CHAPTER 1

The PassivHaus Concept and European Residential Design

In my research for this book, I found many interesting innovations, both cultural and technical, in the European approach to green buildings. Perhaps the most interesting and potentially most meaningful in terms of its impact on energy use and climate change is the approach taken in Central Europe to building design: the Passive House (PassivHaus in German).

For a moment, suppose you were assigned to design an energy-efficient home for a client in the United States or Canada. That appears easy enough. After all, you just add more insulation, upgrade the windows, maybe use some innovative technology such as structural insulated panels or insulated concrete forms, install a more efficient heating and hot water system, upgrade the Seasonal Energy Efficiency Ratio of the air conditioner, and maybe even add a solar water heater, and you're done. For the most part, you would save about 50 percent of the energy use of a conventional home. But now suppose your client wanted to save 90 percent, without sacrificing indoor air quality or reducing the number of windows. That would be a very difficult task, particularly without adding many solar panels for heating and hot water. Well, it turns out that the PassivHaus standard addresses exactly that 90 percent savings assignment.

European governments take far more seriously the problem of global warming than the U.S. government. But while the United States has taken some steps to lower commercial building energy use, Germans and Austrians have tackled the housing sector. Like the United States and Canada, they're still struggling with the more important issue of what to do with the existing housing stock. This is a more critical problem because the turnover of housing stock is much lower in Europe, because of slower population growth, less workforce mobility, and a large number of historically significant buildings, which makes renovating them to be more energy efficient more challenging. The Germans and Austrians are not alone. Each of the twenty-seven countries in the European Union must adopt national standards to achieve carbon dioxide reduction goals. However, according to one expert, only four countries currently have both government and private sector programs to achieve this goal, even though the European Union's 2002 energy directive for building performance is supposed to be fully implemented by 2010.[1]

In April 2008, I attended the annual PassivHaus conference in 2008 in Nürnberg, a delightful medieval city in Bavaria of some 180,000 people, known to most Americans (if at all) only as the place where Nazi war crimes trials took place after World War II, memorialized in the well-known movie *Judgment at Nuremberg*.

The conference is the brainchild of Professor Wolfgang Feist, an academic impresario of residential and commercial green building who has managed over 12 years not only to popularize the PassivHaus concept but also to have it accepted by the German authorities as the national standard. Attracting more than 1,000 serious researchers, businesspeople, students, and foreign visitors, the Passivhaustagung is a great place to begin considering what we can learn from the green building movement in Europe.

WHAT'S A PASSIVHAUS?

The basic concept behind the PassivHaus is quite simple. In a continental climate dominated by energy use for heating during a longer cold season, one should build a house like a thermos bottle that recovers most of the heat in the outgoing air to warm the incoming air. That's it. It is quite simple in concept but very hard to implement in the field because it requires rigorous attention to construction detail, basically sealing up all potential outside leak points.

Look at Figure 1.1. The opposite of the thermos bottle is the coffee cup, which cools off quickly and needs reheating to stay warm, as might be the case in a typical American home.

The PassivHaus standard is quite exacting because it's aimed at achieving an incredibly low heating energy use of 15 kilowatt-hours (of primary energy) per square meter per year. Consider that the average new home in the United States is about 2,400 square feet, or about 220 square meters. To meet the standard, you shouldn't use more than 3,300 kilowatt-hours per year, considering both gas and electricity for heating. Now, look at your own electricity and gas bills. In the United States, in which natural gas is the dominant fuel for heating, cooking, and hot water outside the Northeast, the average annual use of natural gas in single-family homes is 800 therms, or 23,000 kilowatt-hours, seven times the PassivHaus standard, not counting electricity use, which averages nearly 12,000 kilowatt-hours.[2] (In California, with its mild climate, the numbers are closer to 6,000 kilowatt-hours for electricity and 460 therms [13,000 kilowatt-hours] for gas.)

