

BIOMIMICRY STRATEGIES FOR NYSERDA

Workshop Report and Proposed Strategic Road Map

30 JANUARY 2009



TERRAPIN
BRIGHT GREEN

NOTICE

This report was prepared by Terrapin Bright Green, LLC in the course of performing work contracted for and sponsored by the New York State Energy Research and Development Authority (hereafter "NYSERDA"). The opinions expressed in this report do not necessarily reflect those of NYSERDA or the State of New York, and reference to any specific product, service, process, or method does not constitute an implied or expressed recommendation or endorsement of it. Further, NYSERDA, the State of New York, and the contractor make no warranties or representations, expressed or implied, as to the fitness for particular purpose or merchantability of any product, apparatus, or service, or the usefulness, completeness, or accuracy of any processes, methods, or other information contained, described, disclosed, or referred to in this report. NYSERDA, the State of New York, and the contractor make no representation that the use of any product, apparatus, process, method, or other information will not infringe privately owned rights and will assume no liability for any loss, injury, or damage resulting from, or occurring in connection with, the use of information contained, described, disclosed, or referred to in this report.

Table of Contents

Executive Summary	5
Biomimicry Lens	7
Strategic Roadmap for NYSERDA	11

Biomimicry offers a paradigm shift in energy efficient design, and NYSERDA should harness this potential to develop innovations that could be critical for the long-term energy performance of New York State.

Executive Summary

“The workshop and its subject matter were wonderful and timely. I hope that this meeting was just the beginning.”

– *Ed Piñero, Pollution Prevention Institute, Rochester Institute of Technology*

Biomimicry is a way of observing the natural world to identify design solutions and lessons that may enable us to create products and processes that are sustainable and healthy for local and global ecosystems. These natural inspirations lead to new strategies for achieving specific environmental goals, providing a toolbox for identifying and solving problems in areas such as energy performance, efficient use of water, toxin reduction, and waste elimination. In this way, biomimicry brings science, design, manufacturing, and policy together for an interdisciplinary approach to real-world problems, helping to improve how we interact with the world.

NYSERDA has a sustained interest in using innovation and technology to improve New York State's (NYS) energy performance and solve environmental problems. This includes mitigating the environmental effects of energy consumption, developing renewable resources, and advancing innovative technologies in ways that improve the State's economy. Biomimicry offers a paradigm shift in energy efficient design, and NYSERDA should harness this potential to develop innovations that could be critical for the long-term energy performance of New York State.

With this in mind, NYSERDA and Terrapin Bright Green coordinated a Biomimicry Scoping Session to educate stakeholders about biomimicry, generate interest in and consider mechanisms for incorporating biomimicry into NYSERDA's programs, and identify challenges and opportunities for implementing biomimetic principles into scientific research and manufacturing in NYS. The workshop brought together NYS stakeholders from the fields of science, industry, government, and advocacy in order to solicit ideas for this effort, brainstorm specific forms it could take, and create a preliminary timeline for action. This report contains the Strategic Roadmap that resulted from the workshop discussions, follow-up interviews with key participants, and Terrapin's recommendations. This decision-making Roadmap aims to provide NYSERDA with a timeline of strategies, near-term to long-term, for developing biomimicry across multiple sectors and at various scales so as to achieve maximum benefit for NYS.

In the near term, these strategies focus on jump-starting education and collaboration through issue-focused workshops and design competitions, supporting commercialization via feasibility studies and solicitation restructuring, and developing online resources to connect stakeholders to potential NYS biomimicry resources. Mid-term strategies include coordinating interactive meetings between grantees of NYSERDA's biomimicry funding, assembling think tanks, expanding university education, and providing targeted support for product deployment. In the long term, NYSERDA can expand its biomimicry programs to include manufacturing facilities and building performance, as well as integration of industrial ecology concepts and other issues beyond traditional energy efficiency sectors, such as transportation infrastructure, agricultural production systems, and waste optimization. By following these strategies, NYSERDA has the opportunity to lead by example and transform New York State into the center of biomimicry innovation in the United States.

Matrix of Recommendations

Recommendation	Time Frame		
	Now (0-2 Years)	Mid Term (2-5 Years)	Long Term (5+ Years)
Clearly define biomimicry	■		■
Educate NYSERDA staff about biomimicry and integrate these concepts across all programs	■		
Focus on projects with strong commercialization potential	■	■	■
Design effective funding programs	■	■	
Facilitate collaboration	■	■	■
Connect to outside support or other networks	■	■	
Sponsor issue-focused biomimicry retreats	■	■	
Incentivize biomimetic innovations	■	■	
Support feasibility studies	■	■	
Sponsor collaborative design competitions	■		
Educate NYS stakeholders on the value and potential of biomimicry	■	■	■
Inventory the State's biomimicry resources and develop interactive online databases	■		
Support deployment and marketing		■	■
Assemble a think tank and establish a dedicated center for biomimicry		■	
Expand education programs		■	■
Evaluate and update biomimicry inventory and online resources		■	■
Improve the performance of buildings and manufacturing facilities		■	■
Investigate ways to integrate industrial ecology			■
Encourage innovative education			■
Expand support programs		■	■
Explore creating a certification program for biomimetic technology			■
Broaden focus beyond traditional energy efficiency fields			■

“Awareness is the place to start.”

– Glenn Saunders, Rensselaer Polytechnic Institute

In her 1997 book *Biomimicry: Innovation Inspired by Nature*, Janine Benyus introduced the concept of biomimicry and defined it as “the conscious emulation of life’s genius.” She described three tenets of this science:

- 1. Nature as model:** Biomimicry is a science that studies nature’s models and then imitates or takes inspiration from these designs and processes to solve human problems, e.g. a solar cell inspired by a leaf.
- 2. Nature as measure:** Biomimicry uses an ecological standard to judge the “rightness” of our innovations. After 3.8 billion years of evolution, nature has learned what works, what is appropriate, and what lasts.
- 3. Nature as mentor:** Biomimicry is a way of viewing and valuing nature. It introduces a paradigm based on what we can learn from the natural world, not on what we can extract from it.

