar time frame. In November 2009, its parliament said that, "all buildings built after 31 December 2020 must have high energy saving standards and be powered to a large extent by renewable energy." What "high" and "large" meant was not clear, but it followed a statement that the model for these buildings would be a "near zero energy" standard set for just a year earlier that was required of all new government-sponsored residences. The aims are the same for commercial buildings in Europe and California, only set back to 2030. Japan has a simple one-size-fits-all goal: by 2030 every new building built should be zero energy.

A number of non-profit organizations grew up out of that same nineties environment to promote energy efficiency and sustainable building

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practices using rating systems. Among the best-known are the US Green Building Council (USGBC), the Residential Energy Services Network (RESNET) and Germany's Passivhaus Institut. They were later joined by many other ratings, rankings and movements, like the American Society of Heating, Refrigerating and Air-Conditioning Engineers' bEQ ratings and German "Triple Zero" designs.

RESNET developed the Home Energy Rating System or HERS, which was a measurement of energy use in comparison to a standard house. For example, a typical new home received a rating of 100, while a zero energy home was 100 percent more efficient and rated, well, 0 (though for years the numbers were reversed).

The USGBC took a somewhat different approach with its Leadership in Energy and Environmental Design (LEED) certification program. This was a measure of sustainable building practices. HERS was a big part of its scoring system, which was an arbitrary point total linked to Olympic-like medal awards.

The Passivhaus Institut went for deep over broad. Builders who maximized the heating and cooling efficiency front end — meaning around 90 percent better than average — would earn its less than scintillating and marketable "quality approved passive house" certification. All other household energy use barely merits a mention and renewable energy sources are not a requirement of the process.

The Washington, DC-based International Code Council (ICC) effectively shortened the distance builders had to travel to reach zero by pushing the starting point forward. Every three years, the ICC meets to raise the building standards for efficiency in its International Energy Conservation Code (IECC). Nearly every state has adopted at least one version. Again, the first one came out in the nineties.

The Federal government, state and local governments and utilities offered financial incentives for making new and existing buildings more energy efficient and for installing solar installations. Depending on where a building owner lived they could get tax credits, low-interest loans, rebates or all of the above.

By the end of the first decade of the 21st century, the various initiatives appeared to be having some impact. Builders scattered about the country

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began showing an interest in developing the kind of zero energy-rated production homes that might serve as models for large-scale development. Most of them were smaller developers, like Transformations Inc., the developer of the Townsend, Massachusetts, development, but their numbers were growing. Plans were in development, on the drawing boards or in the construction stage from Connecticut to Colorado.

In the next decade the largest home builders started to catch on. KB Home, ranked fifth, and Meritage Homes, number eleven, both laid claim to having built zero energy-rated production homes and promised to build whole developments that — at the request of buyers willing to pay more — could be upgraded to zero energy. Finally, zero energy was slipping into the mainstream. However, more still has to be done. Many more zero energy homes need to be built and they have to prove they can literally produce as much energy as they use year on end. So far, homes that don't receive utility bills appear to be in short supply.

In 2006, the Northeast Sustainable Energy Association (NESEA) created a contest — no cost to enter — to award $10,000 to a home in its 10-state region that qualified as having 12 months of utility bills that added up to zero. It wasn't until three years later that the Massachusetts-based environmental organization found a winner and it was a custom-built home bigger and costing twice as much as the median US house. In the next two annual contests — 2010 and 2011 — there were a total of just ten entries, mostly custom-built, expensive and loaded with solar power.

To be sure, there was also a lot of ground to cover in the century's second decade. A few statistics put the task in perspective. There were 130 million residences in the US in 2009. Single-family homes accounted for 90 million of them, including 7 million attached houses. Mobile and manufactured homes totaled another nine million. In most years before the Great Recession, more than a million new single-family homes were added to the housing stock.

It would be quite a task, to say the least, to suddenly start building that many new zero energy homes when so few were being built 15 years after goals to make them commonplace were set. After all, though the pieces are not new, putting them together for the greatest cost-effective efficiency is beyond the experience of almost every builder and they would have to

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make a commitment they've lacked so far to do by 2020 what they haven't done since 1995.

While this was the first time builders showed an interest in moving zero energy homes into the mainstream, it was not the first time they had shown interest in building zero energy homes. Major builders like Pulte, Centex and Shea had taken stabs at building prototype zero energy homes a decade earlier without following through. More energy efficient features worked their way into their homes, but that was the extent of it.