Passive houses are superinsulated, walls, roof, and below, using the best windows in the world. It's hard to beat a German window manufacturer for quality. Consider what a well-insulated window will do for you. The German design standard for windows in passive homes is that when it's 20°F outside and 72°F inside the home, the surface temperature of the window in the room won't be below 67°F (a 3°C difference), so your body won't sense a cold surface when you're in the room. You can do this only with triple-glazed windows that have no thermal bridges, or "heat freeways," between inside and outside. Feel a standard U.S. builder-grade aluminum frame window on a cold winter night, and you'll instantly feel a surface that's as cold as a refrigerator, so the room is losing heat even while the double-

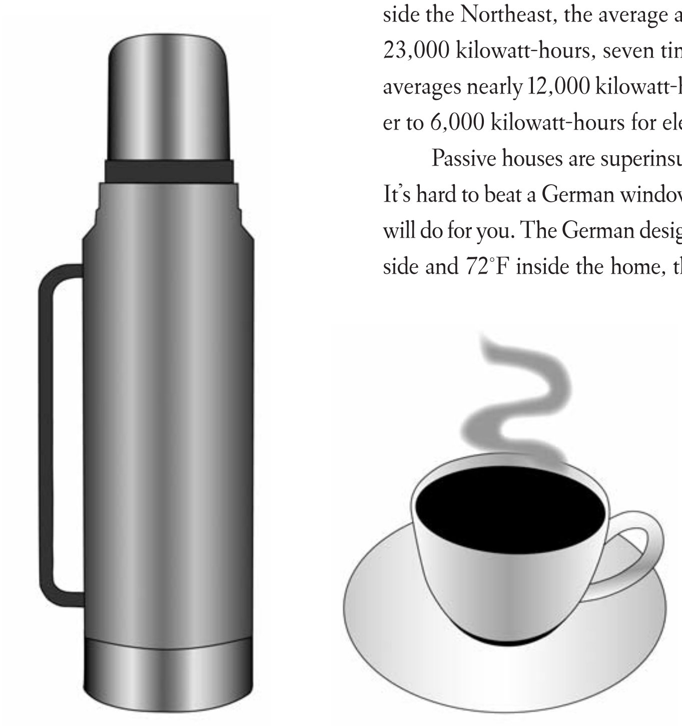

FIGURE 1.1 The PassivHaus system acts like a thermos bottle that holds heat in the building without further energy needs.

glazed window with "low-e" coating is keeping out some of the cold. The cold surface you feel is a thermal bridge that is steadily transporting nice, expensive heat from inside the house to the outside.

What gives the PassivHaus its importance is a strong commitment by the German central government to reduce the entire country's carbon dioxide emissions significantly by the year 2020. There's no way to do this without the PassivHaus being adopted on a massive scale. Consider that all of Germany lies at the latitude of Canada and that heating energy use can represent more than 80 percent of all energy use for heating, cooling, and hot water in the home. You can see why the Germans (and the Swiss and Austrians also, by the way) focus on improving residential design and energy performance.

What's the goal of the PassivHaus movement in Europe? To reduce energy use in residential homes and apartments (considering only heating energy use) by 95 percent of today's average home, which uses about 300 kilowatt-hours per square meter per year. To meet these energy targets Professor Feist and his colleagues are determined to revolutionize the way homes are built and operated.

Passive Homes, the German and Austrian Way

Most of the world's estimated ten thousand passive houses are in Germany and Austria, where winter design temperatures are about 9°F to 16°F.[3] These homes are built to standards that require approximately R-50 walls (equal to about 15 inches of fiberglass batts or 8 inches of sprayed polyurethane foam[4]) and triple-glazed U-0.14 (R-7) windows, with maximum air leakage rates of 0.6 air changes per hour. As a result, these homes have the most efficient building envelopes in the world.

In a typical PassivHaus in Central Europe there is a heating coil in the ventilation duct. Most of these heating coils circulate hot water produced by a gas-fired water heater or a heat pump water heater. So they're not truly passive, but they certainly are low-energy.

What you should get is a home that is very comfortable, with quite low energy bills. Because Central European PassivHaus designers deliver heat mainly through ventilation ducts, heat recovery ventilators act as the key residential heating appliance. In some very cold climates of the United States, such as Minnesota and Wisconsin, there will still be a need for supplemental heat beyond that delivered through the ventilation system.

PassivHaus technical specifications are strictly established in Germany and Austria, and they are generally well understood by builders. The annual energy consumption for space heating must be no more than 15 kilowatt-hours per square meter. (Note that this level of energy use would equate to an annual energy use for heating of 2,800 kilowatt-hours—about 100 therms—in a 2,000–square-foot house, pretty low by American standards in cold climates.)

