**MIDDLE SCHOOL**

**Math & Engineering**

***ME in Your Neighborhood* Introduction**

Beyond Benign is a non-profit organization working in green chemistry and sustainability through workforce development, trainings and curriculum development in academia, community outreach and K-12 education.

Beyond Benign’s *Green Math* program is designed to capture the imagination for math in all students. This unit is intended to demonstrate math in the world connections, facilitated by the concepts of sustainability and green chemistry. Through this unit, all students will see how math relates to their world. For teachers who are striving to facilitate STEM (Science, Technology, Engineering and Math), this unit brings together each of those variables.

With these materials, the goal is to increase awareness of sustainability issues in a non-biased way where data sets help students investigate the world around them. Students use math skills to solve problems, reach conclusions and come to new understandings; therefore answering the age old question, “Why do I have to know this?” and placing mathematics at the forefront of critical and innovative thinking.

**Acknowledgements**

Thanks to the curriculum development team for this project:

**Bill Van Loo**, Honey Creek Charter School, Ann Arbor, Michigan

**Tom Pachera**, Skyline High School, Ann Arbor, Michigan

**Matthew MacGregor**, Maple Lane Public School, London, Ontario

**Lisa Gunderman,** Fitch Middle School, Groton, Connecticut

**Brooke Carson,** Summit Middle School, Frisco, Colorado

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**The Twelve Principles of Green Chemistry**

John Warner and Paul Anastas have developed the Twelve Principles of Green Chemistry to aid in assessing how green a chemical, reaction or a process is.

1. It is better to prevent waste than to treat or clean up waste after it is formed.

2. Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.

3. Wherever practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment.

4. Chemical products should be designed to preserve efficacy of function while reducing toxicity.

5. The use of auxiliary substances (e.g. solvents, separation agents, etc.) should be made unnecessary whenever possible and, innocuous when used.

6. Energy requirements should be recognized for their environmental and economic impacts and should be minimized.  Synthetic methods should be conducted at ambient temperature and pressure.

7. A raw material feedstock should be renewable rather than depleting whenever technically and economically practical.

8. Unnecessary derivatization (blocking group protection/deprotection, temporary modification of physical/chemical processes) should be avoided whenever possible.

9. Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.

10. Chemical products should be designed so that at the end of their function they do not persist in the environment and break down into innocuous degradation products.

11. Analytical methodologies need to be further developed to allow for real-time in-process monitoring and control prior to the formation of hazardous substances.

12. Substances and the form of a substance used in a chemical process should be chosen so as to minimize the potential for chemical accidents, including releases, explosions, and fires.

Based on the 12 Principles of Green Chemistry, a similar set was developed for green engineering.**Implementation Options**

**This unit can be implemented in 2 primary ways:**

1. Stand alone unit
2. Year long project with embedded skills

**Stand alone unit:**

**As a stand alone unit, this curriculum can be used to introduce the skills of:**

* fraction
* decimal
* percent
* rounding
* measurement
* area
* estimation
* volume
* scale
* conversion

**Year-long project:**

This unit can be used to support the curriculum you are already teaching in the classroom. With the introduction of each skill, complete the corresponding lesson. Place the papers with the paperclip icon on top in a folder or binder to track student progress throughout the year. Some of the papers are necessary for students to refer back to. Ultimately, you will build a math portfolio for individual students, allowing you, the parents, and the students to track their progress and successes throughout the year.

**Create a Neighborhood to Evaluate Student Understanding**

This unit provides assessment opportunities throughout the course of the curriculum. As a final evaluation tool, you may want to consider building a neighborhood of houses. As each student builds his or her home to scale, he or she will need to apply computation and geometry skills garnered in the unit.

