The LEARNING BARGE is a unique sustainable classroom and floating wetland for the Elizabeth River, the southern-most tributary of the Chesapeake Bay. The Elizabeth River was once home to an abundant and diverse ecosystem but many centuries of port traffic, industrial operations, chemical accidents, and suburban growth have polluted the river. Founded in 1991, the non-profit Elizabeth River Project (ERP) has been working to restore the river. As part of the educational mission of the ERP, the LEARNING BARGE is a moveable education center powered solely by energy harvested from the sun and wind. As an off-the-grid vessel, the BARGE has a rainwater filtration system, composting toilets, and a variety of ‘green’ construction materials. The vessel was designed and built by students at the University of Virginia in collaboration with the ERP, a naval designer, engineers, steel workers, teachers, and members of the community.

These cards were made possible by an Access to Artistic Excellence Grant from the National Endowment for the Arts.
1. FISHABLE River: students interact with the Elizabeth River creatures and learn how runoff is the number one source of pollution in the river.

2. RIVER Roots: while exploring the onboard wetland, students learn how plants and oysters are natural filters for the Elizabeth River.

3. RIVER Lab: inside the classroom, students explore ‘green’ materials and learn how chemicals affect the health of the river and lead to detrimental algae blooms.

4. SWIMMABLE River: on the aft deck, students discuss the importance of waste management in relation to reducing bacteria levels and creating a healthy river.

5. GREEN Alley: students learn how using sustainable technologies, like solar and wind power systems, help conserve energy and reduce pollution.

