



UNIVERSITY OF
MARYLAND

U.S. DEPARTMENT OF ENERGY SOLAR DECATHLON 2017



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Contest 5: Innovation Narrative

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Sustainable design is nothing new in today's housing market. 'Green' materials are becoming increasingly commonplace, as are low flow water fixtures. Renewable energy systems including photovoltaics are experiencing slow but steady growth in the U.S. as well. In general, however, the stated goal of 'sustainable' construction is often to waste less and do less harm. Team Maryland believes that to be truly sustainable, it is imperative that our buildings be designed and constructed to enhance nature's regenerative capabilities, not merely to degrade them less. reACT (**resilient Adaptive Climate Technology**) shifts from a "less bad" to a "more good" paradigm is an innovation in design thinking that will bring about a revolution in the housing market, as reACT will demonstrate.

reACT represents a new paradigm for housing, a regenerative model of sustainability, able to serve diverse communities, and be integrated with diverse natural ecosystems. The concepts, processes and technologies demonstrated in reACT are applicable to a wide range of scales, densities and formal configurations. The prototype is built upon providing a common 'DNA' for not just one house, but an entire range or community of homes or other smaller buildings. Regenerative design principles guided the design process recognizing that local climate, individual choice and culture influence the specific forms employed in the design of the reACT prototype. reACT seeks to avoid the "one off" limitations of many past U.S. Department of Energy Solar Decathlon competitors.

INTEGRATION

One principle of regenerative design embodied in reACT is that each element should perform more than one function, and that each function should be performed by multiple elements. This web of functionality is essential to resilience and adaptability. reACT achieves this goal through integration of passive and active systems throughout the house.

The heart of reACT is the integrated Core and Greencourt. Courtyards are common in arid climates, providing a sheltered space for residents to enjoy both sun and shade throughout the day. By enclosing the Courtyard in a glass skin, a sort of greenhouse, the innovation of the Greencourt is realized. It extends the outdoor living season into the colder months by capturing solar heat. In the summer, operable walls and roof with built-in shades create a place sheltered from the sun and cooled by seasonal breezes. The Greencourt also serves to moderate between indoor and outdoor environments, making the rooms surrounding the court more comfortable. The Greencourt distributes daylight and natural ventilation throughout the house.

The Core of reACT integrates all the technical systems in the house in a compact modular form. Housing these systems together facilitates the interchange of thermal energy and water between components, making reuse of heat and moisture more efficient. The most prominent example of this innovation is the interaction of the Core and Greencourt. In the winter, the Greencourt preheats the air fed to the variable refrigerant flow (VRF) heat pump compressor, which is housed in the Core's Attic. This excess heat is also harvested by a heat pump water heater (HPWH), and stored in reACT's hot water tank for later use. During the summer, the Greencourt can be periodically closed and the excess heat stored in the hot water tank, or it can be opened and shaded to cool the air used by the VRF compressor. This flexibility allows the system to optimize its performance under a wide range of weather conditions. This same capability also makes reACT adaptable to a wide range of climate zones.

The performance of the VRF system, including compressor and mini-split heat pumps has been extensively researched under different climate conditions in an environmental test chamber. The HPHW system has been similarly studied in the laboratory and the viability of the design has been demonstrated. Testing suggests that using the courtyard's air, the VRF and HPHW system experiences a 10-20% increase in efficiency for even a 4°C change in temperature between the outside environment and the courtyard.