Indeed, few builders of any size have made producing even modestly efficient housing part of their routine. For over a decade, the Department of Energy (DOE) has encouraged the nation's home builders to develop Energy Star homes, which are required to be 15 percent more energy efficient than standard homes. Yet, only one million were built or about five percent of all the homes constructed since the Energy Star home program began in 1995, the same year Building America was started. In 2008, DOE started an Energy Challenge program for builders who would build homes that were 30 percent more efficient than standard, but only several thousands homes were built in the first 3 years of the program.

If builders haven't been enthusiastic, buyers haven't shown much interest either. Indeed, home buyers have not given any thought to reducing energy consumption, much less eliminating its costs. When first-time home buyers responded to a study by the National Association of Home Builders (NAHB) released in January 2008 to list the most important factors in buying a house, they named price, layout and space in that order. When pressed to list all the factors that mattered to them they named the same three, followed by the yard, exteriors and quality. If there was a place for energy efficiency and production the only category that would appear to fit would be "quality" — a distant sixth.

Seasoned buyers don't appear to be any different. They were asked only to list their first three reasons, with no follow-up, but the trend seemed clear. They gave the same responses with a slight switch of order that had layout moving ahead of price.

Some experts might say that if pressed on the quality issue, energy efficiency and production still wouldn't make it onto buyers' wish lists. In a lecture Nobel-prize winning physicist Steven Chu gave in 2008, midway

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between the NAHB study's release and his appointment as Secretary of Energy, he said that new houses could be made more efficient with an investment of $1,000, but that "American consumers would rather have a granite countertop."

Nor would an appeal to their concern for the environment do any better. At least that's the view of some of the wittier observers of social mores, the creators of *The Simpsons.* In *The Simpsons Movie,* when Green Day announces it wants to say a word about "the environment" (after just giving a three-and-a-half-hour performance), they get stoned by the audience, then sink into a toxic sludge while playing the music played when the Titanic went down. Since then — in polls from November 2008 to May 2011 — fewer Americans believe that global warming is occurring. Even among those that do, fewer are sure of it and less than half believe that humans are responsible for it.

Money — or rather the lack of interest in spending it on energy efficiency and renewable energy — is at the heart of the challenge of building zero energy homes. They cost more up front. How much more depends on a number of factors, including the square footage of the home, but about 25 percent more to achieve a zero energy rating is not unusual. Since home buyers in the NAHB study rated price as the most or second most important consideration, zero energy homes start at a huge disadvantage.

The alternative is to build smaller homes so as to reduce the total cost. However, builders love space. It costs relatively little to add, but allows them to increase the home's price and their customers want the extra room. As the third most important factor in home buying, builders have been adding space to homes prodigiously for decades. The median size of the American home was just 1,525 square feet in 1972. Thirty-seven years later it was 2,135 square feet.

This increase doesn't fit with what has been happening to the size of American households, which have been undergoing steady downsizing. There were 3.7 residents in 1940, 3.1 in 1970 and just 2.5 in 2010, so as much as homes have grown, the amount of space individuals have to themselves has increased even more. They each have 854 square feet now compared to about 492 square feet 36 years ago — a staggering gain of more than 70 percent.

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Buyers are also unlikely to find in zero energy homes the ideal layout to fit their particular needs. Zero energy homes are laid out with energy efficiency in mind, not the way buyers envision rooms being arranged to match their tastes. Most of the living space and windows, for example, should face south in most parts of the country to make the most of the sun's heat and light. Of course, by virtue of the law of averages there will be some perfect matches. Residents on the south shore of Long Island provide one such example. Their homes contain banks of windows facing the Atlantic south to the horizon, while far fewer windows look out to the noisy traffic along the road on their north side and neighbors east and west. However, across the island to the Gatsby-era estates of the north shore, homeowners would be unlikely to see any wisdom in zero energy design and well they shouldn't. Their homes offer panoramic views facing north along Long Island Sound.

While the two nearby shores may represent extremes, builders throughout the country will generally be caught somewhere in the middle, unable or unwilling to make the best use of the sun. Shade from trees, hills or buildings coming from any direction or unattractive views on their south sides may provide them with good excuses too.