6. RIVER Art: students creatively express their experience with the Elizabeth River; by using the river for artistic inspiration, students learn to become conscientious river stewards.
Photovoltaic panels
solar energy collection
The LEARNING BARGE uses photovoltaic panels, known as PV panels, as a source of renewable energy. The cells of a PV panel convert solar radiation from the sun into direct current electricity. The electricity collected by the eight Evergreen 195W PV panels is stored in four batteries, located in the white deck box on GREEN Alley, then dispersed to elements such as lights. PV panels are most efficient when they are oriented perpendicular to the sun; however since the BARGE changes locations every season the panels were fixed in place. The humid climate and occasional cloud cover in the Elizabeth River area are actually beneficial factors for PV power: approximately 50 to 80% of the light received is diffused light, making perfectly perpendicular PV orientation unnecessary.
Charge controller
solar energy collection
The voltage and current generated by solar panels can be irregular due to temperature fluctuations. These irregularities cause the batteries to either overcharge or potentially discharge. Neither of these conditions are desirable because they strain the batteries beyond recommended levels, significantly reducing the life span of the batteries, and can even cause system failure. In order to eliminate these problems and control the system’s input vs. output the LEARNING BARGE uses a charge controller. A charge controller regulates the current flow and also delivers the maximum power using MPPT (maximum power point tracker). The MPPT displays the state of charge, meaning how much energy is stored in the batteries.
Monitoring system
solar energy collection
The custom-designed wireless monitoring system consists of wireless sensors, a base station, and a data display board in order to collect, store, and display data related to the energy systems of the LEARNING BARGE. The DC wireless sensors monitor power generation (current and voltage) while the environmental condition sensors collect data on the temperature, humidity, wind speed, and the flow of the solar hot water heating system. The base station is the central part of the monitoring system. It serves as a hub to facilitate communication between various sensors and the data display board that shows visitors to the BARGE real-time feedback on the function and conditions of the power systems onboard.
Exterior lights
solar powered
All of the lights on the LEARNING BARGE are powered by energy from the sun and wind. There two main light-types onboard are compact fluorescent (CFL) and light-emitting diode (LED). The CFLs along GREEN Alley are much ‘greener’ than typical incandescent light bulbs because they use less energy, last 8-15 times longer, and do not radiate heat. The CFLs on the BARGE have Edison screws, meaning they could be used on a traditional light fixture. LEDs are used to illuminate the ramp: these small, efficient lights have a long lifespan and use very little energy. The output of LEDs are more efficient than CFLs, however they are more expensive and require different current management. The BARGE has both AC and DC current, making it easy to showcase these two different light sources.
Evacuated tubes
solar heat collection
There are two twenty-five tube solar thermal collectors by Solar Panels Plus on the LEARNING BARGE. Evacuated tube solar hot water heaters gather energy from the sun and transfer it to the water contained in the system’s piping. The circular design of the tubes allows sunlight to always strike the tubes at an optimal angle. The glass tubes are sealed and each one contains a thin copper tube filled with a very small amount of glycol and water. When heated by the sun’s energy, the liquid in the copper tube flash boils. The hot liquid is then pumped through insulated copper tubing to the hull of the BARGE, through the thermal mass of two hot water tanks, and then into the heaters in the RIVER Lab where it is converted to steam to heat the classroom.
Batteries
solar energy collection
The LEARNING BARGE has four sealed East Penn AGM solar batteries. The batteries are stored in individual containers within the white, watertight dock box on GREEN Alley. Since the BARGE operates off-the-grid, a medium was needed to store the collected energy from the photovoltaic panels and wind turbines. The BARGE systems required batteries that could supply constant and steady current over long periods of time with constant drain/charge cycles while retaining high energy efficiency. The collective battery capacity of the BARGE was sized to provide power for 3 days if there was no sun or wind to generate additional energy. The system is also equipped with a shore power connection, similar to most boats, so the batteries can be manually charged if needed.
Hydronic heaters
solar heat distribution
Beneath the benches in the RIVER Lab of the LEARNING BARGE are three Heatercraft 900h hydronic heaters. The heat comes from the evacuated tube solar hot water heating system. The evacuated tube collectors above GREEN Alley collect energy from the sun all summer to heat a closed-loop glycol water mixture then the heated water is stored in two large water tanks in the hull under the wetland. Two pumps, one located in bathroom closet and one located in the ‘dogshed’ below the bathrooms, control the flow of the water heating system. In the winter months the heaters in the classroom are switched on, drawing the hot water to make heat. The large windows of the RIVER Lab also help to keep the classroom temperature comfortable in the winter months since the direct solar radiation warms the space.
Lexan glazing
Lexan is a brand of highly durable polycarbonate resin thermoplastic and is often used on boats as an alternative to glass. It has a high impact strength as well as high resistance to heat, cold, water, UV light, and flame. Lexan was used on portions of the LEARNING BARGE’s Artifact Wall to provide clear views to the aft deck. Lexan also forms the outer layer of the one-of-a-kind light fixtures in the RIVER Lab. A graphic of the Elizabeth River’s own benthic fish, the mummichog, was engraved onto Lexan panels using a laser cutter. A similar engraving technique was used to create the images on the cabinet doors in the RIVER Lab. However, unlike the clear engravings on plexiglass, etchings on Lexan are a sepia color due to the UV protectant embedded in the material.
Thermoclear twinwall

glazing
GE Lexan Thermoclear twinwall polycarbonate is a durable plastic material often used as roofing material for simple structures like sheds and bus stops. Onboard the LEARNING BARGE twinwall is used for parts of the Artifact Wall and the clerestory of the bathrooms. Twinwall is translucent and can be a better alternative to glass because it is both lightweight and has a ribbed structure that provides better insulating properties. It also diffuses light and blocks harmful UV rays due to an embedded film in the material. Unlike glass, twinwall will not shatter when broken, making the material particularly attractive for use on the BARGE since the Elizabeth River area experiences coastal storms and even the after-effects of hurricanes.
Laminated glass