For an entire residence, the PassivHaus standard specifies that the maximum annual energy budget for all purposes (including space heat, domestic hot water, lighting, appliances, and all other electrical loads) must be no more than 120 kilowatt-hours per square meter (11 kilowatt-hours per square foot, or about 760 therms per year for a 2,000–square-foot house in the United States). Although this is a small energy budget, it is not zero energy by any means. If you want a net-zero-energy house, you'll have to supply the balance with solar thermal and photovoltaic panels for both heating and hot water. In a mild climate without a significant air-conditioning need, these systems would be quite affordable in most parts of the United States and Canada, taking into account energy prices along with current local, federal, and utility subsidies.[5]

The Innovator, Wolfgang Feist

Unlike many academics, Professor Feist emphasizes the practical nature of the PassivHaus standard and its usefulness in North America.[6] He says 15 kilowatt-hours per square meter (1.4 kilowatt-hours per square foot) is not arbitrary but a good benchmark.

> The definition of a PassivHaus doesn't need any [particular] number. As long as you build a house in a way that you can use the heat-recovery ventilation system—a system that you need anyway for indoor air requirements—to provide the heat and cooling, it can be considered a PassivHaus. Since you need a house to be tight, you need a supply of fresh air. If you need that anyhow, the idea is to do everything else—the heating and cooling and dehumidification—with the ventilation system. To do that, the peak load for heating and cooling has to be quite low, including appliances.

Delivering heating by methods other than through the ventilation system has adverse impacts, according to Feist. For example, direct electrical heating is inexpensive to install, but the primary energy use (for electric power production) is extremely high, so he thinks that's not a good idea, in most cases. Woodstoves are okay with him, but a good one is quite expensive, so you should use just one stove. If you do that, and you still want to have good thermal comfort all around the building, you will need quite good insulation. Because biomass is limited, if you burn biomass (e.g., in the form of wood pellets) in your house, the house should be well insulated—in the range of what is required for a PassivHaus. Keeping the heat source in the ventilation system (in the form of a hot water coil) is not necessary, but in Feist's opinion it's the cheapest way.

Feist believes that in many of the milder climates of the United States, low-energy houses can indeed include standard exhaust-only or supply-only ventilation systems and not use heat recovery ventilators.

> If you can meet the requirements for a very low amount of additional energy, in summer and in winter, without a heat-recovery ventilator, why not? In San Francisco, for example, you don't need a heat-recovery ventilator; just build the house with operable windows. [In colder places], I think it is important to install a heat-recovery ventilator before any other system in the house, such as a forced-air heating system.

The PassivHaus standard has very exacting requirements for window performance, specifications that would be hard to meet with standard double-pane, low-e windows that are the current U.S. definition of an energy-efficient window, with or without thermal breaks.

> The window specification depends on the climate. In Central Europe, we need an R-7 [U-0.14] window. You would not need the same window in Florida or California. The reason for the U-value that we now require in Europe is *the comfort of the occupants*. It is a functional definition. During the winter, the coldest surface temperature in the room will be the window. If you don't have a radiator in your room, the difference between the surface temperature of the window and the average surface temperature of the room should not be more than 3°C (5°F); that's for comfort reasons. [For this, you need very efficient windows.]

This is not as complex as it sounds. In essence, Feist believes that a home design should be kept simple, by improving insulation and windows and by installing a heat recovery ventilator. In

North American climates, the biggest problem may be changing mindsets about how to get started. For example, Feist says, "Most builders I have talked with in North America still think that increasing insulation is an expensive thing. I'm surprised, because insulation is the cheapest thing you can do." The main issue is doing away with the notion that energy efficiency upgrades must "pay back" in terms of current energy prices. He says, "I think it is important to do away with this idea of the payback calculation. We should do advertising to say that a payback calculation is not important for determining energy efficiency, because a house will be there for more than five years—it will be there for maybe 70 years."

Explained this way, do you think now that you could use the PassivHaus standard to design a 90 percent energy-efficient home just about anywhere in North America?

The Role of Government Regulation

The larger issue in adopting a standard such as PassivHaus may be in our own approach to regulation and energy codes. Germans have a long history of government regulation, including the building sector. The first laws regulating quality in buildings came about at the same time (1882) as the lawless Arizona Territory saw the gunfight at the O.K. Corral, where Wyatt Earp, Doc Holliday, and other Earp brothers gunned down the notorious Clanton gang in the aptly named town of Tombstone. In much of the United States, we're still fighting battles over the role of government regulation that the Europeans settled long ago, in favor of the government.