**House Model Building Options for Teachers**

**Things to be aware of:**

To use this method, you will need to source the materials. Cardboard for foundations can be gathered from recycling bins, and foamcore for walls can be ordered from art supply stores. There are several options for glue – Elmer's glue works well for attaching the floor plan to the cardboard foundation, rubber cement or hot glue work well for attaching walls. Razor knives and cutting mats may be available from your art teacher, or can be ordered from art supply/tech education supply catalogs. You will have to prep some material for student use, including cutting the larger foamcore boards into smaller pieces. You will need to plan on adequate space to store project as they are being built.

**Wafer Cookies**

Building with wafer cookies is an inexpensive, easy way to build the house model. Wafer cookies are used for the walls, and sugar icing is used as glue to attach walls to the foundation and to one another.

**Advantages**

Materials are cheap and easy to source (grocery store)

Material is easy to work with – no special tools required (plastic knives work just fine to cut cookies into necessary sizes)

Cookies have 1/4” increments already baked in

Kids can take models home when completed

**Disadvantages**

Materials are consumable – have to purchase for each time you run the project

Building process can be messy

Kids will eat building materials :)

**Things to be aware of:**

You will need to plan on adequate space to store project as they are being built.  Icing dries out if not stored properly between sessions

**Google SketchUp or equivalent CAD/3D modeling software**

Another possibility for creating house models is to use Google SketchUp, or an equivalent CAD/3D tool, to create 3D electronic models using the computer.

**Advantages**

No physical building materials required

Can easily be used to in an electronic portfolio

Google SketchUp is free and available for both PC & Mac

**Disadvantages**

Need consistent access to computers

Need to have software installed

Time to learn

Can be a great tie-in with technology

**Things to be aware of:**

Instructors will need to familiarize themselves with Google SketchUp in order to support students as they create their models. This could be run in conjunction with a technology class. May require support from instructional technology staff depending on the comfort level of the instructor(s). the program

**Snap Cubes**

Many math teachers have snap cubes (also called Unifix cubes) available as a manipulative. These can be used to quickly and easily build the house model, simply by snapping the cubes together to form walls.

**Advantages**

Can build quickly

Many classrooms already have available

Not a consumable – materials are reusable year-to-year

**Disadvantages**

Models are fragile

Kids can't take models home when completed

Not messy

**Things to be aware of:**

To use this method, you will need to have the necessary quantities of blocks available. You will need to plan on adequate space to store project as they are being built.

**Lego**

Lego bricks are another option for building house models. Students use Lego bricks to build the walls for their house, and build directly on top of their floor plan.

**Advantages**

Can build quickly

Many classrooms already have available

Not a consumable – reusable year to year

Not messy

Lego bricks have a built-in scale (using the dots that connect bricks together)

**Things to be aware of:**Need to have necessary quantities of blocks available. You will need to plan on adequate space to store project as they are being built.

**Staff**

**Matt MacGregor** has been teaching Middle School, in both Scotland and Canada, since 2003. He holds a Bachelor's Degree in Sociology from the University of Western Ontario and a Post Graduate Certificate in Education from the University of Edinburgh, Scotland. Matt has facilitated math learning conferences for existing teachers, has worked as a professional mentor in his district's 'New Teacher Induction Program' and has hosted a variety of student teachers as a recognized associate teacher in his district. In addition to being an active member in his district's Math and Science Task Force(s), which required him to write, implement and analyze new science and math curriculum. Matt was also a facilitator in Green Chemistry's first visit to Canada. Additionally, he facilitated the pilot Green Math workshop held in Mystic, CT in 2009. Although, he dearly misses his Bonnie Scotland, Matt is currently living in his hometown of London, Ontario, Canada with his wife Joanne, and daughters, Isla and Isabella.

**Lisa Gunderman** is a math intervention teacher for 6th, 7th, and 8th grade students at Fitch Middle School in Groton, Connecticut. Prior to that, she has taught math in a regular education classroom and has been a teacher since 2000. Lisa earned her Bachelors of Science in Civil Engineering from Villanova University and her Masters of Education from Sacred Heart University. Lisa is currently engaged in a curriculum writing project for her district focusing on aligning state standards with district curriculum. When not in school, Lisa continues to work toward her black-belt in Thai Kickboxing.

