and bicycling; the museum provides bicycle storage and changing areas. Because parking structures are nearby, no new public parking was required. A white roof, landscaping, water features, and other elements were designed to reduce the urban heat-island effect.

The museum requires about 20 percent fresh air at a time. An energy wheel, more commonly used in office buildings abroad, allows exchange of air in such a way that the temperature and humidity of the air being removed can be transferred to the incoming air—without mixing the air streams—thereby reducing energy use. For instance, during the winter, the outside air being brought in can be warmed and humidified by the inside air being removed.

While climate-control needs limit potential energy savings, museum goals for indoor air quality fit LEED standards well. Because volatile organic compounds (VOC) can damage art, the museum aggressively sought low-emission materials, achieving projected VOC levels less than one-quarter those allowed under LEED standards, according to the GRAM.

The museum footprint is designed to admit natural light from courtyards, and rooftop skylights, called lanterns, admit light to galleries. Natural lighting illuminates an estimated 70 percent of public, gallery, and managerial spaces. However, natural light makes it harder to control temperature, and direct sunlight damages art. These problems are solved by three-layer ultraviolet glass, including translucent outer layers, with argon gas between window glass panels, and louvers and interior shades that can be adjusted to meet exhibition demands. The three-layer glass also enhances building insulation. Overall, lighting and heating, ventilating, and air-conditioning systems are designed to yield 34 percent cost reductions and 30 percent energy savings.

The museum channels rainwater from the roof into 15-foot- (4.6-m-) tall cisterns holding up to 19,000 gallons (72,000 liters), sized for a 100-year storm, and uses it in the water wall and reflecting pool, and for landscape irrigation and toilet flushing, thereby reducing demand for city-treated water by 20 percent.

About 58 percent of construction materials, including concrete used extensively in the exterior, came from within 500 miles (800 km) to reduce transportation costs and carbon emissions. About 20 percent of construction materials came from recycled sources, and construction waste was recycled.

The GRAM building should open eyes to new possibilities of serving both artistic and environmental goals in museum design.

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A GREEN FANTASY?

"Imagine for a minute, just a minute, that someone running for president was able to actually tell the truth, the real truth, to the American people about what would be the best—I mean really the best—energy policy for the long-term economic health and security of our country. I realize that this is a fantasy . . ."

From "Truth or Consequences," by Pulitzer Prize-winning author Thomas L. Friedman, *New York Times*, May 28, page A23.

New Colorado Neighborhood Aims for Net Zero Energy Use

In Colorado, green building is fast becoming a norm. Not only are local building codes evolving to support sustainable development, but also Colorado's Amendment 37, passed by voters in 2004, created incentives for use of renewable energy and sustainable technology. The initiative required that the state's largest utilities obtain 3 percent of their electricity from renewable energy sources by 2007, 6 percent by 2011, and 10 percent by 2015. It also established standards for photovoltaic systems to connect to the power grid, and called for 4 percent of renewable energy to come from solar sources.

In Arvada, Colorado, the 250-home, urban mixed-use neighborhood Geos, which began construction in April, is slated to be the largest net zero-energy solar community in the United States. The project—a hybrid of green design and new urbanism with a focus on sustainability—aims to provide homes that combine innovative design, energy efficiency, and use of renewable resources, all at a cost no higher than the region's market-rate housing. Geos—from the word *geosolar*, meaning earth and sun—will be located about ten miles (16 km) northwest of downtown Denver, next to the Rocky Mountain foothills and surrounded by residential subdivisions and light-industrial sites.

What inspired Geos, says Norbert Klebl, principal of Geos Neighborhood in Boulder, Colorado, the developer of the 25-acre (10-ha) project, was the idea of developing a whole neighborhood of net zero-energy homes through an urban plan that pushes new urbanism toward solar orientation, and includes high-efficiency building techniques and renewable-energy systems.

Buildings are responsible for 38 percent of greenhouse gas emissions and consume 70 percent of all electricity generated by U.S. power plants, according to the U.S. Energy Information Administration. Klebl says he seeks to take advantage of Colorado's annual average of 300 days of sunshine, along with geothermal resources, to power Geos's energy grid.

Designed by Michael Tavel Architects of Denver and David Kahn Studio of Eldorado Canyon, Colorado, Geos will extend community orientation beyond mixed uses, parks, and meeting places to incorporate on a neighborhood scale renewable energy resources such as geothermal and photovoltaic solar power. Tavel and Kahn created a sustainable onsite stormwater management plan.

MICHAEL TAVEL ARCHITECTS/DAVID KAHN STUDIO

The master plan includes a central square with two- and three-story urban mixed-use buildings providing ground-floor retail space. Also on the square will be a 34-unit intergenerational cohousing community and a common house that can be shared with the neighborhood for community gatherings. Housing will range from stacked flats to three-bedroom, single-family detached houses, and will include duplexes, townhouses, and live/work lofts. Forty percent of the site will be open space, including nine acres (3.6 ha) of community and pocket parks. Pedestrian paths and bike trails at Geos will connect with existing trails in city open space along a creek.