The Earth is a laboratory in which life has evolved adaptations to the design challenges of its diverse environments. The organisms surrounding us are the winners of these design experiments, those that developed a dynamic equilibrium in their environments while using resources sustainably. Biomimicry studies these biological adaptations to help designers, engineers, architects, and business leaders solve design and engineering challenges. The goal of biomimicry is to create products, processes, and policies that are well-adapted to sustaining life on earth and that provide innovative improvements to our way of life. The study of biomimicry has identified the following core traits of nature’s genius:

- Runs on sunlight
- Uses only the energy it needs
- Fits form to function
- Recycles everything
- Rewards cooperation
- Banks on diversity
- Demands local expertise
- Curbs excesses from within

The field of biomimicry differs greatly from bio-utilization, which entails harvesting a product or producer (e.g. logging timber) and from bio-assisted technologies, which domesticate an organism to accomplish a function (e.g. bacterial purification of water or harvesting wool from sheep). In Benyus’ words, “Instead of harvesting or domesticating, biomimics consult organisms; they are inspired by an idea, be it a physical blueprint, a process step in a chemical reaction, or an ecosystem principle such as nutrient cycling.” These three basic approaches – form, process, and ecosystem – can be used to categorize biomimetic innovation. The following examples illustrate the diversity of nature’s inspiration in today’s leading initiatives:

Form

Inspired by natural shape and function

Inspiration	Application	Product/Company
Lotus leaf	Non-toxic textile coatings to repel stains; Paint that allows surfaces to self-clean with rain	Greenshield – G3 Technology Innovations Lotusan – StoCoat
Sea fans and tuna tail fins	Flexible wave and tidal power generation	BioWave & BioStream – BioPower Systems
Humpback whale fins	Efficient wind turbine blades and propellers	Tubercle Technology – WhalePower
Termite mound	Low/zero energy natural ventilation and temperature regulation	Eastgate Centre (Harare, Zimbabwe) – Arup
Kingfisher beak	Increased aerodynamics and energy efficiency, and reduced noise when entering and exiting tunnels	Shinkansen Bullet Train – West Japan Railway Company
Box fish	Optimized aerodynamics to interior volume ratio	“Bionic” concept car – Mercedes-Benz
Namib Desert Beetle	Water-harvesting materials and surfaces; Low-energy dehumidification	In R&D
Gecko feet	Non-toxic dry adhesives	In R&D

Process

Mimicking how a task is performed or a material is made

Inspiration	Application	Product/Company
Natural logarithmic spirals; Evolution via natural selection	Drag- and noise-reducing fans (to move air) and impellers (to mix liquids) designed using CFD and advanced 3D prototyping to test iterative designs against one another	PaxFan – Pax Scientific Lily Impeller – Pax Water Technologies
Human lungs	Enzyme-based capture of CO ₂ from flue gas and other emissions streams	CO ₂ Solutions
Growth of bones and trees	Structure optimization using software to model where material should be added or subtracted to optimize strength, weight, and use of materials	“Soft-kill option” software – Claus Matteck “Bionic” concept car – Mercedes-Benz
Spider silk	Manufacturing high-strength, durable fibers without heat or toxins	In R&D
Abalone shell / nacre	High-strength ceramics that resist cracking, self-assemble at ambient temperatures and pressures	In R&D
Blue mussels	Non-toxic adhesives that can set underwater	In R&D

System

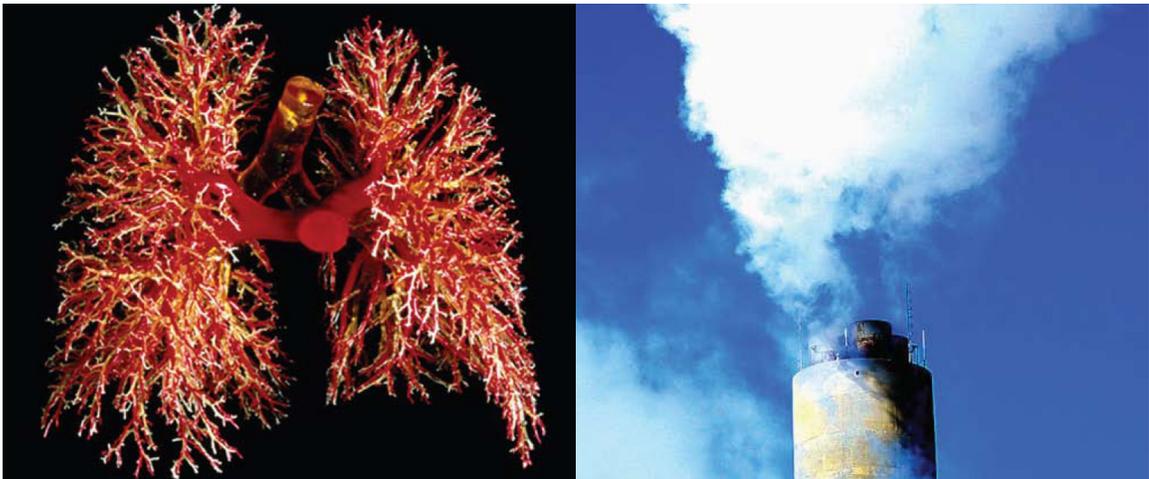
Applying the synergies and sustainability of ecosystems to larger systems and economies

Inspiration	Application	Product/Company
Aquatic ecosystems' ability to remove excess nutrients	Low-energy biological wastewater treatment that is modular and scalable	Eco-Machine – Todd Ecological Design
Nutrient cycling	Sustainable product lifecycles, designing for disassembly into biological and technical nutrients	Cradle-to-Cradle Certification – McDonough Braungart Design Chemistry
Prairie ecosystem	Deep-rooted perennial agriculture that can produce high yields of grain and maintain or improve water and soil resources upon which future agriculture depends	Undergoing modeling by the Land Institute