**Brooke Carson** joined the Beyond Benign team as a curriculum specialist in July of 2009. Prior to this role, she was a middle school teacher for 8 years in the state of Colorado, specializing in differentiated instruction and integration of cross-disciplinary units. Brooke previously served as the Director of Teacher Training at The Keystone Center in Keystone, Colorado for 8 years; by instituting programs with government agencies such as NASA, The Department of Energy and corporations such as, SC Johnson Wax and Pfizer, she had the opportunity to grow the professional development division from one yearly institute to eight curriculum projects. She has presented sustainability concepts to corporate audiences locally and internationally. The bulk of her experience rests with local, national, and international teacher training, and she continues to focus on providing professional development experiences for educators. Living with her husband in a small town in Colorado at 10, 400 feet, Brooke predictably loves being in the outdoors.

**Kate Anderson** is the Outreach Coordinator for Beyond Benign. Kate earned her Master’s in Education: Curriculum and Instruction with an emphasis in Environmental Education from Florida Atlantic University in 2006 after graduating with her B.A. degree in Political Science from the University of Massachusetts Boston. She has worked as a Sustainable Project Manager in the seafood industry in Massachusetts. Kate's previous experience took place in the K-12 classroom setting. As a program coordinator for non-profit environmental education programs, she developed curriculum, taught K-5 programs, managed service-learning projects and supported professional development workshops and trainings for teachers. Kate's passion is working with students and teachers to improve education. She is excited to be spreading the word that green chemistry offers solutions to the environmental challenges of today and tomorrow.

***ME in Your Neighborhood* Lesson Sequence**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Number | Lesson Title | Math Skills | Sustainability Content | Technology Education Standards |
| **1** | **Whose House**  Students view the houses of various celebrities and try to guess whose house is whose. This acts as an intro to students thinking about what goes into a house. | Math Skills graphic organizer | Social Equity | Design Process  Engineering Design |
| **2** | **Intended Occupants - optional**  Students decide who they're building their house for. | Math-Literacy connection | Social Equity | Design Process |
| **3** | **Leave Only Footprints**  Students analyze the environmental impacts of their lifestyles | Mean, median, mode, reasoning | Environment |  |
| **4** | **Decision Graphic Introduction**  Analyzing the economic, environmental, and social equity impacts of construction. | NCTM #10 (Data-driven decision making)  Averaging | Environment  Economics  Social Equity | Engineering Design  ITEA #5 (environment) |
| **5, 6** | **All A Loan**  Students learn to construct a budget and calculate the interest for a mortgage. | Fractions  Decimals  Percents | Economics |  |
| **7** | **Measurement Madness**  Students practice measuring and converting measurements using equivalent fractions. | Estimation/Actual  Equivalent Fractions |  | Engineering Design |
| **8** | **Scale the Wall**  Students measure rooms in the school to gain an understanding of space and scale. | Scale  Proportion | Environment | Engineering Design |
| **9** | **Hit the Deck**  Students practice creating a floor plan & using scale. | Spatial Relations  Scale  Area & Perimeter |  | Design Process, Engineering Design |
| **10** | **Drafting Bubbles**  Students create a rough draft that shows how the square footage of their house is divided and used. | Proportion  Estimation | Environment  Economics  Social Equity | Engineering Design |
| **11** | **The Final Floor**  Students design their final floor plan. | Scale  Area  Linear Measurement | Environment  Economics  Social Equity | Engineering Design |
| **12, 13** | **Greenhouse**  Students analyze how much the materials for their house will cost, and decide which materials to use, making choices based on economic and environmental factors.  There are optional hands on demonstrations to show students how some of the materials work | NCTM #10 (Data-driven decision making)  Averaging  Area  Perimeter | Economics  Environment | Engineering Design  ITEA #5 (environment) |
| **14** | **Final Budget**  Students create the final budget. | Number Sense  Numeration | Economics |  |
| **15** | **Build-A-Math**  Students build the 3D house model. This can be done in a number of ways (see “Building Options” for description of possible building methods). | Scale | Economics  Environment | Engineering Design |

**News Article for Teacher Background Information**

*The Green House of the Future*

We asked architects to draw up plans for the most energy-efficient houses they could imagine. They imagined quite a bit.