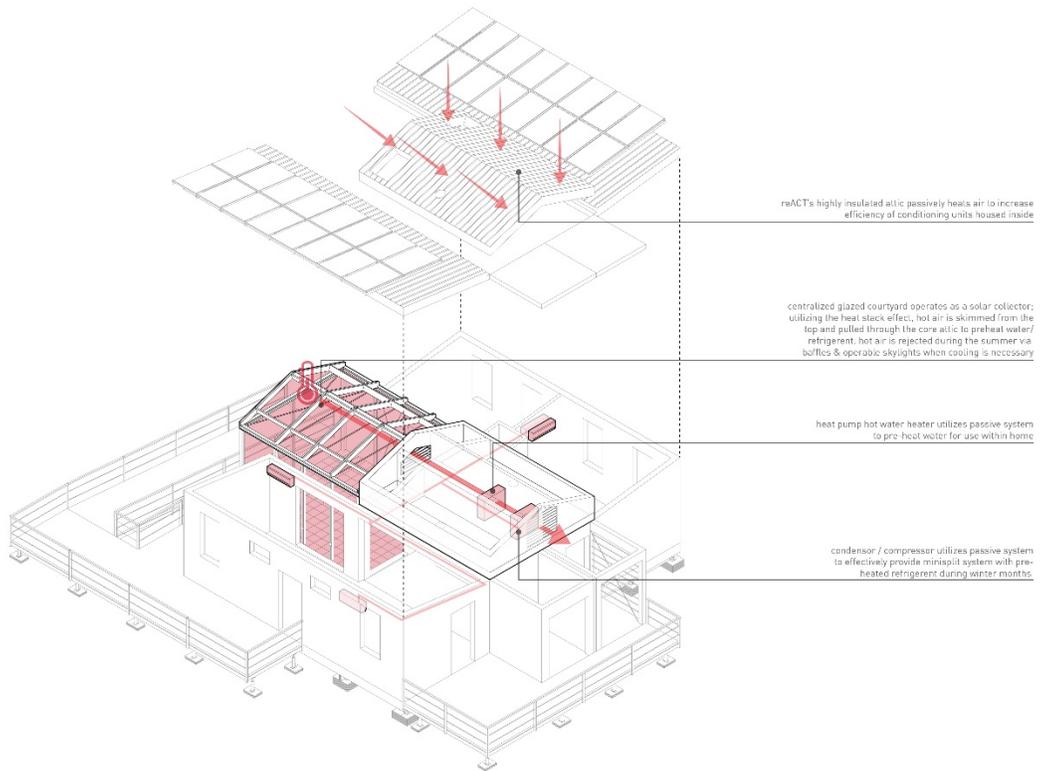


Figure 1 – Harvesting heat from the Greencourt



Figure 2 – Test Rig for the Heat Pump Hot Water Heater

DISENTANGLEMENT

The advantages of integration have been outlined above, but there are also advantages in keeping things separate for maintenance, expansion of the living space, and upgrades in technology. It is important that the systems of the house be disentangled from each other and from the structure. **reACT** organizes the house systems along a central spine, with a cross spine for distribution. The spine is clad (on both kitchen and bathroom sides) with removable panels for accessing the distribution systems. The main components of the system are accessible from the Mechanical Room located at the spine's end.

Interior faces of nearly every wall and ceiling (systems are not distributed through the floor) are removable, allowing easy access to wiring and sprinkler plumbing throughout the house. This innovation in interior design facilitates efficient and timely maintenance and future technological upgrades. Cutting into structural framing or insulated walls is unnecessary for wiring or plumbing.

SOLAR APPLIANCES

An Attic above Core is home to appliances designed to use solar heat directly. The Solar Oven/Food Dryer is located in the ceiling of the core adjacent to the kitchen, while the Solar Clothes Dryer is located in the ceiling outside the bathroom laundry space. Electric lifts take food and clothes conveniently from the living space to these solar appliances. Solar ovens are simple but effective tools for cooking and dehydrating food, but have thus far not made a strong appearance in the U.S. market. At the Solar Decathlon 2017, homeowners will be able to see these novel appliances in action at **reACT**. Clotheslines are familiar to many Americans, but the innovation of moving them inside to use concentrated sunlight and heat will be introduced in Denver.

SOLAR POWER

After researching home installation of solar panels, it soon became apparent that the choice of inverter configuration was central to the effectiveness of our design. String inverters and micro-inverters were considered, but eventually the SolarEdge single phase inverters were used because of their compatibility with DC-DC optimizers, adaptability to different design configurations, monitoring capabilities, and ease of maintenance.

When the DC/DC optimizers are coupled to the SolarEdge inverter, the optimizers automatically maintain a fixed string voltage. This allows individual modules within the string flexibility in terms of orientation, shading, and even module type. Additionally, the optimizers feature maximum-power point tracking, sophisticated module-level monitoring, and an automatic module shut-down mechanism when the inverter is shut down or grid power is lost.