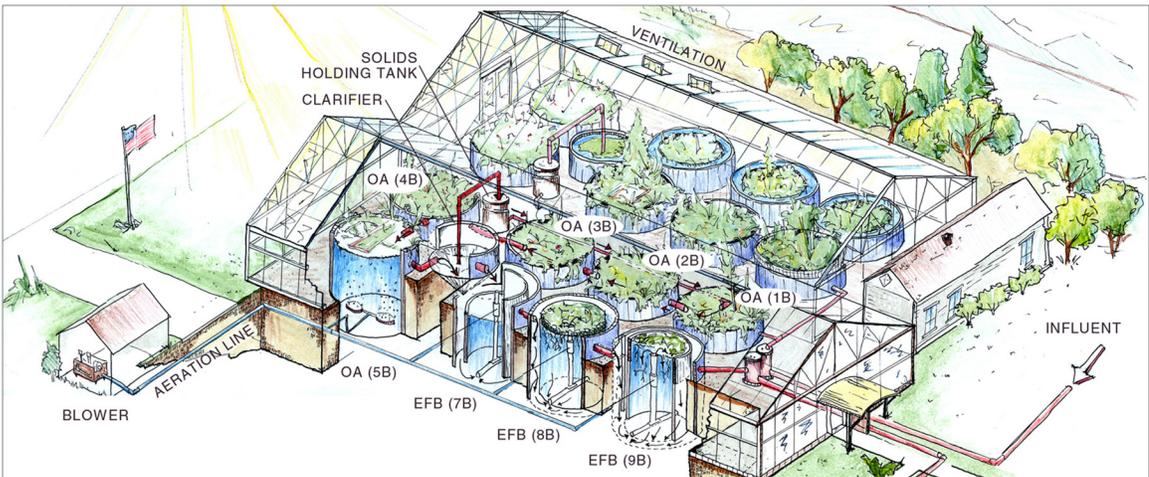
Coatings such as Greenshield and Lotusan mimic the surface structure of plant leaves to repel water, stains, and dirt without using toxic chemicals.

Photo courtesy of the Biomimicry Guild



CO₂ Solutions and Carbozyme are developing processes to capture carbon from smokestacks and other gas streams by mimicking the enzymes that transfer CO₂ between the lungs and blood of mammals.

Photo courtesy of National Geographic



The Eco-Machine by Todd Ecological Design achieves low-energy wastewater treatment inspired by aquatic ecosystems' ability to remove excess nutrients.

Image courtesy of Todd Ecological Design

Historically, humanity has considered nature as a resource to be mined rather than a mentor from which to learn, sometimes resulting in harmful consequences for all. We have not always understood how natural systems work, and proper application of biomimicry requires a deep understanding of how living systems function in an environment. Nature designs in parallel by simultaneously competing iterations against one another and allowing the best design features for a given environment to emerge as dominant. Nature's mechanisms do not seek global optimization from the start, but instead randomly make iterations that are adaptations to local environmental characteristics. Most importantly, biomimetic designers must understand that these designs and iterative improvements are intensely context specific and what is successful in one location or ecosystem may not be a good strategy for another.

As NYSERDA's mission is to improve energy and environmental performance in New York State (NYS), it will logically focus on energy solutions when supporting biomimicry resources and the research and development of biomimetic technologies; this includes developing products, manufacturing processes, and facilities that are energy efficient. For this reason, when determining target industry sectors or evaluating funding proposals for biomimicry programs it may be particularly useful for NYSERDA to consider how nature manages its energy budget. For example, nature uses symbiotic relationships, complementary systems, and efficiency to optimize the use of resources. An additional resource for identifying target sectors for initial funding could be the list of nature's design strengths compiled by Steve Vogel at Duke University:

What Nature Does Well	What Engineers Do Well
Making load-tuned composites with directionally-dependent properties	Manufacturing using metal
Making and using complex materials that have both viscous and elastic properties	Wheels and axles
Integrating material and structure	Ropes and twisted fibers
Making and using complexly non-rigid structures	Woven fabrics
Complex surfaces (self-cleaning, dry adhesive, etc.)	Displacement hulls
Tensile joinery	Lighter-than-air vehicles
Efficient utilization of solar energy	Transmission of electricity
Nutrient cycling	Casting
Filtration and particle/molecule capture	
Designs responsive on multiple time scales	
Motility with coordinated mini-motors	
Oscillating hydrofoils	
Legged locomotion	

This list could potentially be used to identify suitable manufacturing sectors or supply chains and connect them with types of biomimetic technology likely to benefit them.

Biomimicry is also a lens through which scientists, designers, and manufacturers can reexamine their work. It is a toolbox for identifying and solving problems in areas such as energy performance, efficient use of water, toxin reduction, or waste elimination. In addition, biomimicry brings biology, chemistry, and physics together for an interdisciplinary approach to real-world problems, just as they are inseparable in nature. Innovative solutions develop more easily with cooperation among these fields, and innovations such as these are critical for the long-term energy performance of New York State.

Strategic Roadmap for NYSERDA

“NYSERDA provides the support these innovators need to instigate their ideas.”
– Dr. Joe Bringley, G3 Technology Innovations

Introduction

Improving energy performance in New York State will require NYSERDA to go beyond funding key technologies to deeply influence the mindset of design. Part of the value of biomimicry is that natural features resonate with people, which is essential because energy technology solutions must address both design and the behavior of the end user. However, drawing the right inspirations from nature will require potential biomimics to ask the right design questions, and developing this skill may require funding, time, expertise, networking, and consultation. Designers and engineers need to understand how living systems function, and biological science must be integrated into applied science to make biomimicry a readily accessible tool. In order to achieve this, NYSERDA understands that NYS programs should support a deeper understanding of the science behind biomimicry to ensure that design decisions remain practical and high in quality. In addition, getting ideas implemented and achieving statewide performance results requires making clear to manufacturers the energy and cost benefits of biomimetic innovations, emphasizing whole system design for energy efficiency while stressing low first costs.

To this end, NYSERDA sponsored a Biomimicry Scoping Session, facilitated by Terrapin Bright Green, bringing together NYS stakeholders from the fields of science, industry, government, and advocacy. The goals of this workshop were to:

- Educate these stakeholders about biomimicry
- Gather a diversity of ideas for NYSERDA programs utilizing biomimicry to generate innovation and energy efficiency in NYS, and to generate interest in this effort
- Form specific strategies and steps NYSERDA could take
- Frame a preliminary timeline for these actions

This Strategic Roadmap is a result of the discussions during the Scoping Session, follow-up interviews with key participants, and recommendations collected and synthesized by Terrapin Bright Green. We have structured the Roadmap into a timeline of near-term, mid-term, and long-term recommendations, as well as provided our over-arching general recommendations and observations.