One of the biggest challenges in creating the urban design was the complexity of laying out a connective, walkable neighborhood while siting 250 homes in a dense development pattern that also allows each building maximum solar exposure. To maximize solar gain, Tavel and Kahn oriented the buildings to allow the largest surface area of each house to face some degree of south to capture the sun's rays for the most hours. They rotated the neighborhood grid about 10 degrees toward the east to gain the ideal passive solar orientation and to accommodate the shape and topography of the site.

A big part of their method of maximizing solar access within a traditional neighborhood layout was executed in what they call the checkerboard blocks, an area that will span five blocks with alleys and cover about 60 percent of the buildable acreage. Every other single-family house will be set back on an alley to allow maximum solar access for each house. Half the units will have porches on the street with a courtyard behind, and half will have porches facing a courtyard that fronts the street. The doors and windows of most homes will be oriented to the south, as will living spaces, with staircases, bathrooms, closets, and utility rooms generally located along the north side.

Geos will achieve net zero energy by reducing energy demand by two-thirds—one-third through the checkerboard passive-solar orientation and one-third through energy-efficient Passive House construction—with the remaining energy needs met by solar and geothermal energy-producing systems, according to Klebl.

Passive Houses—meeting what is considered the world's leading standard for energy-efficient design and construction—are superinsulated, airtight houses that use passive elements for heating, such as heat generated by appliances and lighting, as well as the body heat of inhabitants, in conjunction with an air-heat exchange system that provides fresh air and recycles the heat of exhaust air. Special windows and an envelope built from high-efficiency insulation panels help keep the heat inside. They use as little as 10 percent of the energy required by conventional homes and cost only up to 10 percent more to build, according to studies conducted in Europe. They rely on relatively simple technology, such as heat pumps that heat water and air, rather than more expensive and complex technologies, such as radiant heat systems.

In the United States, several individual certified Passive Houses have been built in Urbana, Illinois, and a couple more are being designed or are under construction in Berkeley, California, and on Martha's Vineyard in Massachusetts, says Katrin Klingenberg, executive director of the Urbana-based Passive House Institute U.S. and a Passive House designer. Geos is the largest Passive House development in the United States to date, she says. As many as 10,000 Passive House units have been built in Europe, mostly in Germany, Austria, and Switzerland. (See "The Eco-Prefab Revolution," May, page 64.) Many are subsidized affordable multifamily housing, though there are also schools, office buildings, and factories. The European Parliament recently adopted a resolution to require all new construction to meet Passive House standards beginning in 2011.

Geos's net zero-energy homes will go a step beyond the Passive House Standard to include renewable energy technology. The neighborhood will be tied to the Xcel Energy Company grid to complement its own solar electricity production, and, Klebl estimates, will deliver as much electricity to the grid as it consumes on an annual basis. Photovoltaic panels will be installed on all the rooftops as part of the collective solar-powered energy system.

The homes will not have furnaces or compressed air conditioning, both standard systems in new conventional homes in the region, which has temperatures that fluctuate from 100 degrees Fahrenheit in summer to below zero (38 to –18 degrees Celsius) in winter. The source of warm and cool air will be the heat pump, fed by water that has been heated or cooled by a geothermal system. A mechanical ventilation system will bring in fresh air from outside and use a fan to circulate the water-heated or water-cooled air.

To further reduce heat loss, the development team is ordering double-pane European-type window systems, made in Canada, which will provide a maximum energy-efficiency rating of R6.5—significantly more energy efficient than low-emissivity windows rated at R3. Optional insulated "intelligent" blinds connected to the thermostat will be automatically raised and lowered to gain and retain solar heat in winter and deflect it in the summer.

Installed in a seven-acre (2.8-ha) floodway park next to Ralston Creek, the geothermal loop field will be composed of PVC pipes—filled with a fluid that does not freeze—that wind horizontally about six feet (1.8 m) below ground. The fluid in the pipes will absorb the earth's constant temperature of 50 to 55 degrees Fahrenheit (10 to 12.8 degrees Celsius) and be pumped continually to a pump house with a heat exchanger. There, heat from the mixture will be transferred to four different heat pump systems, one for each part of the neighborhood, and then into each housing unit. The constant temperature of the fluid will preheat the water systems in homes in winter or precool them in summer.

Geos, a 250-home, urban mixed-use neighborhood in Arvada, Colorado, is expected to be the largest net zero-energy solar community in the United States. To maximize solar access within a traditional neighborhood layout, alternative single-family houses are set back on an alley to allow maximum solar access for each house.