WATER

Water shortages and degradation of water quality are critical problems throughout the world. **reACT** is designed not only to use less water than a normal house, but also to reuse it as a resource instead of treating it as waste. **reACT** is also designed to function within a new decentralized water infrastructure, treating water locally instead of relying on expensive municipal water supplies that often damage the ecosystem.

reACT treats potable water, greywater (water from fixtures containing no biosolids) and blackwater (water containing biosolids) differently. Unlike most homes in America, **reACT** does not use potable water for applications like irrigation where non-potable water is suitable. This preserves the highest quality water harvested from the environment (such as from wells which tap precious aquifers) for particular uses like cooking and drinking. This shift in water use is, in itself, an innovation that the Team Maryland believes we must adopt throughout the U.S. in order to create a sustainable future.

In arid climates like Denver, which only receives about 15 inches of precipitation per year, harvested rainwater is often not sufficient to meet all of the home's non-potable needs. Meeting those demands requires that we also recycle potable water for non-potable uses. reACT therefore includes a highly effective system of filters and UV sterilization to convert greywater (containing soap and other contaminants) into non-potable water suitable for irrigation and ground infiltration. Preliminary bench testing of system prototypes have proven promising in meeting these goals. reACT demonstrates the viability of such decentralized treatment systems at the scale of a single family dwelling, but the technology is scalable to a range of projects from a single home to apartments, commercial buildings and small communities. Research into technologies for treating non-potable water to potable standards will continue as part of a UMD Gemstone Honors program.