General Recommendations

Clearly define biomimicry

For the purposes of refining its programs, NYSERDA must clearly define what it means by biomimicry, and what types of technologies or processes qualify under this definition. The definition should be included in any relevant program solicitation, because a strong definition is necessary to ensure that proposals are clear, of high quality, and viable. Additionally, solicitations should include examples of biomimetic products or processes to further clarify the definition.

NYSERDA's definition must provide a clear direction in order to be inclusive of the best ideas without confusing the applicant pool. The definition should avoid broad terms that cannot be quantified, such as “bio-inspired”. Also, any Program Opportunity Notices (PONs) that include biomimicry should have clear requirements for citations of the relevant concept from biology, chemistry, or physics and for demonstrating how the science behind the technology was garnered from the natural inspiration.

In addition, grantees should describe in clear, quantifiable terms how their work would yield results toward the end goals of improved energy performance and a safer environment. When responses do not fit NYSERDA's biomimicry definition closely enough, we recommend referring them to NYSERDA's other, more relevant programs rather than risk excluding potentially good ideas.

NYSERDA's definition can also be a working one that develops in parallel with the programs it affects, but at a minimum the definition must focus on energy improvements due to NYSERDA's stated mission. With these considerations in mind we suggest the following definition be used as a starting point for NYSERDA:

Any material, technology, or process that is demonstrably inspired by at least one natural form, process, or ecosystem and has potential to quantifiably improve energy performance in New York State, as well as at least one of the following benefits: greatly reduced or eliminated use of petrochemicals and toxins; efficient use of resources including water and materials; greatly reduced or eliminated emission of greenhouse gases; reduction of waste streams via increased efficiency or the recycling of technical or biological nutrients; and/or a material contribution to economic development.

Applicants must clearly demonstrate the biomimetic relationship in their proposal and provide appropriate reference material. NYSERDA should be prepared to refine this definition as needed on a periodic basis to maximize its impact in developing a green industrial base and energy sector that is safe for workers, the public, and the environment, as well as healthy for the economy of New York State.

Educate NYSERDA staff about biomimicry and integrate these concepts across all programs

As part of a broad approach to adopting biomimicry, NYSERDA should launch efforts to educate its staff about the principles of biomimicry and integrate these concepts into all of NYSERDA's programs. A potential education effort may take the form of a "Train the Trainer" program, where NYSERDA representatives are sent to existing educational programs, such as the Biologists at the Design Table or Biomimicry & Design Workshops offered by the Biomimicry Institute and Guild, and return equipped to instruct others. Alternatively, NYSERDA could propose a relationship with these organizations to begin a New York-based version of these workshops, which might later become an educational tool NYSERDA could continue on its own and tailor for particular industry sectors. Another option may be to encourage staff to participate in the Biomimicry Institute's new Two-Year Certificate Program in Biomimicry, a mostly remote education program with occasional on-location workshops with the Institute. At their most basic level, all of these programs should focus on the biomimetic process – teaching methods of accessing information and inspiration from nature, as well as fundamentals of whole-system thinking, energy efficiency, and understanding the natural world.

While the principles of biomimicry can be applied to all forms of innovation, even a broad effort to integrate biomimicry across NYSERDA's programs needs to focus on the areas with the highest rate of return for NYSERDA. This effort should include creating an entirely new biomimicry-focused funding program for each targeted industry sector, as well as incorporating a biomimicry component into existing solicitations. This may include refining how solicitations for proposals are structured and evaluated. Beyond a clear definition of biomimicry, the solicitations for proposals should be designed to attract the highest quality pool of applicants so that NYSERDA can select the best and most beneficial projects to fund. To this end, NYSERDA's evaluation of proposals should in some way incentivize biomimicry, including considering biomimicry during the evaluation of applications. As part of this effort, consider expanding NYSERDA's support for potential applicants by providing access to one-on-one meetings with NYSERDA staff who understand the application process and what the selection committees are seeking.

Focus on projects with strong commercialization potential

Regardless of the definition of biomimicry NYSERDA chooses to use, the goal is to develop products and/or processes that can be brought to market and yield measurable energy benefits for NYS. To be viable, when compared to existing products these new technology solutions should have equivalent or superior performance, be equivalent or lower in cost, and demonstrate a measurable reduction in environmental footprint. To this end, the solicitations and review process should be structured so as to encourage proposals with strong commercialization possibilities over potentially esoteric research projects that may not yield significant products. In other words, in addition to supporting the study of new ideas with large potential, NYSERDA should evaluate funding based on projects' potential to deliver innovation.

This might involve basing a portion of the solicitation response's evaluation on how clear the commercialization path is, adding weight to submissions that include letters of interest from corporations already familiar with the product and its potential, or increasing the relative funding for projects that obtain a certain amount of third-party funding. Lastly, NYSERDA could incentivize well thought out implementation plans using a tiered recoupment strategy based on the level of NYSERDA product development support provided and how quickly the technology can be commercialized. For example, if an energy-saving product can be launched in 2 years, NYSERDA would recoup less than if it takes 5 years.

A potential model for including commercialization plan requirements for submissions is the Department of Commerce National Institute of Standards and Technology's (NIST) Technology Innovation Program (TIP). Under the TIP program, licensees are required to provide a detailed proposed research plan that is scientifically sound, and includes tasks, milestones, timeline, decision points, and alternate strategies. Potential licensees must also submit a plan for actively developing and commercializing the technology. NIST uses this plan to establish certain technical and commercial milestones in the license agreement which the licensee must meet in order to retain the license. TIP will fund no more than 50 percent of total project costs, and the rest must come from cost-sharing with private sources. Additionally, TIP funds may be used only for so-called direct costs, not indirect costs (such as overhead), profits or management fees.

Resource: NIST's Technology Innovation Program, www.nist.gov/tip/

Design effective funding programs

Targeted research, development, diffusion, and transfer of technologies will require funding programs that are designed to be effective both in terms of funding amount and duration. While the pool of funds available for a biomimicry program may be inflexible, how it is distributed and applied affects the project outcomes. The workshop participants suggested that \$50,000 per year is the smallest useful seed money for a research institution project. They also suggested that funding be allocated differently for basic research than for applied design, because these may require vastly different funding amounts to achieve NYSERDA's desired results. Initial NYSERDA funding to prove the commercial potential of a biomimetic idea is critical since most venture capital is not accessible at this early stage.