glazing
All of the steel windows of the LEARNING BARGE are composed of laminated glass. Double glazed windows were not used on the BARGE because the steel structure of the BARGE is an excellent thermal conductor and the insulation properties of double glazed windows were not beneficial. Laminated glass was used because the film embedded in the glass prevents the glass from dangerously shattering if broken. Instead, the glass remains in one piece but simply splinters in spiderweb-like patterns. Laminated glass is a more sustainable alternative to traditional window panes: during a storm, such as the strong coastal storms that strike the Elizabeth River region, broken glass stays in place rather than falling into the watershed.
Shadecloth
sun protection
Instead of using air conditioning powered by fossil fuels, the LEARNING BARGE uses natural cooling techniques. Shade is created on the BARGE by the roof overhang and a special shade fabric that blocks harmful UV rays. Above the Storytelling Stairs and along the large windows of the RIVER Lab, there are custom-made shade devices using a product called Polysack. This shade fabric is typically used on farms and in greenhouses to keep plants and animals protected from the harsh sun, especially in southern climates. The shade cloth comes in different colors and woven patterns; the black shadecloth used on the BARGE provides 78-82% shade and blocks 95% of UV rays but is visually translucent to retain views of the surrounding landscapes.
The bright colors of the LEARNING BARGE reflect light, unlike dark colors often found on barges that will absorb light. During the hot summers, the light grey of the deck and roof will help keep the vessel stay cooler. The bright orange and yellows are accent colors that highlight various components of the BARGE’s design. For example, the yellow stripe that wraps from the bow to the fore deck lines up with the longest filtration basin while the stern stripe aligns with the vibrant steel bench in the RIVER Lab. The pale yellow doors of GREEN Alley are painted with bright yellow stripes to mark the layers of the river. Even the bits are painted orange, and the cleats yellow, to call attention to typical components of a barge that usually go unnoticed by visitors.
Wind turbines
energy collection
The two wind turbines on the LEARNING BARGE are AirBreeze 200W, made by Southwest Windpower. Humidity and cloud cover can reduce the effectiveness of photovoltaic panels but typically, gloomy days are paired with higher wind speeds so the BARGE uses wind turbines for extra energy collection. Unlike the sun’s predictable position, angle and seasonal movement, wind speeds, and frequency are variable especially in a coastal area like the Elizabeth River watershed. The BARGE team used data from the National Oceanic and Atmospheric Administration (NOAA) to predict wind patterns in the region: the average wind speed per month is approximately 15.75 feet per second. The marine-grade wind turbines used onboard have a low start speed so even small breezes can generate energy.
Operable windows

ventilation
The custom-fabricated windows on the LEARNING BARGE are Bliss Nor-America steel windows and were designed with two specific sustainable elements. First, steel is the most widely recycled material in the United States: it produces less scrap and waste, has the highest strength to weight ratio of any building material, and is fire resistant. Second, the operable clerestory and casement windows, as well as the large, completely operable door to the RIVER Lab facilitate natural ventilation and keep the RIVER Lab cooler in the warm summer months without relying on fossil fuels for air conditioning. As a design feature, the large size of all the windows was intended to give unobstructed views of the Elizabeth River’s beautiful natural and industrial landscapes.
First-flush system
water filtration
The bright orange first flush discharge tank on the LEARNING BARGE collects the first twenty gallons of water shed from the roof via the gutter. These first gallons have the greatest concentration of roof dirt so they flushed from the onboard water filtration system. The water is slowly released to the river via drip valve in the bottom of the tank. There is also a strainer and a filter at the bottom of the tank that are easy to remove for cleaning during the season, depending on how often it rains and the amount of airborne pollen or dirt present. The red ball valve, to the left of the first flush tank, controls whether water is sent directly overboard or is allowed to enter on-board water filtration system. During the BARGE’s off-season in the winter months, the water is sent directly overboard rather than being processed through the system.
Sand filter
water filtration
After the collected rainwater from the roof of the LEARNING BARGE is processed through the first flush system it travels into a 600 gallon water holding tank in the hull of the BARGE. The water is then hand-pumped into a thirteen gallon priming tank, visible in the closet through the small window near the bathrooms. The water from this small holding tank then drains by gravity into the sand filter, made from a recycled rain barrel. The filter is composed of three layers: sand at the top, pea gravel in the middle, and coarse gravel at the bottom. The layers are separated by screens to make removal of the sand and gravel easier. As water slowly passes through the layers, contaminants are removed. A pipe at the bottom of sand filter carries the clean water into a 600 gallon holding tank in the hull.
Holding tank
water system
The water used for hand washing on the LEARNING BARGE is collected from the roof and cleaned in a two-part filter system. The hand-pump on the wall between the two bathroom doors is used to pump water from the 600 gallon clean water tank in the hull into a custom-fabricated six gallon holding tank. The two sinks of the bathrooms are gravity fed by the water tank. The engraved lines on the tank are gallon markers: visitors can monitor how much water is being expended while the sinks of the bathrooms are in use. It is estimated that forty gallons/day of filtered rainwater are used onboard the BARGE for hand washing and other non-potable uses. With the BARGE’s visible lessons in water conservation, hopefully visitors will save water at home and work by turning off their faucets when not in use.
Concrete sinks
water system
The two concrete sinks in the bathrooms of the LEARNING BARGE were custom designed and fabricated to show how an everyday material like concrete can be shaped into an object of art. The concrete sinks were cast with smooth forms, unlike the concrete basins of the wetland, and a charcoal-colored pigment was added to the concrete mixture before it was cast to make the dark color. One sink is a trapezoidal shape while the other was cast to represent a topography model. This sink can be used to start a discussion about watersheds and how the contours of the earth shape where water travels. The back splashes of the sinks were also custom-made, with iconic BARGE-related details. Water from both of the sinks drains into the wetland onboard via steel channel cast into the concrete floor.
Cast iron hand pumps