Thomas Siebel, a billionaire Silicon Valley philanthropist, recognized the dilemma of building zero energy homes that could be sold at the same price as the traditional single-family home. In February 2009 he announced that he would award $20 million in prize money to find a solution to the problem. The Energy Free Home Challenge, as he called it, had two stages, both open to anyone in the world. In the first stage anyone who came up with the best technology that would make a marketable zero energy home possible would receive $5 million. In the second stage, ten finalists would be chosen to build zero energy homes, with this new technology at their service. They would each be given $250,000 in prize money and another $250,000 to build a 3-bedroom, 2-bath, 2,000 square-foot house. That month the average price of a new home was $258,600, while the median was $209,700. The homes also had to be built in the same northern locale, probably on land near the campus of the University of Illinois (Siebel's alma mater), necessitating both heating and air-conditioning.

The winner would take home a grand prize of $10 million. It was expected to take about five years to crown a winner, but just as the contest

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was ready to get underway in the summer of 2009, Siebel was stomped by an elephant in the Serengeti Plain of Tanzania. The challenge was postponed "indefinitely." his foundation said, while he endured 16 operations on his leg over the next year.

Siebel hoped to make a full recovery. The challenge of developing a zero energy home at the same cost as a conventional house remains and, in fact, has become even more challenging. The world's love of all things that run on electricity has only grown with time. In the first half of electricity's first century in American homes, lighting, radios and refrigerators were the only significant users. In the post-war era, there was an explosion of electric appliances and gadgetry. Television, clothes washers and dryers, dishwashers, air-conditioning, ranges, microwaves, computers, video game sets, DVD players, cell phones and innumerable electric gadgets, including electric blankets, tooth brushes, hair dryers, can openers, exercise equipment, chargers, iPods and e-books became fixtures in the homes of developed nations. Many were always on, sucking "phantom" energy as if through a straw.

It's no wonder then that residential electricity use had grown to 1,379 billion kilowatt hours annually in 2008 from 67 billion kilowatt hours annually in 1949, according to the Energy Information Administration (EIA), far outstripping the growth of the population. (The numbers are virtually the same for commercial electric consumption.) In recent decades the rate of growth has slowed considerably, but the outlook for cutting back on our energy use isn't encouraging. Whatever timelines governments may impose, the EIA doesn't see any reduction in residential energy use — nor in commercial, transportation or industrial — out to 2035.

Still, that doesn't mean there can't be a dramatic drop in residential energy use. Evidence suggests that incentives are an important engine for change. Solar electric use, for example, is highest in those states that have them and lowest in those that don't. Six of the top ten solar markets listed by the Interstate Renewable Energy Council have among the best financial incentives, including number one California which also has abundant sunshine. The remaining four are western states with plenty of the latter and space for utilities to develop large-scale solar panel fields.

Lew Pratsch, a former zero energy homes project manager in the Building America program, thinks it's just a matter of moving enough

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money around. "If you increase the cost of utilities, then used these revenues to provide financial incentives so that homeowners could see it, then it would work," he says. In short, the cost-effectiveness of efficiency and solar production would be obvious and irresistible should the government wield financial carrots and sticks.

Yet, even if zero energy homes remain a major challenge for large-scale development, they will increasingly become the standard by which housing is measured in the developed world.

It's a standard whose meaning is clear virtually everywhere and whereas it can be stretched, it can only be stretched so far. Homeowners who say they live in a zero energy home while paying $100 or $200 a year in utilities are adhering to the spirit if not the letter of zero energy. There's no living up to the spirit of a "green," "efficient," "sustainable" or "eco-friendly" home since there's no standard or benchmark for any of these — certainly, not the high, exact standard of zero — that means the same thing to everyone. Builders toss "green" around with impunity for adding a few good features, like Energy Star appliances, that modestly improve a home's efficiency.

Even the word "zero" or one of its common English synonyms is the same throughout the developed word. For example, it's pronounced and spelled "zero" or close in France, Spain, Italy and Poland.

As ideas travel around the world, zero energy homes will become increasingly accessible to builders and homeowners committed to developing and living in one. In fact, with the passage of time they will be proven to be cheaper than traditional homes. That's because owners who stay in them over the length of a typical mortgage will get a return on their investment through energy savings far greater than with any other housing.

Not that the obstacles facing large-scale development prevent individuals from developing their own zero energy homes now. They merely need a willingness to be open to something new and different. Where and how the house is built, by whom and with what and how it's financed — all concerns for building any home — will require a fresh perspective.