The duration of funding can be almost as important as its magnitude. Therefore NYSERDA should endeavor to get submissions reviewed and evaluated quickly and to sustain funding for as long as a project's viability or commercialization is on target and on schedule. An added benefit of sustained dedication to biomimicry projects is that the potential pool of new applicants will become more likely to educate themselves on the topic and seek out new biomimetic ideas for future submissions, thereby increasing the strength and quality of the State's biomimicry network.

Facilitate collaboration

Both in the near- and long-term, NYSERDA has the opportunity to encourage and support cooperation among different segments of the potential NYS biomimicry network. This includes facilitating collaboration between industry sectors, individual manufacturers or businesses, universities, and research laboratories. Beyond funding and coordination, there are benefits and challenges to these collaborations that NYSERDA can make clear and demonstrable. For example, smart companies should consider the dual benefits of collaborating with research institutions to develop biomimetic technology. While the resulting technology is the main product of such collaborations, another deliverable is the human capital, since research and development allows both entities to properly train and retain the next generation of student or employee. A metric of success for each collaboration may not be royalty transfer but rather job creation and how quickly the technology solution can be implemented in the real world.

Acting as a third-party supporter of biomimetic innovation NYSERDA, acting alone or in conjunction with NYSTAR, could use its influence to reshape stakeholder expectations with regard to timeframes for implementation. For example, interdisciplinary cooperation may require finding a middle ground between the traditionally longer university and research laboratory timeframes and the much shorter timeframes expected by the business community.

Another consideration for all collaborations is the delicate issue of intellectual property (IP). Fights over IP issues pose a serious challenge to long-term collaboration, and these issues become especially important when multiple companies partner together on R&D. All parties must have a clear agreement on IP issues in order to ensure success.

Connect to outside support or other networks

To encourage more applicants for its programs, NYSERDA could interface with third-party facilitators such as NYIRN, ITAC, or other NYSTAR centers, who could help educate manufacturers on biomimicry's potential. Increasing the pool of quality applicants will be of growing importance because even with innovative ideas, sometimes a critical mass of interested stakeholders is needed to create conditions allowing for market entry. NYSERDA could also collaborate with these organizations to develop specific green technology targets, especially when selecting projects for feasibility studies. Working with NYSTAR, NYSERDA could also assist promising projects in finding additional financing from third-party funders, eco-conscious investors, and venture capital. Lastly, it may also be possible for this network to connect potential projects to other outside resources such as Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) opportunities.

Resources: SBIR and STTR, www.sbir.gov
www.sba.gov/aboutsba/sbaprograms/sbir/index.html

Near-Term Recommendations (0 – 2 Years)

Sponsor issue-focused biomimicry retreats

To jump-start activity in the field of biomimicry, NYSERDA should develop a series of workshops focused on particular energy or environmental issues. These workshops would bring together biomimicry experts with researchers and manufacturers familiar with the issues, and would provide stakeholders access to knowledge and a forum for disseminating it, as well as discovering potential collaborations. Focused workshop topics might also make it easier to attract experts and keynote speakers. These multi-day workshops would include an introduction to biomimicry and the biomimetic process, detailed presentations of case studies that address the topic, and brainstorming potential solutions to the issue.

NYSERDA should select participants based on their areas of expertise, access to resources for developing ideas further, and track record for success. These retreats should be structured to yield proposals from participants for feasibility studies and generate future PONs focused on biomimicry. The workshops will also serve to sow larger discussion of biomimicry and develop a community among NYS stakeholders. When NYSERDA identifies relevant problems in targeted industry sectors, these issues should be matched with scientists who can brainstorm with manufacturers to generate inspired solutions.

While these workshops might be more effective if focused on particular issues, NYSERDA must determine how broad or specific they should be. Potential workshop topics include:

Industry Issue	Biological Issue
Energy Performance	
Low energy dehumidification	Collecting moisture from the air
Advanced HVAC systems	Modulating temperature
High-performance insulation	Reducing thermal conductivity
Low energy filtration	Removing particulates (food, dirt) from a medium (water/air)
Energy efficient light sources	Bioluminescence
Energy efficient water and wastewater treatment solutions	Removing organic nutrients, nutrient cycles
Environmental Health	
Identifying and replacing toxins in products and processes	Using local materials at ambient conditions
Surface modification without toxins	Surface protection, sealing surfaces from decay
Benign coatings and adhesives / naturally adhesive surfaces	Adhesion
Safe metal finishes	Oxidation resistance
Reducing resource consumption / generation of waste	Closed loop nutrient cycles

Additional resources for topics could include the NYS Pollution Prevention Institute's (P2I) ranking of NYS sectors on the basis of environmental problems, emissions, employment, number of establishments, value added, etc. Their findings indicate that improvements to the manufacturing of fabricated metal products, computer and electronic products, and chemicals may yield the best environmental and economic performance results. Topic lists for scientific conferences such as Gordon Research Conferences (GRC) and those held by the Materials Research Society (MRS) may inspire other biomimicry workshop topics. Additionally, energy problems identified through NYSERDA's many PONs may suggest issues that could benefit from analysis under a biomimicry lens.

Resources: NYS P2I Industry Sector Prioritization Information for R&D Projects,
www.nysp2i.rit.edu/r_and_d.html

Gordon Research Conferences, www.grc.org

Materials Research Society, www.mrs.org

Incentivize biomimetic innovations

Solicitations for proposals should be designed to attract the highest quality pool of applicants, and incentivize proposals that incorporate biomimicry. This may include creating an entirely new biomimicry-focused funding program for each targeted industry sector, as well as integrating a biomimicry component into the evaluation of its existing R&D PONs and the Industrial Process and Product Innovation (IPPI) program. For example, NYSERDA could determine a percentage of the evaluation score based on how biomimetic the innovation is, add bonus points for high-potential biomimicry proposals, or accelerate the review process for proposals with promising biomimicry components. Such a system may help avoid poorly targeted biomimicry proposals, and would of course require a clear definition of biomimicry for the purposes of evaluating and comparing proposals. To help ensure the selection of the highest quality and most viable submissions, consider forming selection committees that include biomimicry experts or, at a minimum, NYSERDA staff trained in biomimicry.