Germans tend to regulate everything, including buildings, in a way that most Americans do not understand and probably would not tolerate. For example, it's socially unacceptable to jaywalk in Germany. After visiting a fantastic green building near the Frankfurt Airport, I wanted to cross a completely empty street against the light. My German guide wouldn't hear of it. Why? It would set a bad example for the children, she said, and they might dash out into the street and get run over. (Good reason, except that there were no children anywhere near this busy commercial area; Germans just like "Alles in Ordnung.") What this means is that if the German government puts something in the building code, such as the PassivHaus standard, it's likely to be taken up and followed by one and all.

Building Physics

Building physics underlies the PassivHaus standard. The Germans are quite taken with the notion and language of building physics, a topic and field of study mostly unknown in North America and certainly not part of the common language and thinking of most homebuilders, architects, or engineers. Simply stated, building physics looks at heating, cooling, and moisture management in buildings from a scientific viewpoint. Simple physics principles most of us learned in high school can be used to design better buildings; for example, heat flows from warm to cold, moisture flows from wet to dry, moisture condenses on a cold surface, and heated air rises.

While in Munich, the home of *Bier und Bratwurst*, I visited the world-famous Fraunhofer Institute for Building Physics, a research station employing about three hundred people who are looking for new ways of heating, cooling, and dehumidifying buildings, using scientific research methods. I saw hundreds of mold and algae cultures being tested to see under what environmental conditions they thrive (and therefore how to prevent them from growing, by eliminating those conditions). I also went inside a three-story research building with twelve different types of building façades being tested for environmental performance. The researchers at Fraunhofer are developing new types of external and internal paints that will inhibit mold growth, even in severe wet winter weather. The institute's work will continue to form the backbone of many building regulations in future years in Germany.

WHAT CAN WE LEARN FROM THE PASSIVHAUS APPROACH?

There is no way to stop global warming over the next 40 years without significantly reducing household carbon dioxide emissions to well below 1990 levels. In the housing sector, the PassivHaus concept shows that it is possible to maintain a high-quality standard of thermal comfort with only 10 percent of the current average energy use—*if* we learn to build our homes better.[7]

The U.S. Department of Energy has been laboring for the past 20 years, with a dedicated group of researchers, to accomplish the same results with their Building America program. But I don't think it has had the impact and acceptance among practical builders that the PassivHaus standard has had in Central Europe. Part of the reason is that the United States has greater diversity in climate zones than Germany. If you live in Miami, you've got a tropical climate (wet–humid), and if you live in St. Louis or Dallas, you have cold winters and hot, humid summers (mixed–humid). If you live in Phoenix, you have desert (hot–dry), and if you live in Los Angeles, you have a Mediterranean climate. So in the United States, we need more diverse approaches that take all these different climate zones into account and then translate those differences into simple standards that every builder can use. (In fact, the federal government's Building America program has done this to some degree.) We also have to return to better skill in homebuilding, something that may have been lacking in the rush to overbuild in the first half of the present decade, but a skill of which German homebuilders are rightly very proud.

You've probably got the idea already that solutions to the problems of energy use, global warming, and carbon dioxide production will vary depending on the culture of each country. But we don't have a lot of time to make the changes in practices (and expectations among buyers) that will result in much more energy-efficient homes. My research for another book (on green homes in the United States) led me to believe that most builders have the skills and know-how to build much better, even 50 percent better than current codes (based on the 2004 International Residential Code), but that they lack motivation to do so and don't see a consumer demand for energy-efficient housing.[8] To counter that perspective, I would point out that only 5 years ago, most Americans were clearly opting for gas-guzzling SUVs, not hybrids. Five years from now, we're going to see a clear preference for cars that move away from the dominant conventionally powered, conventionally fueled automobile, perhaps in favor of the plug-in electric hybrid vehicle, as the technology of choice.

The Solar Decathlon House

The superiority of the PassivHaus concept was demonstrated in an unusual way in the summer of 2007. A team of German architecture and engineering students from the Technical University of Darmstadt, initiated by Barbara Gehrung and under the leadership of Professor Manfred Hegger, a colleague of Feist, competed with nineteen other schools in the biennial Solar

Decathlon, held on the Capitol Mall in Washington, D.C. during a hot, humid 10-day period in August. The 2007 Solar Decathlon challenged twenty college teams from around the globe to design, build, and operate the most livable, energy-efficient, and completely solar-powered house. Solar Decathlon entrants must meet all the home energy needs of a typical family using only the power of the sun. The winner of the competition is the team that best blends aesthetics and modern conveniences with maximum energy production and optimal efficiency.[9]

The objective was to design and build a 700–square-foot home that approximated realistic energy demands from a typical American household, but one that was almost or completely sustainable. The homes were judged on engineering, economic, and social criteria, including marketability. The German entry took top prize, beating out such formidable competitors as Penn State, Georgia Tech, Maryland, Carnegie Mellon, Colorado, and Massachusetts Institute of Technology.[10] Moreover, the German students' home was the only entry that generated more power than it used over the trial period. Nearly 150,000 people visited the homes in the Solar Decathlon.