At this stage in the history of zero energy, prospective developers will have to be pioneers. Builders will be self-taught and home buyers will have to take on the role of general contractor. This in itself is not an unusual role for home buyers to be in. Enough information is available so that

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there need be no mystery to developing a house that is extremely efficient and produces as much energy as needed at a price middle-class buyers can afford. Production information, builders and even designs are a click away. Attics loaded with insulation are readily obtained. Low-flow plumbing fixtures' time has come. The advantages of buying the most efficient type of mass-produced refrigerator should be indisputable. More than a few tasks should be routine, cost effective and supremely satisfying.

It will take some adjustments. Size will likely have to be scaled back and there has been some scaling back by builders. Compromises in layouts may be needed, though moving exposure to sunlight up the wish list should be easy to accept. Behavior may also need to be modified. The neighbors will probably have more electronic gadgetry and hands need to be seen as the useful substitute they are. Zero energy will need to be seen as "cool" the way giving up smoking became a goal worthy of the effort. This will come, many behavioral scientists and economists think, when enough Jones's live in zero energy homes and many others will strive to keep up with them.

Not that the homeowner or buyer has to go all the way all at once, or ever. While the aim is to hit zero, anyone taking on the job can pull up short or pick and choose what they want to do knowing that no more than a handful of builders have even gotten halfway there. Given the low risk of failing to beat the pack, there's no better place to start than the beginning with nothing or, rather, zero to lose.

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2

Following the Sun

The two-story home on the south side of a straight flat stretch on a road outside of Urbana, Illinois, appears to be as much a part of its rural environment as the ground surrounding it. Large stone bases support beams holding up a porch roof at the front and eastern and western sides of the house. The siding is a combination of earth tones. A three-foot high strip of brown gives way to the brownish-gray color of the roof. Its sharp square shape and low gabled roof gives the home a solid imposing look of midwestern permanence.

Yet while it seems, like many homes in its area, to have been planted on its foundation and been quietly blending into its surroundings for a long time, that image is deceiving. This Urbana home was completed in 2008 and its shell or envelope is not just standing there, but is very busy reducing the amount of energy needed to run the home.

This work is done just by the way the home is designed and built, a concept known as passive design. The idea is that by incorporating a few relatively simple features into the house it will make the most — and, when wanted, the least — of the sun's energy. Passive design succeeds best when it allows as much of the sun's heat in as possible through its windows

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Gregory Stanton

Outside of Urbana, Illinois, facing north (right) and east.

during cold months and keeps it out in hot months. Good passive design also allows sunlight in through the windows, while keeping the wind from penetrating the seams around them or anywhere else in the house's structure all year round.

Letting the sun through the home's windows in the winter means a homeowner can bask in its warmth and natural light while paying smaller utility bills. Keeping it from shining through the windows in the summer means the cost of running air-conditioning systems will be less.

Passive design could just as easily be called simple design. Its focus is on not complicating a few mostly basic features common to all buildings. These include orientation, shape, size, insulation, windows, doors, ventilation and landscaping. There are no moving parts to contend with, except with ventilation and, to a lesser extent, windows.

Good passive design is desirable throughout most of the country because the sun's heat and light can contribute to energy efficiency almost everywhere. Where there isn't much of a need, if any, for its heat indoors, as in the Deep South and parts of the Southwest where cooling predominates,

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developers may decide in favor of having little or no direct sunlight in the house all year long.

The Right Spot

Passive design begins with site selection. Ideally, it's best to have a site where the southern boundaries of the property are unobstructed and the entrance to the home will be on the eastern, western or northern side.

The light from the sun entering Earth's atmosphere spends most of its time in the northern hemisphere shining on the southern face of anything it strikes. An unobstructed window facing that direction — plus or minus 20 degrees, which at the greatest deviation will still provide 92 percent of the sun's heat facing due south — allows more of the sun's energy to pass through during the course of the day than a similar window located on any of the house's other sides. (In the southern hemisphere it's north-facing windows that do best.)

The ideal however, is as rare a commodity for zero energy homes as it is with most things in life. Roughly speaking, less than 25 percent of home sites qualify.

Take a typical housing development, the kind built by major home-building companies that are laid out on vast tracts of land in grid-like formation. The classic example is Levittown, New York, built between 1947 and 1951. More than half a century later the tradition of building large planned communities continues. The top ten builders in the US, which includes D.R. Horton, Lennar, Pulte and Centex, alone build 25 percent of all new homes and that percentage is expected to rise to 33 percent in the coming decades.