By integrating these incentives directly into PONs, NYSERDA may facilitate the education of the larger applicant community and potentially spur interest in biomimicry education programs, as well as in the PONs themselves. Using the PON process as an incentive may also allow NYSERDA to begin conversations with manufacturers earlier in the development of a product, thereby potentially increasing the likelihood of commercialization. As part of the transparency of such a program, NYSERDA should encourage full disclosure and communication about the safety profiles and environmental performance of any products that result from the program.

Support feasibility studies

An immediate opportunity for investing strategically in the development of biomimetic technologies is to fund feasibility studies for new innovations. NYSERDA may even be able to assist with energy modeling and product prototyping to demonstrate the performance and competitiveness of specific products or processes, bolstering their credibility by directly helping to demonstrate the energy savings offered by new technologies. We recommend a funding program for feasibility studies with both of the following objectives:

- Integrating existing biomimetic technologies (e.g. the PAX fan, Eco-Machines, Carbozyme filters, Qualcomm Mirasol display technology, etc.) into existing NYS facilities
- Developing new and innovative biomimetic technologies, projects, and processes

These would be small exploratory projects that could then phase into larger projects. These studies may require connecting companies and academic institutions to allow companies access to the testing equipment necessary for their ideas to move forward. Feasibility studies are also an early, easy step that may circumvent the aversion some stakeholders have to financial risk and changes to the status quo.

Sponsor collaborative design competitions

In collaboration with universities and advisory groups such as ITAC and NYIRN, NYSERDA could sponsor design competitions for innovative products. By supporting interdisciplinary cooperation, these competitions could serve as tools to educate the public about biomimicry, identify emerging talent, generate interest in NYSERDA programs, and perhaps even lead to products that could be implemented in NYS to yield energy and environmental performance results.

Educate NYS stakeholders on the value and potential of biomimicry

To encourage interest in a program supporting biomimicry, NYSERDA should promote or develop educational programs about biomimicry. These programs should be designed to reach the following audiences:

- Scientific community
- Manufacturers
- Policy advocates
- Venture capital fund managers

This effort may model itself on existing educational programs, such as the Biologists at the Design Table, Biomimicry & Design Workshops, and Two-Year Certificate Program in Biomimicry offered by the Biomimicry Institute and Guild. Alternatively, NYSERDA could propose a relationship with these organizations to begin a New York-based version of these workshops, which could later be replicated by NYSERDA. NYSERDA could also engage biologists and other biomimetic thinkers to support the education of community leaders through workshops and other programs. These programs must focus on teaching stakeholders to think biomimetically, including lessons about methods of accessing information and inspiration from nature, understanding the natural world, energy efficiency, and whole-system thinking. Additionally, NYSERDA should educate venture capital fund managers and other entrepreneurs about how biomimicry can increase a technology's likelihood of success, accelerate the path to success, and provide a compelling marketing story.

To market an educational program such as this to NYS stakeholders, NYSERDA employees should attend or present at conferences with technology startups such as the Cornell University Center for Materials Research Symposium, Clarkson University Center for Advanced Materials Processing Symposium, and the University of Albany's College of Nanoscale Science and Engineering conferences. NYSERDA could also target established State-based technology companies such as GE, Kodak, Xerox, and Bausch & Lomb. Lastly, since young people are vectors for ideas and innovations, NYSERDA should consider providing programs or funding in support of university education focused on biomimicry, such as curricula in green chemistry and bio-inspired design, or subsidizing cross-disciplinary student intern research projects in these fields.

Within these educational programs, NYSERDA should present or provide access to clear success stories of how its programs have helped improve energy efficiency and bring innovative technologies to market. NYSERDA should also include case studies of biomimetic solutions and technologies that have resulted in measurable improvements in energy or environmental performance, with the goal of clearly defining biomimicry and presenting a variety of examples to benefit different audiences and address their different needs. Similarly, when selecting case studies NYSERDA should try to identify the "eureka" moments that seem to make the field of biomimicry so compelling.

The goal of these case studies is to enable stakeholders to speak the same language, whether their backgrounds are in science, industry, business, or government. The case study approach will be important for building credibility and interest in biomimicry, while simultaneously teaching participants how to think biomimetically. In addition to educating individuals about the principles and concepts of biomimicry, these programs will serve to excite stakeholders about the opportunities, facilitate a multidisciplinary approach to solving problems, and teach the process of letting nature be the mentor for innovation. NYSERDA's educational support will help train observant minds that can study natural systems and identify innovative solutions.

Inventory the State's biomimicry resources and develop interactive online databases

Since a goal of NYSERDA's biomimicry program should be to support existing efforts and encourage new collaboration between industry and research agencies, it is critical to fully inventory the academic and research assets of the State that currently support or could support biomimetic technology development. Those organizations with experience in the field, such as Brookhaven National Labs and others, represent untapped sources of information that could help inform a statewide effort and that could be made available for public access. As part of this inventory, NYSERDA should investigate whether or how biomimicry has been incorporated into other programs at various scales, such as by the New York Academy of Sciences or the National Science Foundation.

Fully informing and engaging potential stakeholders in NYS-based biomimicry programs will require easy access to knowledge for all. To this end, NYSERDA should consider developing a central clearinghouse of data on biomimicry, including case studies of precedent innovations, existing research areas and programs, and other State resources identified in the inventory discussed above. This clearinghouse should be web-based and user-friendly, and could even link to or interact with broader resources such as the Biomimicry Institute's Design Portal, Nature's 100 Best, and the Encyclopedia of Life. This online resource will allow development and evolution of information over time, help ensure wider effectiveness of the biomimicry education program, and quickly guide stakeholders to experts with experience relevant to their specific design problem. It also has the potential to facilitate matching of local problems to local solutions, allowing the industries themselves to communicate what R&D they feel is most needed to improve their processes and energy efficiency. Finally, such a resource could help lay the foundation for a stronger NYSERDA program by collecting expertise in one central location.