The stormwater management system will use all rainwater on site to irrigate a network of green streets, parks, and community gardens. Conventional developments in Colorado generally hold stormwater in giant detention facilities, but Geos will detain it in a greater number of smaller detention areas. The stormwater system will include street-tree rain gardens and bioswales in private yards, public parks that will serve as larger-scale stormwater detention facilities, and the creekfront park, which will handle stormwater outflows. The site will be able to detain the stormwater equivalent of a 100-year flood, then discharge it within 24 hours.

Geos houses will be built for $200 per square foot ($2,150 per sq m)—the average for high-quality housing construction in the Arvada area, says Klebl. For the same amount of money, instead of higher-end finishes, he says, the average Geos homebuyer will be getting a higher-performing, energy-efficient structure. The estimated total of $5.4 million for the collective solar and geothermal energy systems will be apportioned according to square footage; the price of an average-size Geos home of 1,500 square feet (140 sq m) will include $15,000 in shared energy-system costs.

The Passive House standards for insulation and tight construction will add 8 to 10 percent to the construction costs compared with conventional construction, says Klebl. He estimates that energy savings of 80 percent, compared with conventional residential energy-system costs, will save residents hundreds of dollars every month and make up the difference of a slightly larger mortgage.

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A NONGREEN BODY DOUBLE?

"Let's say I do bother, big time. I turn my life upside down, start biking to work, plant a big garden, turn down the thermostat so low I need the Jimmy Carter signature cardigan, forsake the clothes dryer for a laundry line across the yard, trade in the station wagon for a hybrid, get off the beef, go completely local. . . . [W]hat would be the point when I know full well that halfway around the world there lives my evil twin, some carbon-footprint *doppelgänger* in Shanghai or Chongqing who has just bought his first car . . . is eager to swallow every bite of meat I forswear and who's positively itching to replace every last pound of CO_2 I'm struggling no longer to emit. So what exactly would I have to show for all my trouble?"

From "Why Bother? Looking For a Few Good Reasons to Go Green," by Michael Pollan, author/Knight Professor of Science and Environmental Journalism at the University of California at Berkeley, *New York Times Magazine*, Green Issue, April 20, page 19.

Norway Sets Sustainable Development Strategy

Norway, one of the few nations anywhere to include its sustainable development responsibilities within its finance ministry, this year launched an updated sustainable development strategy along with its 2008 national budget. "This new strategy . . . sets ambitious goals and will be an important basis for our efforts in the years ahead," Norwegian finance minister Kristin Halvorsen said during her budget announcement. "Climate change is a major concern in this context."

In Norway, she noted, the finance minister is responsible not only for public finances and economic and tax policies, but also for coordinating the government's work on sustainable development. "I firmly believe that integrating this work in economic policies is key to success in our efforts," stressed Halvorsen. "It is imperative that sustainable development becomes an integrated part of all decision-making processes."

Norway has a goal of being carbon neutral by 2050 and has pledged to move this deadline up to 2030 within the framework of any binding agreement that may be reached among all industrialized countries.

One of the world's leading petroleum producers, Norway is committed to reducing its own greenhouse gas emissions by 30 percent between 1990 and 2020. It is not currently on course to achieve this, observers note, so the sustainable development strategy and follow-up will be critical.

The strategy highlights seven priority areas—international cooperation, climate change, biodiversity, sustainable economic and social development, natural resources, hazardous chemicals, and the perspectives on environmental and natural resource management of the indigenous Sami populations in the north of the country. Energy use is a core theme. Energy consumption in housing has remained relatively stable for the past 15 to 20 years in Norway and is at the average level for the Nordic countries.

However, the proportion of electricity in the energy mix is high, so the sustainable development strategy highlights the large potential for improving energy efficiency and for much more widespread use of heat pumps, bioenergy, and district heating. It warns that energy use is likely to rise unless prices are increased.

In February 2007, new building regulations were introduced in Norway, which had the effect of tightening limits on everyday energy use by around 25 percent. The new rules also require that new buildings can be heated using alternative fuel sources.

According to the Norwegian Ministry of Local Government and Regional Development, the new energy requirements will result in savings of 400 million to 450 million kilowatt-hours (kWh) of electricity starting this year—the equivalent of total annual energy use by 20,000 homes.

Enova—a market-oriented public body promoting energy efficiency and renewable energy development—and the State Housing Bank jointly support construction of low-energy homes through grants. Through this mechanism, more than 3,000 homes have been built in recent years with annual heating demand of about 9.2 kWh per square foot (100 kWh per sq m); a typical home in Norway consumes 13 to 14 kWh per square foot (140 to 150 kWh per sq m).

Cultural heritage is considered significant in the sustainable development strategy, but the strategy document notes that the full value of protected buildings can only be realized if there is increased investment in them. According to the most recent survey, more than 70 percent of privately owned buildings with statutory protected status are in need of repair.