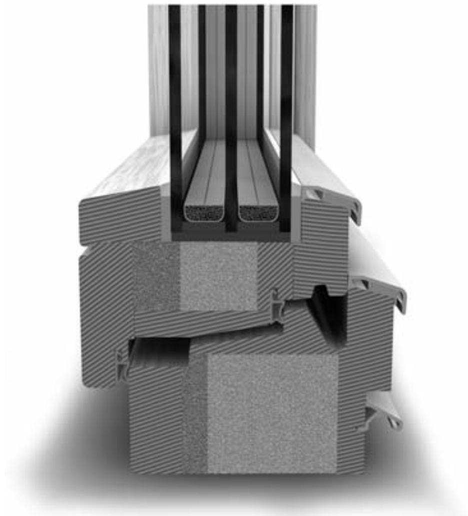

FIGURE 1.2 A key to any low-energy home is windows with an R-5 to R-10 rating. German windows are made like German cars, with superior engineering. *(www.energate.com)*

One especially nice feature was the triple-glazed windows (quadruple on the north side) from a modest 90-year-old German company, located in Speyer, a 2,000-year-old Roman town in the state of Baden-Württemberg. The company, Häussler Fenster (Häussler Windows), produces some very attractive, highly energy-efficient windows, shown in Figure 1.2. The current head of the firm is Ludwig Häussler, the third-generation owner and an expert in wood technology. As is typical with much building technology in Germany, the windows are as finely engineered and built as their cars. (That's a lesson we could easily learn, one that many high-end U.S. window manufacturers could adopt quickly. The bigger issue is getting U.S. homebuilders to buy and install good windows instead of just trying to meet basic energy code requirements.) Germany has been increasing requirements for windows since 1977, through its Wärme Schutzverordnung (heat protection ordinance).

The German students' entry (Figure 1.3) had a number of innovative features, including photovoltaics on the shutters that kept direct sunlight from entering the building and a solar water heater for the home's hot water needs. It was also an attractive building, with a nice deck for sitting outside and a hidden bed that lies under the floor during the day (almost a Japanese futon-style solution).

FIGURE 1.3 The German student entry won the 2007 Solar Decathlon, producing more energy than it consumed using building-integrated photovoltaic systems. *(Kaye Evans-Lutterodt/ Solar Decathlon)*

The Werner Sobek House

On a number of occasions in my European visits, I came across a project so unique and interesting that I felt it had to be shared in this book. Such is the case with Werner Sobek's house. One of Germany's top consulting structural engineers, Sobek is also a professor at the University of Stuttgart, and the first president of the German Green Building Council, the Deutsche Gesellschaft für Nachhaltiges Bauen.[11] In June 2000, he and his wife built the first emission-free home in Germany on a hillside overlooking Stuttgart. The four-level home on Römerstrasse, named R-128, is 250 square meters in area (about 2,700 square feet) (Figure 1.4).

What's unusual about this home? First, it's all glass and designed for disassembly: Everything is bolted together from modular components. Second, it's on a difficult sloping site, requiring careful planning and engineering, Sobek's specialty. Third, it's designed for zero emissions for heating on an annual basis.[12]

The goals were to offer the user maximum transparency, daylight, openness, and year-round comfort, the latter hard to achieve in most homes, let alone in an all-glass house. The climatic concept has cool water circulating through ceiling panels in summer to take heat out of the house; the heat energy is stored below the house and recovered for space heating in winter. This is one of the few examples I've seen of trans-seasonal thermal energy storage, a concept that could be exploited in more areas with dramatic annual temperature swings, such as the northern United States and most of Canada. In circulating water to draw heat away from the house in summer (thus cooling it) and return it back in winter, the home also draws minimal electrical energy to pump small amounts of water. With radiant heating and cooling panels covering 40 percent of the ceiling area, the home is easily made comfortable in all seasons.

Temperature and lighting levels are controlled by sensors and touch screens. Lighting can be voice activated or remote controlled. All sanitary fixtures are sensor controlled, so they are very hygienic and water conserving.