Resources: Biomimicry Design Portal, www.asknature.org

Nature's 100 Best, www.n100best.org

Encyclopedia of Life, www.eol.org



The Biomimicry Scoping Session brought together scientists, manufacturers, policy advocates, and NYSERDA staff to learn about biomimicry and brainstorm about how it could be integrated into NYSERDA's programs.

Photo by Jason King

Mid-Term Recommendations (2 – 5 Years)

Support deployment and marketing

Since NYSERDA's goal is for innovation in biomimetic design to yield energy performance benefits to New York State, its programs should support deployment of products and enhance their marketability. In business, even great technological innovation will not succeed without quality marketing. Luckily biomimicry itself is a very attractive concept and often involves a great story that opens the door to consumers. In the end, of course, products need to compete well with conventional products in terms of performance and cost.

NYSERDA's educational programs may inherently boost the marketability of these products by developing a more informed marketplace. NYSERDA could also assist small suppliers with finding their market within the larger supply chain and help to level the playing field with large competitors. Additionally, designers and consumers tend to drive the development of greener products more than manufacturers. If the demand for green, biomimetic products is high enough, manufacturers will meet that demand. It is therefore possible that NYSERDA could help biomimicry entrepreneurs overcome "first cost" concerns by using education and marketing assistance to grow demand.

Providing support for technology deployment could have the added benefit of giving NYSERDA some oversight into how technologies are distributed and installed. Maximizing energy efficiency usually requires viewing whole systems rather than individual components, and providing some guidance over product deployment will allow NYSERDA to ensure proper installation and optimal efficacy of new technologies.

One approach to deployment may be to create a key deployment location for a technology, and bring together similar industries to observe demonstration programs using that product. By demonstrating biomimetic innovations under controlled conditions, NYSERDA may allow industries to share results and case studies without divulging proprietary secrets, increasing the awareness of products and potentially increasing the rate of uptake into the market. Additionally, NYSERDA could help pair promising technologies with venture capitalists, who are uniquely able to dramatically affect how long it takes to implement an innovation. As part of this process, grantees may need to demonstrate to venture capitalists that they are invested in their own idea and not just passively chasing after funding without a clear path to implementation. Perhaps as part of the selection process, NYSERDA should verify that potential grantees' implementation teams have the appropriate skill sets to bring their idea to market, a plan to hire third-party marketing skill sets, or some other way to prove to venture capital providers that their technology is ready for backing. Such a program would be similar to NYSTAR's work incubating applicants so they can compete for venture capital or other private funding sources.

Assemble a think tank and establish a dedicated center for biomimicry

As projects are underway, there may be a benefit to encouraging interaction among the different involved parties. For example, NYSERDA could require annual meetings between all participants in its biomimicry program so that they can network and share ideas and progress without surrendering their individual project secrets. Such meetings could also allow NYSERDA to document the process and use its own program to create new biomimicry case studies in real time.

A further opportunity may include bringing together non-competing companies to form a statewide think tank that can generate ideas, fund strategies, and help offset the first costs of developing biomimicry products or initiatives. This approach might involve regular meetings of a core group of stakeholders, who may collaborate more effectively over time as they gain experience working together and with the application of biomimicry. Additionally NYSERDA, in collaboration with NYSTAR, should explore creating a dedicated center or department to promote biomimicry and to coordinate and manage the State's biomimicry programs.

Expand education programs

As industry sectors and companies gain experience with biomimicry, NYSERDA should continue to facilitate interaction between the research and industrial arenas through focused conferences, retreats, and presentation panels. Consider hosting statewide biomimicry mini-conferences where companies or individuals can learn from companies who are designing and deploying biomimetic products. An early focus for such conferences would be teaching engineers and scientists the skills they need to decipher nature's lessons and extract usable knowledge from biological examples. An ongoing result of these conferences could be cross-trade internships that serve to facilitate collaborations and disseminate knowledge and skill sets between industries and fields, or support for biologists in applied science positions.

Evaluate and update biomimicry inventory and online resources

To provide up-to-date information about NYS resources and ongoing support for biomimicry, NYSERDA must periodically repeat its statewide inventory and ensure its online data clearinghouse is current. Encouraging biomimicry and achieving significant energy and environmental performance benefits to NYS in the mid- and long-term will require building on the successes of near-term efforts and making case studies and performance data available to all stakeholders.



The workshop featured Dr. Joe Bringley of G3 Technology Innovations and Dr. Peter Fiske of PAX Scientific, who presented on their respective experiences developing biomimetic products.

Photo by Erika Hanson

Long-Term Recommendations (5+ Years)

Improve the performance of buildings and manufacturing facilities

If NYSERDA's program continues to grow, it may become possible to explore how biomimicry can improve the energy performance of manufacturing facilities. This may be achieved through installing biomimetic materials and products into building systems. A more complex solution would involve developing unique biomimetic solutions for specific conditions, and could even lead to a new product for the building market.

Investigate ways to integrate industrial ecology

To identify further ways to improve the energy and environmental performance of infrastructure and industry, NYSERDA should explore integrating principles of "industrial ecology" into NYS operations. Drawing on thermodynamics, systems theory, and ecology, industrial ecology is an approach to modeling the efficient, symbiotic relationships found in nature. Industrial ecology engages traditionally separate industries in a collective approach involving physical exchange of materials, energy, water, heat, and/or byproducts. For example, when planned in clusters of complementary development, the byproducts of one industry can be used as raw materials for another, eliminating waste and dramatically reducing resource consumption. Industries can also share utilities and other services to reduce costs. When developed as an integrated, symbiotic industrial ecosystem, these components can strengthen one another while increasing productivity, reducing costs, and improving the sustainability of the whole.

Industrial ecology can be applied to several small manufacturers and scaled up to industrial parks and co-generation models. This model can result in 'closed-loop' manufacturing systems while minimizing costs, driving innovation and helping companies stay ahead of the growing demand for socially and ecologically responsible practices. These factors can result in significant competitive advantage for NYS. Consider launching feasibility studies in conjunction with the NYS economic development program to identify high-potential linkages between industries and develop an implementation plan to harness these efficiencies. Such a plan should include industrial ecology education programs for the target engineers, operators, and managers of existing and developing facilities.