By [ALEX FRANGOS](http://online.wsj.com/search/search_center.html?KEYWORDS=ALEX+FRANGOS&ARTICLESEARCHQUERY_PARSER=bylineAND) - APRIL 27, 2009

What will the energy-efficient house of the future look like?

It could have gardens on its walls or a pond stocked with fish for dinner. It might mimic a tree, turning sunlight into energy and carbon dioxide into oxygen. Or perhaps it will be more like a lizard, changing its color to suit the weather and healing itself when it gets damaged.

Those are just a handful of the possibilities that emerged from an exercise in futurism. The Wall Street Journal asked four architects to design an energy-efficient, environmentally sustainable house without regard to cost, technology, aesthetics or the way we are used to living.

The idea was not to dream up anything impossible or unlikely -- in other words, no antigravity living rooms. Instead, we asked the architects to think of what technology might make possible in the next few decades. They in turn asked us to rethink the way we live.

"This is a time of re-examining values, re-examining what we need," says one of our architects, Rick Cook, of the New York firm Cook + Fox. "We are re-examining the idea of home."

A fresh look may be long overdue, given the amount of damage that homes can do to the environment. It's easy to envision a power plant spewing pollution or a highway full of cars burning billions of gallons of petroleum. But buildings -- silent and unmoving -- are the quiet users of much of our energy, through electricity, heating and water consumption. The U.S. Energy Department estimates buildings are responsible for 39% of our energy consumption and a similar percentage of greenhouse-gas emissions.

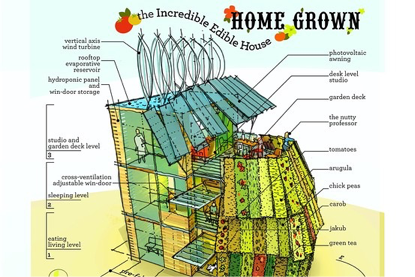
The growing awareness of that fact helps explain why green building is one of the most pervasive trends in the construction industry -- even as the economy struggles and home-building is at its lowest level in a generation.

So, how will the green homes of tomorrow help solve the energy puzzle? Here's a gander into the future.

RCH Studios

ON THE HOUSE The Rios Clementi Hale Studios house has a garden façade that includes chickpeas, tomatoes and other plants. The plants also provide shade and cooling. A rooftop reservoir collects water and keeps the building cool, while rooftop windmills generate energy.





Out on a Limb

"I'd love to build a house like a tree," says architect William McDonough of the Charlottesville, Va., firm William McDonough + Partners. And that's what he set out to do here.

The surface of his house, like a leaf, contains a photosynthetic layer that captures sunlight. Unlike today's solar panels, which are often pasted above a roofline, these are woven into the fabric of the exterior. They heat water and generate electricity for the home -- and create oxygen for the atmosphere, to offset carbon produced in other areas of the home.

The appeal of ultrathin, integrated solar panels goes beyond convenience. Today's solar is plain ugly and off-putting to many homeowners, something Mr. McDonough calls the "potpourri of miscellany stuck on our roofs." Unseen solar arrays, especially ones that create hot water, will be a "breakthrough from aesthetic perspective, which is a huge issue," he says.

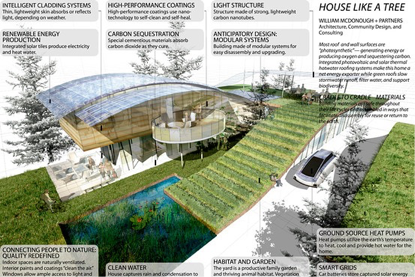
As for the rest of the design, Mr. McDonough envisions a sleek, curved roof with generous eaves to provide shade, which lowers the heat load in summer, thereby reducing the need for energy-hogging air conditioning. The roof also insulates and provides an outdoor garden. (Mr. McDonough designed a similar "green roof" for a Ford Motor Co. factory -- one of the first large U.S. buildings with that design.)