The building façade consists of triple-glazed panels with transparent foil between the outer and central panes. An inert gas fills the space between the panels. The glass alone has an R-value of about 13 (compared with most double-pane, low-e glass that has an R-value of 3 to 4), making it the equivalent of a wall with 4 inches of fiberglass insulation. Because

FIGURE 1.4 Werner Sobek's all-glass house in Stuttgart uses trans-seasonal thermal storage to provide heating in winter, along with solar photovoltaic and thermal panels.
(Roland Halbe fotografie)

of this superinsulating glass, there is no overheating in summer or overcooling in winter. According to Sobek, on a cold winter day the inside pane of the glass can feel warm, even while ice crystals are forming on the outer pane.[13]

Heat is recovered from all exhaust air, which is designed to exit through the bathrooms, doing double-duty as ventilation air. In winter, incoming fresh air is preheated through the heat recovery module to about 20°C, even at low outside temperatures. During the warm months, the ground-coupled heat exchanger cools the supply air by 6° to 7° Kelvin without any net energy input.

The flat roof contains forty-eight solar panels with a peak power output of 6.7 kilowatts, quite large for any home, even mounted horizontally. The annual output for this system in Stuttgart's latitude is estimated at about 8,000 kilowatt-hours, more than enough for heating and cooling in this climate.

Overall, the R-128 house is a great example of creative engineering to meet the goals of a passive house without sacrificing comfort, aesthetics, or light. And, to coin a phrase, "people who live in glass houses shouldn't use energy."

Passive Buildings in Switzerland

In Switzerland, the prevailing energy design standard is called Minergie (minimum energy), administered by the Swiss Minergie Association. One of the key goals for the standard is to keep the cost premium within 10 percent of a standard house while reducing annual energy consumption for heating, hot water, and ventilation, measured in terms of heating oil, to about 1 gallon (4 liters) per square meter of floor space. For a 150–square-meter home (1,650 square feet), this would imply a heating oil use of about 150 gallons per year. By comparison, some older Swiss homes might use as much as five times that amount. Americans and Canadians who heat with oil might want to compare these goals with their own energy use to get an idea of how restrictive the Swiss standard really is.

Minergie also certifies commercial buildings, apartments, townhouses, and many other types of structures. By 2007, more than 8,200 buildings had received Minergie certification, totaling more than 8.3 million square meters (nearly 90 million square feet) of floor area.[14]

To meet the Minergie standard, a new single-family house or apartment block must keep annual *primary* energy consumption for space heating, hot water, and ventilation below 42 kilowatt-hours per square meter (this is roughly equivalent to the PassivHaus standard, which is based on end use or site energy use). An annual threshold of 80 kilowatt-hours per square meter is applied to refurbished buildings (for which it's harder to retrofit the entire building envelope). Primary energy consumption includes a weighting factor for the total value of fossil fuels consumed, either directly as heating oil or indirectly as electricity. The weighting factor to convert energy use at the home to primary energy is a multiplier of 2.0, reflecting Switzerland's abundance of hydroelectric energy. For countries with less hydropower in the electricity mix, the weighting factor could be 3.0.

As of 2009, these energy targets will drop still further to 38 and 60 kilowatt-hours per square meter, respectively. Well-insulated buildings are capable of meeting these thresholds even with fossil fuel (e.g., oil- or gas-fired) heating systems. Yet experts recommend the use of heat pumps or wood-fired heating systems as a more effective means of saving energy by reducing the primary energy use for power production.[15]

Minergie certification for a single-family house provides five options for space heating: a ground-source heat pump, a wood-fired heating system in conjunction with solar collectors for hot water production, an automatic wood pellet–burning heating system, connection to a district heating system running on waste heat, and an air-to-water heat pump for space heating and domestic hot water supply.

Just like the PassivHaus, the Minergie standard requires a compact, well-insulated, and airtight building envelope in all situations. To comply with it, the envelope has to have a 15- to 20-centimeter (6- to 8-inch) thick insulation layer and, minimally, double-glazed windows. Similar to the PassivHaus approach, the Minergie standard also requires an automatic ventilation system with heat recovery. This saves energy by minimizing the net heat losses through ventilation.