Encourage innovative education

As part of an ongoing educational program, NYSERDA should continue encouraging youth education programs about biomimicry. Consider supporting courses or internships in biomimicry for the K-12 audience, as well as developing interactive online educational games or websites. Such user-friendly tools will help nurture the next generation of biomimicry scientists and professionals.

In addition, NYSERDA should continue to break down the barriers between disciplines through its ongoing academic and professional education programs. These programs should include not only building interest in the field, but also focus on developing the skills necessary to implement biomimicry and support the creation of skilled jobs in NYS. A potential strategy for skill building may be to encourage and promote the development of interdisciplinary university courses in biology, engineering, and design. These courses should focus on teaching biomimicry-related skills such as how to observe nature and distill design solutions via critical thinking, systems-level engineering and ecology, energy modeling and optimization, 3D prototyping, green chemistry and nanotechnology, and educational strategies. Another effort may be to work with State trade associations to encourage sector-based trade school education programs that include biomimicry and whole-system design. In the long-term, skills and jobs may develop naturally as funding encourages biomimicry enterprises, but NYS should continue existing incentives that aim to keep jobs within the State in order to achieve lasting results.

Expand support programs

By funding key technologies, NYSERDA may eventually be able to influence the entire mindset of design in NYS. With supporting programs designed to promote biomimicry on an industry-wide basis, NYSERDA will encourage a self-reinforcing network and community that could help make NYS the heart of biomimetic research in the US. In the long-term, NYSERDA should strive to strengthen the relationship between science and business in an effort to shorten the time between innovative ideas and implementation. One method may be to educate companies about, and encourage them to use, a computer-aided iterative design process that filters for the best design elements over generations of product testing, similar to biological evolution via natural selection. NYSERDA could also organize biomimicry trade shows and conferences for specific target industries. Another strategy could be to create a biomimicry funding bank or consortium of funding. This may allow NYSERDA to address a broader definition of biomimicry, since developing holistic solutions to the State's energy problems may be difficult for any single agency of authority.

Explore creating a certification program for biomimetic technology

NYSERDA may wish to explore a certification or label to designate any biomimetic technology or process that emerges from its supportive R&D programs. Such a labeling system would both establish the quality of these technologies as well as distinguish them from non-biomimetic products. However, if NYSERDA does create an official label for these biomimicry programs, it will be imperative that the standards established for these labeled products be quantified as much as possible to grant the maximum amount of transparency and validity to the certification.

Broaden focus beyond traditional energy efficiency fields

While manufacturing facilities are major energy consumers, NYSERDA seeks to address all types of energy consumption in the State and therefore should support projects that extend beyond traditional energy efficiency measures. As the State's biomimicry resources grow, and NYSERDA's experience with administering biomimicry programs is refined, consider expanding to other energy intensive fields and sectors beyond manufacturing. Some potential additional focus areas for NYSERDA could include energy infrastructure, transportation infrastructure, and waste stream issues. Biomimetic improvements to infrastructure may have energy benefits related to energy generation, transmission, and the use of buildings, equipment, and transit. There may also be opportunities to encourage efficient and environmentally responsible agricultural production systems. Additionally, there is an energy implication for evaluating and optimizing waste and waste reuse streams, including supporting the development of zero-waste products. NYSERDA could support the expansion of its own program or similar programs to address waste issues such as by increasing production yield and reducing breakage waste during manufacturing, increasing product quality, and enhancing recyclability of products by designing them to be disassembled into recyclable components. NYSERDA could also encourage end-of-life product recycling by facilitating the creation of more recycling locations, sponsoring marketing campaigns for drop-off recycling, encouraging manufacturer take-back programs, and by endeavoring to shift wasteful consumer behavior and mindsets.

Challenges to Implementation

As with any shift in mindset, adopting biomimicry as an integrated component of NYSERDA's programs will have its challenges. The first involves clearly communicating the definition and goals of the programs. A clear definition will result in high-quality proposals, which will help to legitimize the overall effort.

Once the programs have been initiated, the next challenge will be overcoming the institutional inertia of NYS stakeholders. It will take time and education for manufacturers and scientists to understand how to take advantage of biomimetic opportunities in their work. As part of this process, scientists with an understanding of biomimicry need to be introduced to the applied science and manufacturing community and act as resources for inspiration and design. This further underscores the need for education within the State to ensure long-term success of the program.

Another set of challenges lies in the differences between the scientific research and manufacturing sectors. There will be different budget constraints, development processes, deployment timelines, and expectations of returns on investment. Aside from complicating collaborative relationships between diverse parties, these obstacles may make it difficult to keep on schedule. As with any collaboration, intellectual property (IP) issues between institutions and industry pose many challenges. Universities have different interests, operational frameworks, and goals than companies, including an end goal of writing papers and disclosing information. Industries are naturally more protective of IP and desire to keep sensitive information proprietary. These IP challenges must be considered before undertaking any potential collaboration between academia and industry. Potential solutions to these issues may include providing other benefits to academic institutions in exchange for research assistance in lieu of publishing rights, such as grants.

The final challenge will be maintaining the success of the program throughout NYS. NYSERDA must use its resources such that the viability of innovations becomes self-evident, such as via technical demonstrations. This should be part of a systemized approach to biomimicry that will allow industries large and small to learn about biomimicry, integrate it into their operations, and replicate the process on their own. Documenting a demonstration project from inspiration to product release can be a critical educational tool and can be disseminated quickly across the State. More importantly, both NYSERDA and the case study company would have learned from the process. The company could then repeat the process without NYSERDA, addressing its own challenges in the future. These cost sharing ventures can help to develop a more refined process that can be reapplied to specific problems. They can also result in products with great market potential, increased real-world relevance, accelerated implementation, and direct energy performance benefits.

Biomimicry has unlimited potential to advance NYS's manufacturing industries and to develop a unique State program that can set a national precedent. Developing a biomimicry-focused community of scientists, manufacturers, and advocates will give NYS a unique position in the world market as government and industry continue to move toward addressing energy use, climate change, and other pressing environmental and security issues.

“A program like this will get New York attention because it will be the first of its kind. I hope other states will be watching.”

– Dr. Peter Fiske, PAX Scientific