water filtration
Some of the concrete basins in the LEARNING BARGE’s wetland are for brackish water, a mix of saltwater and freshwater, found the tidal estuary system of Elizabeth River. The two black cast iron hand pumps are used to pump water into these brackish basins. The piping below each of the hand pumps runs through the hull of the BARGE and is open to the Elizabeth River: visitors to the BARGE use kinetic energy to pump the lever in order to create suction in the pipe which draws water directly from the river. The piping attached to the hand pumps has a small diameter; a smaller surface area has a more efficient ratio of lift. The simple hand pumps used on the BARGE are similar to those used for shallow land wells across the world.
Hand bilge pump
water system
The LEARNING BARGE uses two simple hand pumps along the exterior wall of the bathroom enclosure as critical components of the onboard water collection and filtration system. Each pump draws water from large holding tanks in the hull into smaller, visible tanks above deck. For example, the hand pump on the wall between the bathroom door pulls water from the clean water tanks into the clear six gallon holding tank that feeds the sinks onboard. The JABSCO hand pumps are actually small, adapted bilge pumps. Bilge pumps are typically used in the lowest compartments of ships in order to remove the bilge water collected from rough seas, deck drainage, or small leaks. The bilge water on the BARGE is managed with a different system and water comes from condensation along all the steel plates of the hull.
Concrete basins