Austrian Energy-Efficient Homes and Buildings

To understand the approaches taken in another cold Central European country, Austria, consider the work of a long-time green architect, Vienna's Georg Reinberg. He has been building energy-efficient buildings and homes, mostly with passive solar design principles, for nearly three decades. Reinberg's book on the subject, *Ecological Architecture: Design, Planning, Realization*, appeared in the fall of 2008, showcasing a lifetime of projects and design principles. Reinberg maintains that the PassivHaus concept needs to be expanded beyond just concern over heating and ventilation to include the embodied energy of building materials, hot water consumption, electricity consumption for appliances, and cooling energy.[16]

Take a look at the B!otop company's office building and studio, a 5,000–square-foot office building located on an existing pond, shown in Figure 1.5. It has solid wood construction (cross-laminated panels) with a solid sunlit memory wall inside. The glazed south zone serves as an opening, providing communication and a connection with water, weather, and sun. The adjacent

FIGURE 1.5 Georg Reinberg's B!otop office in Austria uses a full range of integrated design strategies to create a low-energy building. *(Rupert Steiner)*

zone is illuminated diffusely; direct light comes from the north and through the inside shaded windows, creating optimal conditions for office workers.

The south façade is generously glazed and forms a connection between the inner space and the outside. The glass wall is interrupted by a blue–violet vertical collector wall covering the stairs. A footbridge over the water makes it possible to walk around the pond.

The energy design is based on highly insulated outside walls, with high-quality glazing to reduce heat losses. Supply air is fed into the building through ground channels and exhausted through a regenerating air heater. Fresh air is blown into the offices through the winter garden and is exhausted from bathrooms directly to outside, as in Sobek's design. The interior is open to the winter sun; solar gains are stored in an inner memory wall or used by ventilation equipment (heat exchanger) for warming up the fresh air.

A solar water collector provides hot water for the building. The remainder of heating needs are met by a biomass heating plant that uses wood scraps produced in the market garden. Protection against summer overheating is guaranteed by high insulation, outside shading, cooling of the input air in the ground channels, and automatic night flush ventilation. Additional cooling can be provided by concrete core activation (water running in tubes in the concrete mass).

For this office building, the large new pond is used both for swimming and for demonstrating different planting concepts. Rainwater is fed from the roofs to planted seepage areas, connected to the whole concept of green areas around the site. This building illustrates classic environmentally appropriate, low-energy architecture at its finest.

For this book, we interviewed architect Reinberg to find out more about his philosophy of sustainable design.[17]

> In the beginning, the demand was just for homes, but now more and more clients are building offices and public buildings because they also want to profit from the positive image. They also want to become independent of energy price increases, because energy is much more expensive in Austria than it is in the U.S.
>
> In Europe, beginning with the coming year [2009], every house will have to have an energy passport (*Energieausweis*). When a new home is built, the builder will have to give the owner an energy certificate. The requirements will vary by district. The document will include the home's heating demand and aspects of ecology, such as the source of electricity, warm water, and so forth.

Reinberg exhibits the typical Austrian concern for the source of energy in buildings, the primary energy demand, typically from hydropower, coal, or imported oil.

> What we are working on now is lowering the primary energy demand for all purposes. We're taking into account electricity, warm water, and heating, and we're trying to bring down the energy demand for all three of them. To do that, first, one must keep the heat inside the house in the winter. Therefore, we pay close attention to the details and use a lot of insulation, very thick walls. Normally we insulate the walls with 20 centimeters [8 inches] and the roof with 30 centimeters [12 inches] of insulation. As a standard, we use triple glazing in the windows with an inert gas fill, so we have a very good U-value. We are very careful with the details, and we build the houses airtight, so they don't lose warm air.

Most green architects and engineers share this viewpoint: First reduce energy use with conservation measures, and only then add renewable energy such as solar.

> After the house is designed to lose very little energy, then we add [solar] warm water collectors. Very often, we build warm water collectors that also serve for heating, but those collection installations have to be relatively big. For example, in Salzburg we did a sixty-four–unit housing project. The collection roof is 410 square meters [4,412 square feet], and the storage tank has a 100,000-liter [26,667-gallon] capacity. We need the storage for cloudy days. We normally use photovoltaics as shading devices. We use them for shading house façades from the sun, and then the photovoltaics also reduce electricity consumption. Photovoltaics also supplement the energy used in the collectors and ventilation system for the controlled air exchange.

Because heating is the primary concern, in terms of energy use, standards in Austria and Germany have become more rigorous. Reinberg says, "Since we have a very good standard for insulation, now we're engaging more with solar thermal collectors and photovoltaic collectors. We also use the earth's energy. We take it out indirectly with heat pumps or directly with circulating water from the ground for heat in winter and for cooling in summer." Austria also has a "feed-in tariff" for photovoltaics, a subsidy that pays about five times the amount of what you pay for taking electricity out of the grid. In this way, a homeowner can pay off a photovoltaic system in about 15 years.

