Sarah Hall
Energizing Architectural Glass with Photovoltaic Cells

by Shawn Waggoner

Photos Courtesy of Sarah Hall Studio

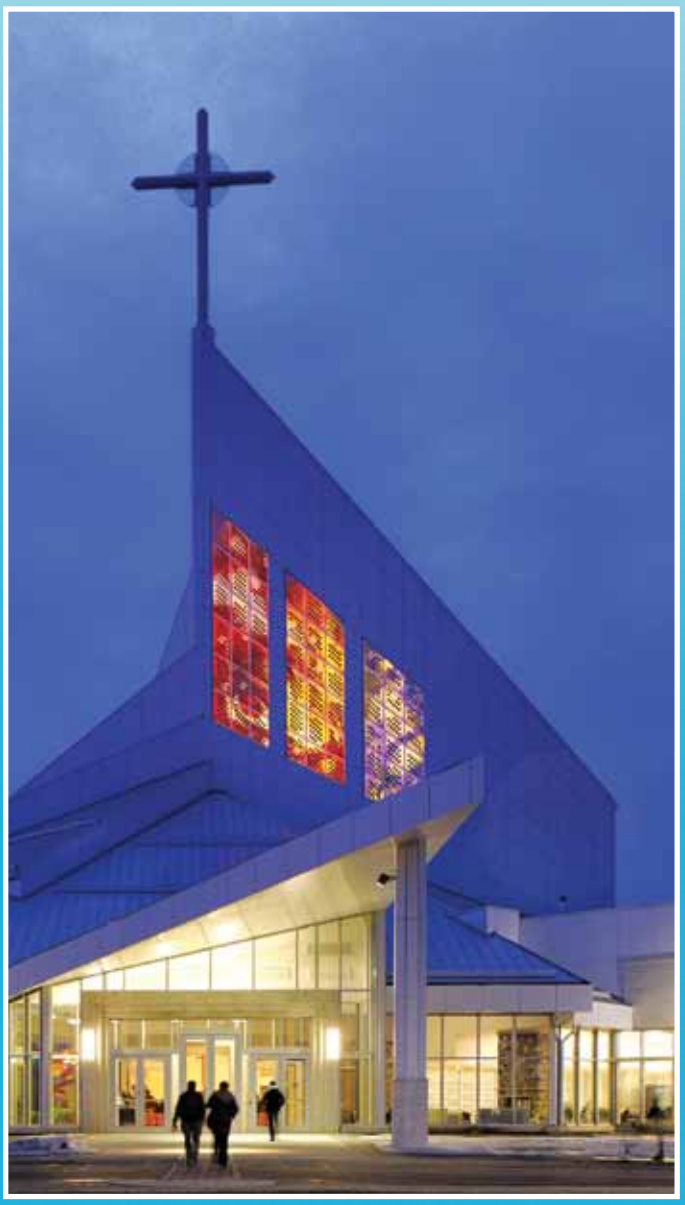
Sarah Hall has refined a unique and high-tech approach to architectural glass that gifts the world with both beauty and power. Through the use of photovoltaic cells that convert solar energy into electricity, Hall's windows can store sunlight by day to backlight the glass by night. They can also produce clean electricity that feeds directly into their respective buildings' energy systems. Though designing with photovoltaic cells presents some challenges, she moves viewers through her stunning mastery of light and color.

Hall designs large-scale solar and art glass projects for clients around the world including embassies, cathedrals, schools, universities, and colleges. Recent commissions include *Waterglass* at Harbourfront Centre Theatre and *Leaves of Light* for the Life Sciences Building at York University in Toronto, Ontario; *Lux Gloria* at the Cathedral of the Holy Family in Saskatoon, Saskatchewan; *Lux Nova* wind tower at the University of British Colombia (UBC) in Vancouver; and *The Science of Light* at Grass Valley Elementary School in Washington State.

Having studied at Sheridan College in Ontario, Hall continued her education in the Architectural Glass Department at Swansea College of Art in Wales, U.K. She followed this with an apprenticeship to Lawrence Lee, Glass Master at the Royal College of Art in London, U.K., and a year in Jerusalem studying Islamic techniques in glass. Her exceptional contribution to the built environment has resulted in Honor Awards from the American Institute of Architects and the Allied Arts Award from the Ontario Association of Architects. Hall's artistic achievements were acknowledged by her induction into the Royal Canadian Academy of Art in 2002. An Arts Fellowship from the Chalmers Foundation in 2005 supported her innovative work in Building Integrated Photovoltaic (BIPV) solar art glass.