water filtration
The custom-made concrete basins of the LEARNING BARGE are an integral part of the constructed onboard treatment wetland, filtering both saline and freshwater. Wetlands remove pollutants from the water through the processes of settling and biological uptake. By pumping water from the river and from the BARGE’s greywater system into the filtration basins, water will be returned to the river cleaner. For example, “waste” water from hand-washing drains into the freshwater basins: as the water flows between the basins, carried by recycled steel channels and pipes that have a rough texture to help oxygenate the water, the plants naturally filter containments. The concrete basins were cast-in-place with exterior plywood formwork: on certain basins you can clearly see imprints left by the wood.
The LEARNING BARGE is the world’s first floating wetland, complete with rainwater reuse and saltwater filtration systems as well as a pool. This shallow pool is the first place water from the freshwater and saltwater basins meet: after the water flows through the respective concrete basins it flows out the recycled steel scuppers and into the pool. From there, the water settles and creates a concentrated ecosystem. Once the water level of the pool reaches the desired height, the plug can be removed to drain the now cleaner water back into the Elizabeth River. The pool also plays a large role in the programs of the BARGE that celebrate cultural traditions around the world that celebrate water such as water drums, lanterns, and parades across the yellow bridge.
The solar hot water heating system of the LEARNING BARGE is mainly composed of two twenty-five tube arrays of evacuated tubes, a closed loop mixture of glycol and water, and three hydronic heaters. Two tanks, twenty feet long and two feet in diameter, are located in the BARGE’s hull under the wetland. They serve as the thermal mass for the heating system since the coiled, copper heat exchanger in each tank is connected to the closed loop heating system. In the summer months, when the sun is producing optimum energy, the evacuated tubes are activated and the closed loop system begins to heat the water of the two large water tanks. Completely powered by green technologies, the heating system uses the insulating properties of the warm water in the tanks to maintain heat through the closed loop in the winter months.
White Oak
rain screen cladding
The rain screen of the LEARNING BARGE is a layered wall construction technique using standard stud walls with Borate treated lumber, exterior grade plywood, building paper, and White Oak cladding attached with stainless steel fasteners. Unlike a typical wall system, rain screens freely drain rain rather than inadvertently capturing it within the wall system thereby causing moisture and rotting problems. White Oak is naturally rot resistant and the wood used onboard was sustainably harvested from dead or dying trees by Appalachian Sustainable Development. The White Oak has been treated with eco-friendly AFM Clear Natural Penetrating Oil and several of the rain screen panels were engraved with a lasercutter to recognize the many generous donors for the BARGE.
Birch plywood cabinets
The custom-designed cabinetry in the LEARNING BARGE’s RIVER Lab is made from laminated Birch plywood. This beautiful, finish plywood is distinguished by its excellent strength, stiffness, and resistance to deform, all essential qualities for a marine environment. It has a high shear strength and impact resistance, which make it especially suitable for heavy-duty wall structures. The Birch cabinetry provides storage space and the three Murphy tables fold down for additional workspace. The Birch plywood has been treated with AFM Clear Natural Penetrating Oil, an environmentally friendly finish that highlights the woods’ natural glow. The ‘window seats’ and bottom compartments of the cabinetry have been treated with a natural black varnish.
Ipê lumber
The woods used to make most decks, benches, and handrails are treated with harsh chemicals in order to resist weathering. Over time, these chemicals seep into the ground and eventually contaminate watersheds. However, the wood used for railings and the benches of the Storytelling Stairs of the LEARNING BARGE will not leach chemicals since it is a unique type of wood called Ipê (pronounced ‘e-pay’). It is a Brazilian hardwood that naturally resists rot, decay, insects, and mold without the toxic chemical treatments typically applied to other decking products. These qualities, as well as its natural resistance to fire, makes Ipê an environmentally conscientious choice. Overtime UV rays from the sun will change the color of the Ipê from reddish-brown to a bright silver or grey.
Borite-treated wood
lumber
The greenish wood that is used for most outside decks, telephone poles, and even playgrounds is called pressure-treated lumber. It is weather resistant because the wood is treated with harsh chemicals like arsenic, copper, and other heavy metals; as the wood weathers and breaks down these chemicals leach into the ground and water. All of the lumber used on board the LEARNING BARGE is Borate-treated ‘eco-lumber’. Borates are natural mineral salts. The wood is soaked in the Borate solution, then dried. This process makes the treated wood pest-resistant without being toxic to humans or plants. Since the Borate treatment process does not cause the wood to turn green, like pressure treated strategies, the wood retains its beautiful natural color.