Mass producing homes laid out on a grid leads to the same exposures repeated time and again. The grid may not be obvious from the ground level. It may be rectangular, irregular or both, like the planned community built by D.R. Horton in Windsor, Colorado, or the one built by Lennar in Waretown, New Jersey, but several left or right turns will quickly bring a driver back to where they started.

For example, think of the streets in one of these communities that run north and south. The homes will generally have their windows facing east and west, to the street and the backyard, with few windows looking out

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on their neighbors on the north and south sides. The other two streets in the grid — the ones running east and west — will have just the opposite arrangement. Most of their window area will face north and south. That gives both the potential for maximizing the southern exposure, but only those on the north end are, for all practical purposes, in a position to realize it. Their south sides — the backyard — are not going to have entrances or garages taking up potential window space and they offer better privacy for bedrooms and living rooms, which get the most window area.

If the grid is square, then 25 percent of the homes will likely have the ideal. If it's a rectangle, it would be more or less than 25 percent, depending on whether the length of the grid runs north and south (less) or east and west (more).

While facing a core of backyards may be the most common way to secure an open southern exposure throughout urban and suburban tracts of homes, it's not the only way. Move up the economic ladder and builders can utilize strategies to orient more homes to the south by developing cul du sacs. This way, the entrance road and the homes can be arranged so as to give the homes a southern exposure while also endowing them with a bit of individuality and perhaps more privacy.

Sometimes though, nothing will work. Tall buildings, trees and hills or mountains can stand in the way of the southern exposure. There are also times when no matter how open a site is to southern exposures no one could be blamed for ignoring it. This could be the northern developer who opens his homes to beautiful vistas of mountains, lakes or urban skylines to the north — braving its brutal winter winds — while turning the back side of their houses, where they install garages and utility rooms, over to highways, shopping malls and other developments. More simply, the southern exposure just may come at too high a price for reasons that may or may not have anything to do with its exposure.

The Infill Exception

There are times when even a southern exposure, even one with a great view and an affordable price, should be turned down. This could be the case when the choice is between developing virgin land or an infill. The main difference between the two is that in the former the land hasn't been

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developed while the latter has been at one time or another. An infill may be a site where a house burned down, or is abandoned or condemned. An infill might be created when a homeowner puts a piece of their property up for sale or an oddly shaped vacant lot between two developments becomes available. Yet another is when a commercial or industrial lot gets zoned for housing. The US Census began tracking density for the first time in the 2000 Census, signaling a growing interest in managing land use better.

What unites infills is that developing them will be more energy efficient than opening up virgin land for a variety of reasons. No energy will likely be expended preparing the land for development because it was likely to have been leveled before. Water, sewage and gas and electric utilities will probably all be in place or reasonably accessible. Public transportation, shopping, entertainment and schools will generally be nearby.

The decades-long decline of inner cities in the Rust Belt where boarded-up homes, closed factories and vacant lots are common provides opportunities for developing infills. More recently, the collapse of the speculative housing market in 2008 that left developments unfinished — with capped sewer connections sticking up out of the ground — has extended the potential for developing infills to other parts of the country.

Virgin land however, will take a lot of energy to develop and there's less of it with each passing year. A stand of trees may have to be cleared for nothing better than kindling which means it will literally be going up in smoke, thereby adding carbon emissions to the atmosphere. A septic tank and well will probably have to be installed and electric utility lines will have to be brought in, increasing the burden on existing systems. The homeowner will also expend more energy living there. Further away from most places they want to reach, they will be spending more time burning fossil fuel by driving to wherever they need to go.

No Southern Exposure; No Problem

In the end, home builders can't count on southern exposure as much as they'd like and not having it means looking for significant energy savings and production elsewhere. Virtually nowhere in Germany or Austria are there vast tracts of open space available for building single-family homes, and finding a perfect southern exposure is many, many times more difficult

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than in the United States or Canada. European countries also receive far less sunlight than most of the US or Canada. Yet, Germany and Austria have literally thousands of passive design homes built since the late nineties that use as much as 90 percent less energy in heating and cooling than the average home. Germany also has far more solar capacity than does the United States.

Germany is able to do it because orientation is just one facet of passive design. Some sacrifice or compromise may be required elsewhere in the building process without the perfect southern exposure, but that's exactly how zero energy homes are developed. Give a little here; get some somewhere else.