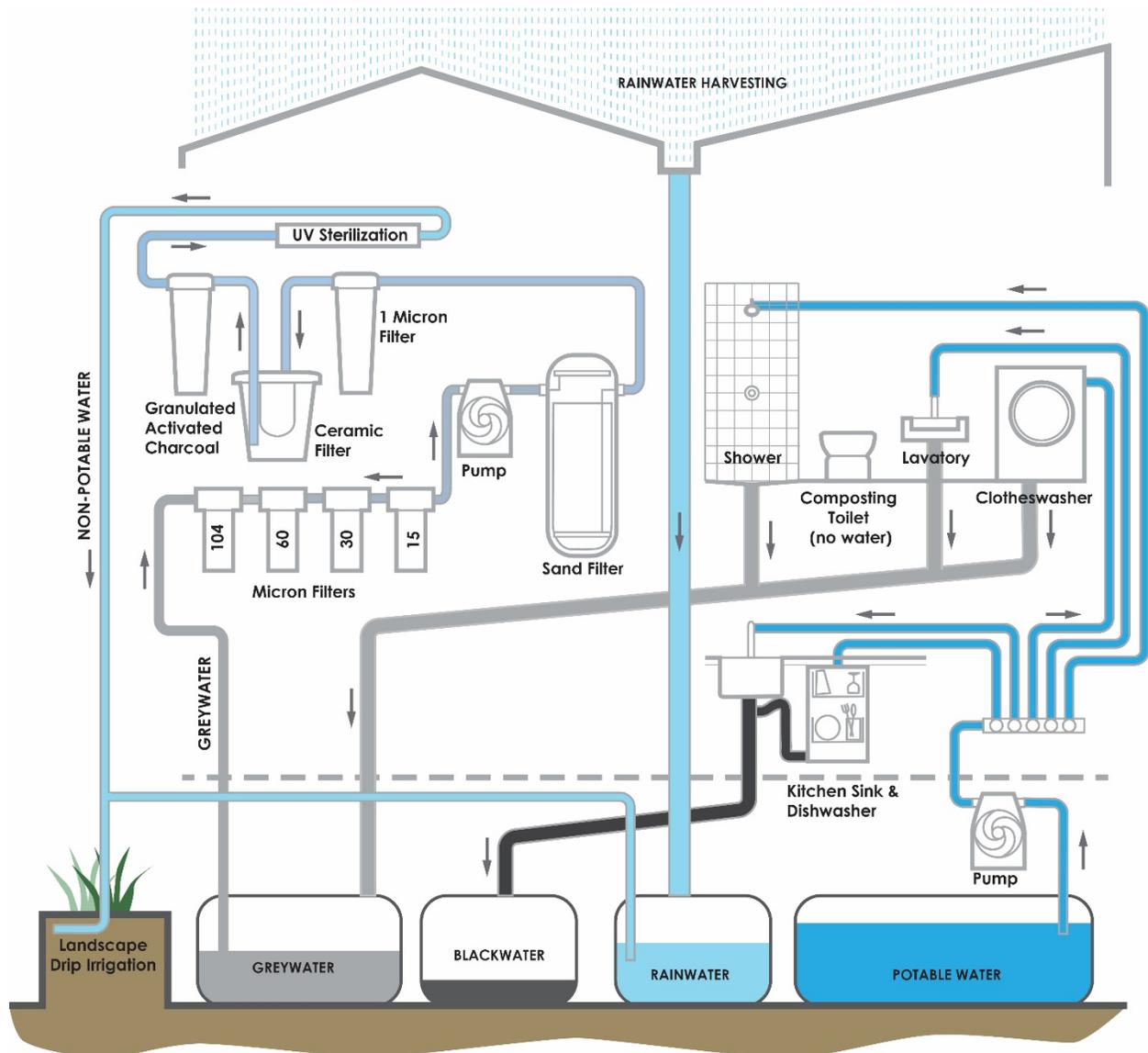


Figure 3 – Water System Schematic

CARBON CYCLE

One of the water saving features used in reACT is a composting toilet. Like many of the technologies found in the prototype, this one has multiple benefits. True to Team Maryland's philosophy of treating 'waste' as a valuable resource, the composting toilet separates urine from fecal matter and converts both to a form which can be used to enrich the environment. Human compost is suitable as a fertilizer for non-food plants. It can be used on crops used as feed for livestock, for example, and the waste from those animals CAN be used on food crops (recycling our waste through a horse or cow).

While use of human waste as a fertilizer is by no means a new practice, it fell out of favor in the developed world early in the twentieth century due to concerns over sanitation in the home. Recent advances in technology, however, has rendered the practice clean and convenient, with no unpleasant smell or mess to deal with. This makes composting toilets one of those innovations combining the best of traditional ecological practices and regenerative thinking with the latest in modern technology.

In addition to recycling our bathroom's solid waste, reACT also has facilities for recycling food waste from the kitchen. A barrel composter turns yard waste and table scraps into nutritious fertilizer that can be used in the food garden.

LIVING SYSTEMS

Connecting the homeowner directly to the ecological systems surrounding them and supporting their home is at the root of reACT. Nature should be viewed as a partner, not something separate from ourselves that is just pleasant to look at. Plant life and food webs integrate with the home, creating a regenerative cycle involving the residents, vegetation, insects, wild life, water and nutrients.

The VGP Tray-Based moveable green wall, made from 100% post-consumer recycled polypropylene panels and trays, are but one element of our living systems. The green wall plants are automatically watered based on the weather predictions and soil moisture of the trays, giving the homeowner the freedom to enjoy their plants without having to constantly tend to them. In Denver, trays will hold indigenous Colorado plants and other ecologically important species suitable for the climate. Plants are changeable to accommodate different climates the house may inhabit. The green walls are modular and can be moved from the exterior decks to walls inside the Greencourt in order to extend the plants' growing season, improve air quality and provide a vibrant interior display during Denver's long winters.

Another reACT Living Systems innovation is an indoor hydroponic garden developed at UMD and artfully crafted from ceramic materials using 3D printing technology. The garden's plants are fed with water infused with small amounts of trace minerals and nutrients to aid in healthy plant growth. reACT eliminates water waste from this system with a closed-loop track that continuously recirculates unused water. Evaporation is reduced by placing the garden inside the house. Small edible plants such as greens and herbs can be grown year-round using hydroponics without the use of pesticides or herbicides that may harm the ecosystem. Conveniently located in the kitchen, residents can quickly harvest fresh garnishes and vegetables for whatever dish they may be preparing that night¹.

¹ Food from the gardens will not be used in meals prepared as part of the Competition.