In 2016, Hall's autonomous glass was featured in the exhibition *International Panorama of Contemporary Glass-Art,* held at the Centre International du Vitrail in Chartres, France. In addition to projects, lectures, and exhibitions throughout North America and Europe, Hall has co-authored 35 articles on glass art and published three books: *The Color of Light (1999)*; *Windows on Our Souls (2007)* with Bob Shantz; and *Transfiguring Prairie Skies (2012)* with Donald Bolen. Her work was the subject of J. S. Porter's volume, *The Glass Art of Sarah Hall,* as well as the CBC documentary series, *Great Minds of Design*. The artist is presently working on a large-format retrospective book of her work, *A Thousand Colours—Sarah Hall Glass*.

Through her glass designs, Hall currently explores ways to generate power and save birds simultaneously. She endeavors to create colored, transparent solar panels that will help power the buildings they cover while preventing some of the 25 million bird deaths per year due to collisions with glass.



Sarah Hall, Lux Gloria, *the Cathedral of the Holy Family, Saskatoon, Saskatchewan. Photo by Grant Kernan.*

A Perfect Storm for Going Solar

Hall has spent the last 10 of her 40 years in glass exploring the possibilities of photovoltaic technology. Her mentor Professor Ursula Franklin at Massey College, University of Toronto, shared with Hall a video titled *Power of the Sun*, which planted the early seeds for this new direction. Hall had seen many buildings in Germany created with BIPV and was convinced it was a great direction for solar. She began forging connections in Canada, the United States, and Europe with BIPV architects and engineers.

A solar/art glass collaboration between the studio that fabricates Hall's work, Glasmalerei Peters Studios, Paderborn, Germany, and artists Klaus Jansen and Christof Erban further inspired Hall's movement toward solar. In 2005, she was awarded a Chalmers Arts Fellowship from the Ontario Arts Council, which funded time and resources for experimentation. Later that year Hall created the first window in North America to incorporate solar cells. It was displayed in the Northern Lights House at the 2005 Solar Decathlon in Washington, D.C.

"I consider making an effort to care for our environment very important. I think we need to find creative, beautiful, ecological ways of living in the world. To my mind, renewable energy is part of that picture. As glass artists we are in a great position to make use of glass-to-glass solar modules. Creating windows that collect energy is a significant contribution to our medium and the built environment."

Sarah Hall, Lux Nova *wind tower at Regent College, part of the University of British Columbia in Vancouver in daylight and at night. Photo by Michael Elkan.*

How It Works

Photovoltaic or solar cells collect energy from sunlight. The type Hall uses are wired together in a panel or array and encased in a glass-to-glass module. The artist's preliminary design combines her artistic response to the architectural site with composing an additional layer of graphic elements or patterns comprised of the solar cells.

These designs are integrated into an electrical field and wiring diagram by solar engineer Erban as an additional layer in the window. The wiring can appear strictly functional and almost invisible as seen in Hall's project for the Cathedral of the Holy Family, Saskatoon. It can also sometimes add an integrated graphic element to the overall composition as seen in her Regent College Wind Tower in Vancouver. "My projects are essentially collaborations with solar engineers. They make it possible."

Solar projects have brought a rigor to Hall's design process, requiring her to combine rigid graphic and technical elements. "There is a very big learning curve for everyone involved, and you need the team of engineers and electricians from the building site to be on board with work they may never have done before. This part of it can be very hard going." The panels themselves must pass CSA or UL certification as electrical components. Additionally, the site must be appropriate for solar energy collection.

Hall's work has introduced many people to a new concept of solar energy, proving it can look beautiful as well as carry meaning. BIPV touts many benefits including the fact that the cost of producing solar cells and panels is paid back within four years. The cells have a lifespan of 40-plus years and importantly do not pollute with greenhouse gas (en.wikipedia.org/wiki/Net_energy_gain). Compare this to fossil fuels, which provide one-time use, release pollutants into the atmosphere every minute, and use original material that is not recoverable or recyclable. For Hall, the benefits of BIPV far outweigh the challenges.