The Shape of Things To Come

The best shape for a zero energy house is the simplest construction with sides, and that is a cube. If that's too simple for builders and buyers then it should, at least, be a rectangular prism whose length is only slightly longer than its width. It's a mathematical certainty that the cube is the most efficient and least costly shape.

The proof is in equations using calculus or algebra, but throwing out a few simple arithmetic examples may drive the point home more clearly. Start with a square with a side of any length. Stretch it out into a rectangle with the same area. The difference is in the perimeter. The rectangle's is greater.

For example, a square with an area of 36 square feet has sides of 6 feet long and a perimeter of 24 feet. The rectangle with the same area and closest whole number dimensions is 9 feet by 4 feet with a perimeter of 26 feet. Stretching it out some more — 12 feet by 3 feet — results in a sum of 30 feet and one more time — 18 feet by 2 feet — leads to a perimeter of 40 feet.

The longer the rectangle (and a square is just a special kind of rectangle), the larger the perimeter. These are not just numbers, either, when it comes to living space. The longer the house and the further it deviates from a square, the more materials a builder will need for the same space. Increase the number of sides and material needs increase even more. All this adds to the cost of the home.

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It gets more expensive when considering what the extra money is being spent on. The simplest way of seeing this is by turning a two-story home in the shape of a cube into a one-story home that is now a rectangular prism with the same volume. The rising costs are not just due to buying more of the same, but in spending the money differently. The two-story home has the added expense of a staircase and a second floor, but having to spend more on siding, framing, foundation, insulation and roofing for the single-story home is going to cost significantly more.

A home that is not a cube will also be less energy efficient. Heat has more opportunity to escape in the winter and penetrate in the summer because there is more surface area for the same amount of interior space and a greater total distance over which sides meet sides, roof and foundation. Plumbing and ventilating lines will be longer — and more costly — in single-story homes than two. The combination of vertical and horizontal lines in a two-story house will be less than the strictly horizontal lines in a single-story home. It's worth adding that with a boxier two-story home it is easier to centralize lines than it is with a long rectangular home with the same space. The advantage is having fewer lines extending to far-off corners of the home — and lower costs yet.

Two-story homes have been gaining in popularity over the last forty years and account for over half of new homes. However, there will always be buyers who will want to live without climbing stairs and, with an aging population, more won't be able to make the effort. It wouldn't be too surprising if the two-story trend goes into reverse in coming decades.

One way of developing two-story homes with single-story living is to have the master bedroom on the first floor. The second floor's value is then to maintain a broad marketing appeal should there come a time to sell the house, and to provide room for visiting adult children, grandchildren and other guests.

Finally, the cube's simplicity helps reduce cost yet another way, by keeping design costs to a minimum, if not eliminating them all together. This is as it should be, according to Matthew O'Malia, an architect who developed a home in rural Belfast, Maine, shaped as a cube (with the obligatory New England mud room attached). It is one of the few passive houses in the United States recognized by the Passive House Institute US. It also has

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solar panels and is nearly a zero energy home too. "You've got to eliminate the cost of an architect," he says. "Otherwise, you can't afford to build and sell a zero energy home at a reasonable price and still make a profit."

Eliminating architects for all but the more expensive homes can be challenging (though not impossible considering that during 2010 one industry estimate put architect unemployment at upwards of 13 percent). The grander the home, the more admired — and energy inefficient — it tends to be, even more so when it comes to shape. The Palace of Versailles is roughly in the shape of an "X" with the forward slash about five times as long as it is wide, while the backslash more than twice as long as it is wide. No side faces south either. The White House is better, but still on the wrong side of efficiency. It's more than twice as long as it is wide, though it does face south.

Nevertheless, there are enough styles that lend themselves to zero energy development and are right for every environment. Colonial, adobe, contemporary and modern designs are often enough little more than cubes. The four hundred-year-old saltbox design provides an excellent match for zero energy development and one very specific home style virtually anticipated zero energy homes when it first appeared on the scene a hundred years ago. It's the American Foursquare design, which is little more than a cube with a porch. Similar to that is the two-story passive house with the Frank Lloyd Wright prairie influence and southern exposure that is owned by a retired couple outside of Urbana, Illinois — ironically, a stone's throw away from the area Thomas Siebel was considering for his zero energy challenge contest.