The "bark" of the treelike house would be thin, insulating films that would self-clean and self-heal, Mr. McDonough says, thus avoiding the need to replace them after years of exposure to the elements.

William McDonough and Partners

BRANCHING OUT William McDonough + Partners envisions its house like a tree. The "bark" of the house is made up of thin, insulating films that would self-clean and self-heal if damaged. A curved roof with large eaves provides shade, which lowers the heat load in summer. The "trunk," or the frame of the home, consists of carbon tubes, while the "roots" are a heat-pump system buried in the yard.





It sounds far-fetched, but some of these technologies already exist. Self-cleaning glass, for instance, has a special coating that uses ultraviolet sunlight to break down organic dirt; rainwater then washes the filth away.

Self-healing paints that contain microscopic capsules of color are in use on some car paint, for instance. These vessels break open when the surface of the paint is scratched to repair the damage. Similar ideas could expand to repair other materials such as glass or cladding.

The "trunk" -- or the frame of the home -- would eschew wood or metals. Instead, lightweight, "resource efficient" carbon tubes would keep the structure standing upright.

Finally, the "roots" of the home would be a ground-source heat-pump exchange system buried in the yard. It would take advantage of the relatively constant temperature of the soil to control the home's climate -- bringing in heat in winter, when the ground is warmer than the surrounding air, and cool in the summer, when the ground's temperature is lower. Such systems exist today, but cost puts them out of the reach of most homeowners.

Other technological advances in the home include cement that would absorb carbon dioxide as it cures, offsetting the heavy loads of energy used to make the material. What's more, special surfaces on the house would capture condensation for water use, avoiding the need for wells or faraway sources.

The design also takes into account what happens to the building when its useful life is over -- something most builders never consider, Mr. McDonough says.

Today's buildings are often filled with chemical insulators and films on windows. While there have been major advances in these areas, such as the use of low-chemical-emitting paints and carpets, most insulating windows today still contain mercury and other heavy metals.

Cook+Fox

UNDER MY SKIN Cook + Fox's house reacts to the weather, turning dark in the bright sun to insulate the house from heat and turning clear on dark days to absorb light and heat. The façade also captures rain and condensation to fill the household's water needs. Inside, walls and furniture are on rollers to take advantage of the fact that some spaces, such as bedrooms, are underutilized most of the day.





Mr. McDonough envisions a building industry in which everything that goes into a house eventually breaks down harmlessly, much as a tree falls and biodegrades on the forest floor. So, in his house, building materials from the cladding to the floors would be easily disassembled and reused, or, as he says, "return to the Earth."

The Reptile House

If Mr. McDonough's house is a tree, then this one is a lizard -- whose skin is among its most important features for survival.

Cook + Fox's house has a "biomorphic" skin that reacts to the weather, turning dark in the bright sun to insulate the house from heat and turning clear on dark days to absorb as much light and heat as possible.

The façade also captures rain and condensation to fill the household's water needs -- much like a desert-dwelling horny lizard rolls drops of dew from its nose to its mouth.

Mr. Cook sees the house of the future looking toward nature's way of solving problems as much as it looks to technology, a concept called biomimicry. "You need to view a house as a surface area for life, as opposed to a thing to be power-washed," Mr. Cook says.

Cook + Fox is well known for its green designs. Its biggest green project is the New York headquarters of Bank of America, which is known as One Bryant Park.

The sculpted white-glass tower, Manhattan's second-tallest after the Empire State Building, creates massive ice blocks in the evening when electricity is cheapest. As the "ice batteries" melt, they are used to cool the building during times of peak electricity loads during the day.