Reinberg is optimistic that in the future, "we will have houses that are producing more energy than they are consuming, and we will have no more energy problems." As one final example of his design approach, he points to a kindergarten now under construction:

> The school has very good insulation. Additionally, it has photovoltaics and solar hot water collectors. The electricity generated from the photovoltaics runs a heat pump, which uses groundwater from a deep well. The groundwater is used for heating in the winter and cooling in the summer. It's balanced over the year; we don't heat up or cool the groundwater in a way that disturbs nature, but we can do all of the heating and cooling through the groundwater. This building is not consuming any additional external energy. Such things are possible now.

Low-Energy Social Housing in the Netherlands

The Dutch have long worked together cohesively because most of the country lies below sea level, and one person or one town can't keep out the sea. In April 2008, I visited respected green architect Tjerk Reijenga in The Hague. He has been designing low-energy homes and green office buildings for the past 15 years.

Reijenga took me to a nice housing development he designed on the outskirts of The Hague, De Groene Kreek ("The Green Creek"), in Zoetermeer, a group of sixty-six townhouses designed to be carbon neutral (Figure 1.6). What I like especially about the design is the fact that in the development, built around a small lake, there are no internal paved roads. At the edge of the development is a light-rail station, so there is little need to drive to work. Recycling containers are highly visible and well marked. Each townhouse has space for its own garden, and each rooftop is oriented for future retrofits of solar hot water and photovoltaics. The project was

FIGURE 1.6 Designed by BEAR Architects, De Groene Kreek near Den Haag provides access to transit and contains no internal roads.

designed in cooperation with the future residents, so they could make decisions about the layout of their homes and the space around the houses.

The Dutch system for evaluating homes includes more than energy. It's called Greencalc Plus (which provides an eco-indicator as a single number for environmental benefit) and includes consideration of water use, material choices, and transportation accessibility.[18] According to Reijenga, it is now a privatized system similar to the United Kingdom's BREEAM rating system, which is explained in more detail in Chapter 4. The Dutch also look at sustainability through the lens of a process called DCBA, in which

D = Meet legal requirements (the normal situation).
C = Energy-efficient design, using best practice measures and products (i.e., correct the problems of the normal situation).
B = Bioclimatic design with use of optimized materials (minimize environmental damage).
A = Zero-energy design, with only renewable materials, flexible, and deconstructible (completely autonomous of fossil fuels and nonrenewable resources).[19]

The Dutch aspire to very high standards in their housing and commercial buildings. The DCBA system is one way to keep moving the bar higher, focusing on continuous improvement and a growing autonomy for communities and the country as a whole.

What can we learn from these European approaches to energy-efficient homes? First of all, it's possible to design attractive, more energy-efficient homes using simple technology. Second, clear standards for home energy use are needed so that everyone knows the target at which to aim. Third, there's no escaping the need for government regulation of energy demand. Fourth, *PassivHaus* probably is not a good term to use for the more active American attitude; perhaps *high-performance* would work a lot better here. Fifth, there is no current market demand for such homes; we need a lot of demonstration projects, allowing people to see that these homes are not only energy efficient, but also attractive, quiet, and comfortable. Finally, a lot of education is needed because the detailed construction techniques are not in most builders' toolkits right now.[20] I'll explore more about the PassivHaus approach in later chapters, when we look at how similar housing standards are being implemented elsewhere in Europe.

One more thing: The European approach is focused heavily on energy use, with attendant benefits of increased comfort and indoor air quality. From the standpoint of the more popular green home standards in the United States, those of the U.S. Green Building Council and the National Association of Homebuilders, that approach is much too narrow. The North American approach considers also land use impacts, links to transportation and vital services, water use, and material use. In my opinion, we need to do both: have "climate-neutral" housing and make sure that the life-cycle impacts of our total approach to homebuilding and home operations are neutral at worst. It is true that in Europe most of those other things are good design practices to begin with. Land, materials, and resources are limited and already managed with stewardship in mind, and most places already have excellent public transportation. Toxins in materials are controlled by much more stringent codes. So there is no need to give points for things that are already a given. The debate over what green building standards should entail will continue, of course, but there's no doubt that any green building should exhibit low levels of energy demand.