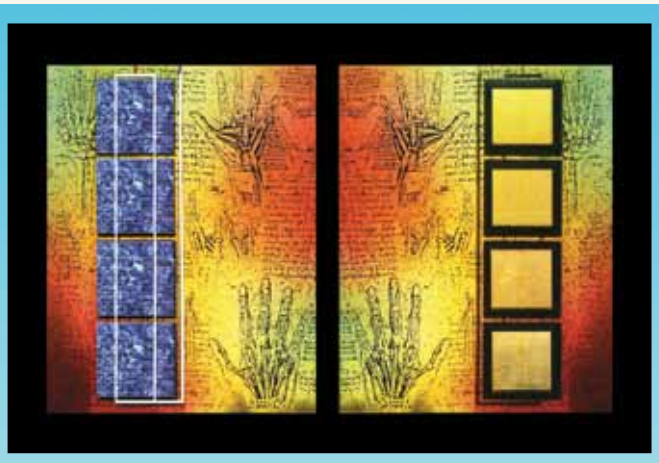
The Proof Is in the Pudding

Two of Hall's recent award-winning commissions, *Lux Gloria* and *Waterglass*, demonstrate BIPV projects that produce clean electricity that is fed directly into their building's energy systems. *Lux Gloria,* installed in 2013 at the Cathedral of the Holy Family, presented an important worldwide first and Saskatchewan's first BIPV system. These stained glass windows not only collect energy but are tied to the energy grid, translating into rebates on energy costs for the cathedral. This innovative project was the 2014 recipient of the American Institute of Architects (AIA) award for its combination of beauty, technology, and solar energy.

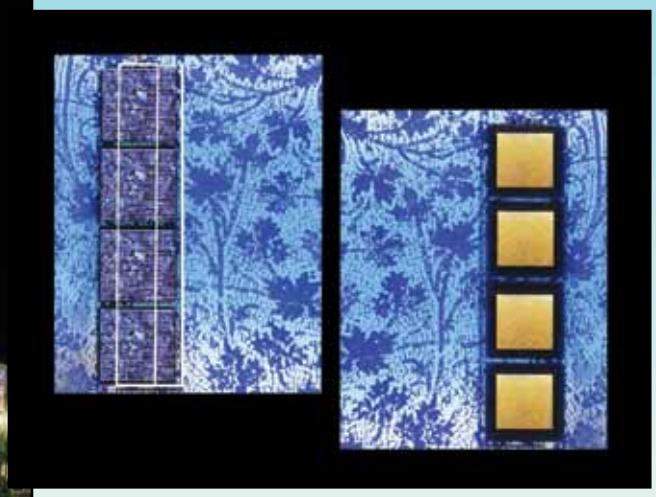
A landmark installation of three monumental south facing windows that grace the upper façade, this project pays homage to Saskatchewan's vast prairie skies. The largest window is 37 feet high by 12 feet wide and sits 107 feet above the ground. Each window is divided into 18 panels of unique sizes, shapes, and designs. With 1,117 hand soldered, silver colored solar cells embedded in the windows, *Lux Gloria* is expected to produce about 2,500 kilowatt hours annually. The city's motto, "Saskatoon Shines," is celebrated and embodied in this pioneering solar installation.

Sarah Hall, Waterglass, *Harbourfront Theatre, Building Integrated Photovoltaic. Photo by Matthew Lavoie.*

Sarah Hall, Waterglass, *Harbourfront Theatre, Building Integrated Photovoltaic, exterior. Photo by Matthew Lavoie.*



Sarah Hall, Homage to DaVinci, *first panel prototype, 2004.*



Sarah Hall, Blue Vine, *second panel prototype, 2004.*

Waterglass, Hall's 2012 work for Harbourfront Centre Theatre, Toronto, combines 1,736 square feet of glass art and photovoltaics in a three-story glass envelope that wraps the entirety of the north, east, and west façades of the building. The glass enables increased thermal insulation and features unique, electricity-generating windows. Sunlight is collected and stored by western solar panels during the day. At night, the multistory complex comes alive in an array of color changing LEDs.

A visual journey through the nautical history of Canada's largest city, *Waterglass* features artistic elements on glass created with airbrushed, fired cobalt mineral pigments and enamels on 6 mm float glass. The image gallery—including 360 images of maps, wildlife, the seasons, ecology, and historical figures from the country's first settlers to its Olympic athletes—combines screen printed photographs and dichroic glass.

An example of a different type of BIPV project, one that collects solar energy during the day to illuminate itself at night, can be seen in Hall's *Lux Nova,* created in 2007 for the tower of Regent College, part of UBC. The aerodynamic 40-foot wind tower was designed by Vancouver architect Clive Grout in collaboration with Walter Francl Architects as a natural ventilation system for the underground library building and a functional symbol of Regent's commitment to a sustainable environment.

Hall's task was to bring further beauty and interest to Regent's tower while continuing the theme of alternative energy. At the heart of her glass design is a luminous column of light, flowing like a waterfall in silvery blue, violet, and white. Included in this column is an array of solar cells that will collect energy during the day and use it for nighttime illumination, acting as a beacon for the surrounding park. Arranged within the design are 12 dichroic glass crosses, creating an ever-changing rainbow of color. Woven through the flowing waterfall of light is the Lord's Prayer in Aramaic, which acknowledges the theology library below.