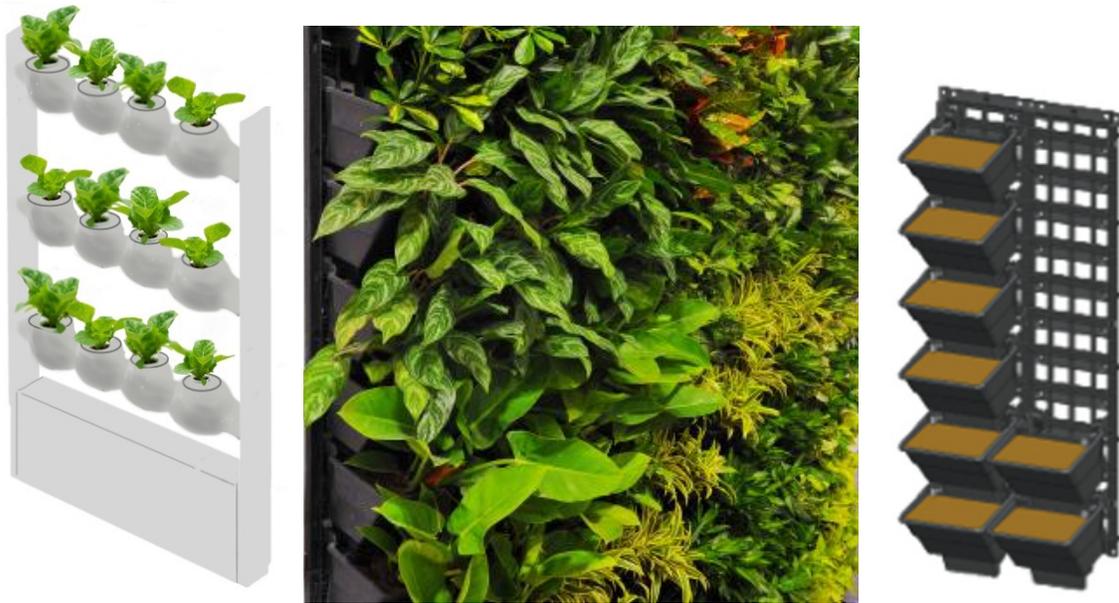


Figure 4 – Hydroponic Wall, VGP Living Wall System with and without Plants

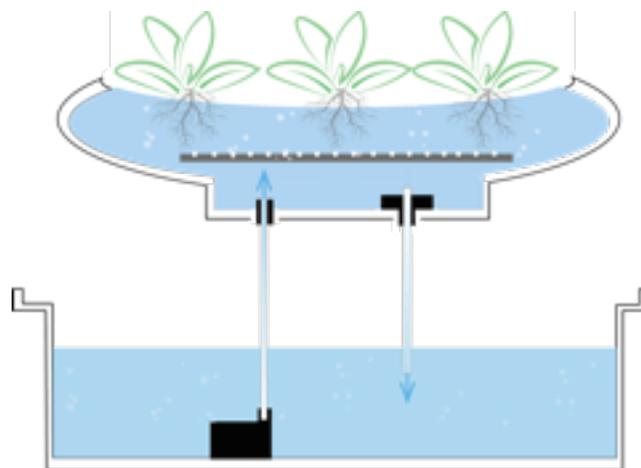


Figure 5 – Hydroponic System

reACT's client is a married Naticoke Indian couple who have move to Denver for professional opportunities. Both spouse's professional work to increase access to healthy, nutritious foods, while reducing reliance on commercially processed foods. Both are working towards establishing food systems that support indigenous self-determination, wellness, communities, families, economies and rebuild relationships with the land, water, plants and animals that sustain us. Building for Indigenous cultures involves a careful relationship with local ecologies. Native Americans have traditionally valued harvesting most of their cultural foods from nature while the average westerner gets their organic food from the grocery store.

reACT's living systems intentionally aid functional food web formation around its exterior. With a diverse array of plant and soil life, thriving communities of beneficial microbes, insects, and other pollinators are encouraged. Creating habitat for the smaller, allows larger organisms to move back into their natural habitat. This design honors important creatures who allow us to survive.

Wherever reACT is placed geographically, vegetation shall be tweaked to fit the biome and corresponding food webs indigenous to that locality. The main goal of living systems is to create a sense of harmony and balance between the house, its human residents and the surrounding ecosystems. The landscape is being developed according to permaculture principles, an intensive systems-based farming practice that employs a web of mutual support between different plants, insects, birds and other animals. Permaculture is an innovative alternative to industrial monoculture farming practices. The garden plot will provide residents with corn, squash, beans, herbs and other vegetables² irrigated using recycled greywater (safe but non-potable) and fertilized using compost from the kitchen.