Size Counts

Size is another facet of passive design, if not the single most important one. The median-size home in the first decade of the 21st century in the US cannot be made into a zero energy home for the same cost as the median price new home. In 2009, the median size home was 2,135 square feet; the median price home cost $216,700. (Median size means that half of all the homes built in the US that year were larger and half were smaller; median price means that half were more expensive and half cheaper.)

It may have been possible to build a 1,500 square foot home for the median price that year, though even that size might be overly generous.

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David Pill, a Vermont architect who built and lives in the first NESEA zero energy winner, thinks 1,300 square feet, about half the size of his home, is a good bet.

His estimate is in line with a number of noteworthy zero energy projects. The winner of the 2010 NESEA award and also the winner of the first and only Massachusetts Zero Energy Challenge, the first statewide competition in the country, was 1,152 square feet. The runner-up in the Massachusetts contest was 1,252 square feet. Both received below zero energy HERS ratings, while the third place finisher narrowly missed touching bottom. It was 1,392 square feet.

Several other small examples can be found across the country. In another part of Urbana stands the first passive house in the US, which is just 1,200 square feet. In Edmond, Oklahoma, Ideal Homes built what it billed as the first zero energy production home for under $200,000, in 2006. It's 1,650 square feet and came up short of zero by about a third when actual energy use exceeded projections during its first year of occupancy.

In Colorado, the first zero energy home built by Habitat for Humanity, which builds homes to sell to low-income families, has a floor space of 1,280 square feet and went beyond zero, producing more energy than it uses.

Mass producing zero energy homes could allow builders like Ideal to realize economies of scale and build homes closer in size to the median that achieve zero energy at the same cost. Sticking to a standard design rather than changing it is worth, says Vernon McKown, Ideal's co-owner and president of sales, a savings of ten percent. True zero energy designs are not likely to become standard until government and most home builders and buyers start thinking smaller. A 3,000 square foot zero energy home is or should become an oxymoron.

Scaling down shouldn't be an insurmountable goal. Americans lived smaller a generation ago and home sizes have through 2010 remained below both their median and average peak, set in 2007. A 2010 survey by the American Institute of Architects found that 57 percent of architecture firms reported a decrease in the square footage in the homes they were working on compared to 13 percent 5 years earlier. Moreover, a significant segment of the population in all developed countries already live well with

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considerably less space than is found in typical homes. Many of them are affluent too. They also may pay far more for their residences than even owners of the biggest McMansions do.

They're apartment dwellers. They occupy more than ten percent of all US residences, and according to the 2000 Census, their apartments average less than half the space found in the median-sized single family home.

Seeing The Light

The homes at 5652 Woodwind Hills Drive and 2663 Woodwind Hills Lane in Lakeland, Florida, are the exact same size and shape and both face

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The Lakeland, Florida twin (front and back) that was built with the aim of reaching zero energy.

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south. The sites are virtually identical, too, as the houses are in a line (on either side of a third house) separated by only two hundred feet over open, flat land.

There is however, one difference in their physical structure and it literally sticks out. The first home's roof extends three feet rather than one and a half feet out from the walls of the house. While hardly noticeable, the effect on energy usage is significant. The home with the broader overhang uses seven percent less electricity than its twin.

Selecting the site, orienting the home and determining its shape, structure and size is only the set-up for how passive designs control the sun's heat and light. The job itself is left to the windows. The kind they are, their size, where they are located and any pairing with thermal mass and overhangs will determine to a significant degree how much heat and light gets inside.

Windows are not part of the shell's construction. They are separate factory-built goods shipped to the site and installed into the envelope. The spaces left for them and any overhangs and thermal masses associated with windows are, however, integral parts of the shell. Windows and doors will get their own chapter, while their place in the envelope is covered here.

From caves to igloos to tepees to yurts to geodesic domes, humans have shown that they can live without windows. Homes without them are cheaper to build and more energy efficient than homes with windows. There are other advantages too, such as no glass to wash and no worries over peeping Toms or baseballs shattering glass.

Buckminster Fuller became famous for his geodesic dome designs, but not rich, and therein lies the rub. Homeowners like windows and like to have plenty of them in their homes. The trick is to satisfy the need to look out and let some light in without making it too difficult to reach zero energy.

Basic passive design in zero energy homes calls for window area equaling about 12 percent of the house's floor space. For example, a 1,500 square foot home would have 180 square feet of windows. The south side of the home should get about 7 of the 12 percentage points. The north would get about four, while east and west together would get the rest, which is to say almost nothing. Follow the numbers this far and the task of achieving zero energy is on track.

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