Composting toilets
waste treatment
The toilets onboard the LEARNING BARGE are waterless remote composting toilets by Envirolet. Below each toilet is a unit in the hull of the BARGE that collects the compost. An aeration fan in the plastic unit continually runs, using harvested solar and wind power, in order to keep the compost decomposing at a uniform rate. Every week, a special composting mix and wood chips are added to the composting toilet units to further accelerate the composting process. Every few months the compost from the BARGE will be removed and used in wetland restoration. The toilets are ventilated by two simple, wind-driven fans that can be seen on the roof. The ventilation pipes are the black tubes visible in each bathroom.
Plants
filtration
The custom-made filtration basins of the LEARNING BARGE are an experiment in constructed wetlands. The BARGE will always have freshwater and saltwater plants, but specific plants onboard may change from year to year depending on how they respond to the system. Plants may also be changed to investigate which ones filter particular pollutants at higher rates than others. The goal is that contaminants such as tributlytin (TBT), gasoline, oil, and enterococci are filtered out of the river water. By growing plants onboard that are native to the Elizabeth River’s wetlands, visitors to the BARGE can learn plant identification and see the beauty of the dynamic wetland up close. Notice how the taller plants are along GREEN Alley, forming an enclosure for the pool area below.
Grating
walking surface
The bright yellow grating of the LEARNING BARGE used over the precast channel in the concrete floor in the bathroom and in the pool of the onboard wetland is a reclaimed material. Found in a University of Virginia Facilities Department storage unit, the BARGE team gave the abandoned grating new life on the BARGE. The reclaimed grating is DURAGRID Standard Pultruded Grating that is flame retardant and corrosion resistant. The material provides a non-skid surface and has low thermal conductivity. The benefits of the fiberglass grating over typical metal grating are that the yellow DURAGRID is almost maintenance-free, lightweight, and will outlast steel in even a submerged or saline environment like the Elizabeth River.
Ramp paint
non-skid coating
All of the LEARNING BARGE’s grey deck surfaces are coated with non-skid paint, a simple aggregate added to the epoxy paint mixture, but the design team wanted to provide extra traction on the ramp’s surface. The ramp on the starboard side is a simple slope and navigates the BARGE’s two different deck heights. The non-skid paint on the ramp was made from recycled tires, ground into a fine pulp and added to the paint mixture. This sustainable technique of reusing a discarded material has been used on other barges and Naval vessels. Tires are a commonly reused material on the Elizabeth River: some tugs boats even use discarded tires from airplanes as fenders, or bumpers, along the sides of the vessel.
Metal signs
cladding
All of the signs and scrap metal pieces used in the two bathrooms of the LEARNING BARGE were rescued from landfills or procured from metal junk yards and recycling facilities. Attached to exterior grade plywood, the signs add colorful character to the bathroom, especially against the white paint intended to reflect light from the clerestory level. Composed of everyday objects, at one time considered trash, the collage walls are pieces of art. Road signs are typically made from aluminum treated with corrosion-resistant coatings as well as reflective sheetings, making it difficult to recycle the metal unless it is treated with a harsh chemical agent to strip the coatings. Therefore, many of the reclaimed signs on the BARGE have been given a rare second life.
Spuds anchoring
The LEARNING BARGE is equipped with two spuds on the port side. Spuds are the typical ‘anchors’ used on barges: the spuds are cranked or pulled by a crane to the upright position (pictured on the front of this card) and then dropped into the water through the steel sleeves in the hull so that the pointed ends of the hollow steel tubes sink into the bed of the river. When both spuds are lowered, the BARGE is anchored by two points of connection and won’t easily drift or put stress on adjacent docks as tides change. The spuds on the BARGE can be raised and lowered using a manual hand crank: the mechanical advantage granted by the gears of the wench allows a single person to easily, but slowly, raise and lower the heavy steel tubes.
Cleats + bits
anchoring
Boats are equipped with cleats, T-shaped protrusions from the deck, in order to have a secure point onboard to tie the boat’s line to a dock or other structure. On the LEARNING BARGE there are four steel cleats painted yellow. Since the BARGE was designed with two deck heights, to dock at both high and low sites, there are cleats on both the port and starboard sides. The BARGE is not a self-propelled vessel therefore the bright orange bits on the four corners of the deck are used for tug boats to tie line to the BARGE in order to push or pull the vessel to its next docking site. With bits on both the port and starboard sides, the BARGE has maximum flexibility in navigating site conditions since a tug boat can easily get the BARGE in and out from either side.