Figure 5 – Permaculture Companion Planting

MODEL-BASED ADAPTIVE CONTROL

Many homeowners might be intimidated by the dynamic complexity evident in reACT, but the Team Maryland has made sure they have nothing to fear. reACT has a brain as well as nervous, circulatory and digestive systems. Commercially available home automation systems allow residents to monitor their energy usage, set their thermostats, activate lights, entertainment systems and appliances. reACT's SmartHouse system provides features like this, but also uses a simulation of the home, a virtual house, to predict its performance under a range of weather conditions. Using downloaded weather forecasts and results from the virtual house, SmartHouse can optimize the performance of the house on a daily and even weekly basis. If it predicts a need for heat later in the day and the weather will be cloudy in the afternoon, it may recommend that the Greencourt be configured to collect as much heat as possible in the morning. If the weather forecast predicts rain, SmartHouse may tell the irrigation system to defer watering. SmartHouse can also predict the availability of power from the PV array and optimize the buying and selling of power to the grid in order to save money. This 'load shifting' is enabled by a lithium ion battery system which store electrical energy from the arrays. Knowing the residents' habits of energy use (when they cook dinner and how much energy that requires, for instance), the SmartHouse system can schedule other operations to ensure that net-zero energy balance is met. Intelligently planning the operation of the house based on available supply and demand, reACT will improve comfort and economy for the residents, relieving them of that burden. A key innovation is the accessibility of data from multiple house sensors and weather data for personal use and manipulation.³

SmartHouse features a predictive control system based on physics-based models of the house that can be adapted to any design or climate. It has a hierarchical monitoring and control structure which allows individual components like HVAC with their own control systems to function semi-autonomously, simply adjusting their set points as needed to achieve overall system goals.

MARKET TRANSFORMATION

Native Americans continue to work to improve and protect their livelihoods, cultures and traditions, and many still practice a respectful and unique form of system-based approach to nature which humanizes

² Food from the gardens will not be used in meals prepared as part of the Competition.

³ Testing with the virtual house prototype has been ongoing since early Spring 2017, and has even 'gone live' on the project's research webpage.

sustainability practices. Understanding this approach gives us clues how we can make sustainable choices while adapting to a changing environment. It also helps us to recognize that human beings cannot be removed from nature, nor nature from human beings. A key element of humanizing sustainability practices is to have core values and cultures that are local or regionally placed and held by a community with a long history. Native Americans have these characteristics and have decision making practices aimed for the betterment of the community, as opposed to one individual. Team Maryland contends that their practices are best practices for making ecosystem-based decisions and responding to disturbances that cycle through human landscapes.

Seven Generations and sustainably sourced material are two principles that go hand-in-hand. **reACT** incorporates native materials with significance to the diverse indigenous landscapes and biomes of America. The life cycle of each material has been considered with the intent of optimizing resources by limiting waste. Building materials and equipment are largely recycled and sustainably sourced.

It is well documented that reducing stress and eating non-processed organic foods increases health and well-being. Creating environments that optimize physical and psychological health and well being is essential. Elements such as engaging with nature is important for reducing stress, **reACT** is designed with multiple indoor and outdoor opportunities to engage with nature.⁴ Architectural daylighting and access to unfiltered sunlight increase mood and have benefits such as raising vitamin D levels.⁵ The Greencourt provides year round access to the health benefits of natural sunlight. Growing one's own food organically produces more nutritious meals with less exposure to the heavy metals in fertilizers and pesticides used in commercial farming operations. Herbs and berries, especially important in the traditional Native American diet, are sources of various phytochemicals, many of which possess important antioxidants.⁶ Cultural heritage in the arts, cuisine, and sports is another way of grounding the individual in a place.⁷

Although regenerative living is a revolution that Team Maryland believes that most Americans will eventually embrace, Native Americans are a natural first market for **reACT** because of how it aligns with their cultural traditions and philosophy of living. UMD believes that this approach to building market share represents an innovation in outreach and development.

⁴ Green, 2011

⁵ Rockcastle, 2017.

⁶ Dragland, 2003.

⁷ Living Community Challenge, 2017