OLD AND NEW The Mouzon Design house uses tomorrow's technologies -- as well as ancient techniques to reduce energy use. Solar paneling built into the roof and façade provides electricity and hot water. The house also employs a "breeze chimney," an ancient architectural tool, as a kind of air conditioning.





The Cook + Fox house has a modern look, but it's designed to fit into a traditional neighborhood setting.

Inside, rooms are easily configurable for lounging or work. Walls and furniture are on rollers, for instance, to take advantage of the fact that some spaces, such as bedrooms, are underutilized most of the day.

What's more, toilets and washrooms are separated, serving more people with less space. Making a house that's more conducive to work is important for energy efficiency because it eliminates driving -- and thus reduces energy consumption.

A key feature of the house is perhaps its most traditional: a front stoop, which enables the home dweller to look out on neighbors and observe the area.

Noting an idea from scientist E.O. Wilson, Mr. Cook says, "No matter how advanced we get with technologies, there are things that make the human feel good no matter what. People like to see a horizon view and feel safe."

Meals at Home

Rios Clementi Hale Studios cheekily calls their concept the "Incredible Edible House."

This somewhat fantastical design seems to be as much about the future of food production as architecture. The façade of the three-story abode is slathered in a vertical garden that includes chickpeas, tomatoes, arugula and green tea. Step outside in the morning and harvest your meals.

The plants both nourish the inhabitants and provide shade and cooling, absorbing heat better than a wall made of wood, brick, stucco or glass.

Rios Clementi Hale, based in Los Angeles, has a reputation for playful and innovative designs. Its best-known works include the angular red, ochre and green-striped campus of the California Endowment in downtown Los Angeles. It has also done designs for Hollywood powers such as Walt Disney's Robert Iger and movie and music impresario David Geffen.

But the plants aren't the only striking feature of the design. At three stories, the edible house is also more vertical than the typical suburban home, a nod to the importance of building dense, urban-style houses in order to reduce energy use. A rooftop reservoir collects water and keeps the building cool; rooftop windmills generate energy.

The house is also put together in an intriguing way: It's made of three prefabricated containers stacked on top of each other that can be moved on a trailer if the mood fits. This method exists today, but it's not used very much, since homeowners associate prefabrication with lower-end homes.

But the benefits for lowering energy use are substantial. The standardized construction in prefabricated homes reduces defects that can hamper energy conservation. And it's easier to ship prefabricated parts, which means reduced fuel use for deliveries.

Learning From the Past

Looking to the future isn't the only way to be innovative. The house from architect Steve Mouzon, of Mouzon Design in Miami Beach, Fla., uses tomorrow's technologies while mining ancient techniques to reduce energy use.

For instance, solar paneling built directly into the roof and façade provides electricity and hot water. But the house also employs a "breeze chimney," an architectural tool used by the ancients, as a kind of old-school air conditioning.

The difference between the air pressure in the chimney and outside causes hot air to flow out of the chimney stack and cooler air to enter through windows and doors.

"It must make sense first," says Mr. Mouzon, a so-called New Urbanist architect who believes in traditional designs that emphasize pedestrian-friendly neighborhoods. His house "isn't trying to do wild and wacky things with roof shapes or wall shapes but a good sensible building that is highly lovable. It is inventive where it needs to be."

Like Rios Clementi Hale, Mr. Mouzon sees the house as a source of food. He would add "melon cradles," an invention he says he thought up for this project, to allow heavy melons and other vegetables to grow vertically up the sides of his house.

Another of his innovative ideas would require Americans to do more than just feed the goldfish bowl: He would install tilapia pools in a "kitchen garden" to provide fresh fish to the homeowner. It's among the most energy-efficient ways to raise animal protein, Mr. Mouzon says.

But the most important order for Mr. Mouzon is to make the house compact. "The smaller thing you can create, the more sustainable it is."

In fact, that's something that all four of our architects agree on: Americans need to learn to live in smaller spaces if we are going to make an impact on the environment.

—Mr. Frangos is a Wall Street Journal staff reporter in New York.

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