In 2011, Hall's work *Leaves of Light,* a solar art installation, brought a similar living light to the northwest corner of York University's Life Sciences Building. The embedded, custom designed blue-gray solar cells were made in Germany and are a perfect match for the innovative sculptural façade of the building itself, which is based on the DNA molecule. The west facing layer of *Leaves of Light* is a tour de force combination of hand painting, digital painting, and screen printing on glass. Hall's artwork includes Goethe's poem *Gingko Biloba* in the original German and in Spanish, English, French, Dutch, Italian, Portuguese, and Japanese. The word *Gingko* is written in Chinese, Greek, Arabic, Hindi, Persian, Hebrew, Thai, Russian, Bengali, and Korean to acknowledge the multicultural character of York itself.

"Every project I take on generates and encompasses a great story made from the purpose of the artwork, specifics of the site and architecture, fresh ideas, technical challenges, the process of designing, and all of the people involved. With *Leaves of Light*, I wanted to make a connection to the gingko trees on campus, look at languages overlapping with images, and make solar look beautiful."

The Bright Future of Hall's Photovoltaic Glass

Nowhere is Hall's intention to demonstrate renewable energy in an imaginative and beautiful context more relevant than her 2009 work, *Science of Light*, Grass Valley Elementary School, Camas, Washington. "The artwork was designed to delight, to teach, and to inspire. Delight resulted from the transformation of sunlight into patterns and colors throughout the stairwell and visible energy showcased in the LED lighting fixture. Inspiration and teaching were accomplished through the innovative use of the solar cells embedded into the windows, offering an ongoing lesson in science, ecology, and the positive use of technology. Producing renewable energy through the sun's light enhances children's ability to see connections between themselves and the natural world."

Working with integrated photovoltaics is neither a craft nor a studio practice, but rather a collaboration between artist and electrical engineer. Many artists and designers are interested in the ideas and technology. In the United States, Lynn Goodpasture created an interesting solar project at the San Jose Library in 2008. Artist Carol Bennett integrated photovoltaics at the Hawaii State Art Museum in a 2012 skylight sculpture.

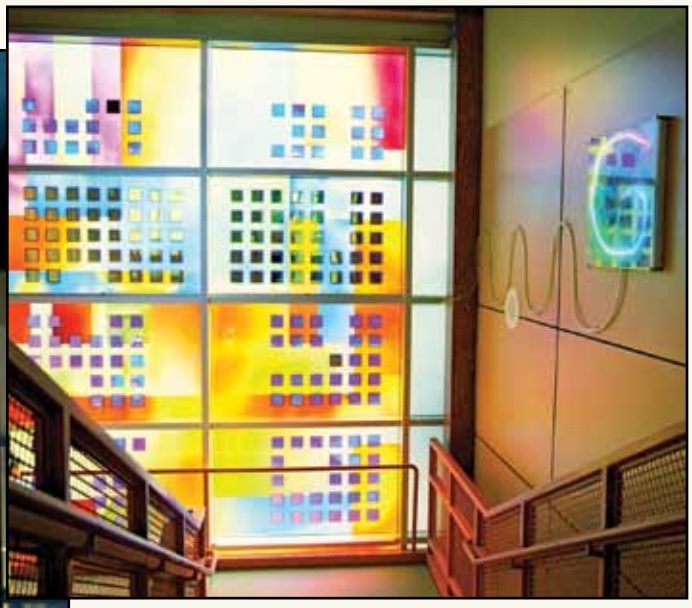
As Hall's journey with BIPV art glass continues, her goals for the work have expanded. A couple of years ago, Toronto architect Paul Raff, encouraged Hall to explore how her solar windows could stop the bird problem. "Birds perceive the reflected image of the sky and trees as real, and they fly into it. Here in Toronto, about nine million birds die every year by colliding with glass. I was staggered by this statistic. Most of the new high-rise buildings being constructed are made primarily of glass. My goal is to replace this with bird friendly, energy producing glass that prevents collision."

Hall's previous solar installations have all been produced with opaque multicrystalline cells inappropriate for high-rise offices or condos where people want transparency in the glass. However, new solar technology based on nanotechnology is being introduced to the market. It is lightly colored, has a low capital cost of manufacturing setup, and a simple screen printing process of application, which offers glass in a range of transparencies.

Hall currently works with Peters Studio to create prototypes of bird friendly photovoltaic glass. If her decade of previous work in BIPV is any indication, she will no doubt conquer the challenges of the bird problem with an artful, beautiful, environmentally responsible solution. GA

Sarah Hall was a recent guest on Glass Art *magazine's new podcast* Talking Out Your Glass. *Visit the link under "What's New" at www.glassartmagazine.com to subscribe to this free podcast today.*

Sarah Hall, Leaves of Light *for the Life Sciences Building at York University, Toronto, Ontario. Photo by Andre Beneteau.*



Sarah Hall, The Science of Light, *Green Valley interior. Photo by A.J. Rose.*

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