Sustainable Laboratories:
A Study of the Application of Green + Sustainable Practices in the U.S. Virgin Islands

An Honors Thesis (ARCH 402)

by

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This Honors Thesis is an extension of the 2011-2012 International Sustainable Laboratory Student Design Competition hosted by the Association of Collegiate Schools of Architecture (ACSA). Ashley Stier, Joshua Stowers, and I joined the competition as a group in Spring 2012. This Honors Thesis served as a tool for expanding and deepening my understanding of green and sustainable practices, and it has acted as a guideline for our competition entry.

The focus of this Honors Thesis is to present research findings on green and sustainable practices that are able to support the requirements of marine laboratories in the climate of the U.S. Virgin Islands (USVI). The research explores many possible options for different building types. The goal is for one or more of the choices to be applicable to the ACSA competition, but also to be used as a model for future projects.

Project-specific metrics regarding each green and sustainable practice are included to show the average requirements of the laboratory campus, and how each selected system, given its design constraints, is able to fulfill the project needs. In order to complete a successful design, a great deal of re-design and re-calculating was necessary before a suitable answer emerged. These metrics are meant to act as a guide for prospective design projects.

Conclusions concerning the ACSA project present the final green and sustainable practices that were chosen to be used in the project and why. The choices made demonstrate a relationship between the research and mathematical application, and explain why the conclusions by the group were successful or unsuccessful at providing the sustainable laboratories with sufficient systems.
ACKNOWLEDGEMENTS

I would like to thank those who provided much appreciated help and guidance throughout the production of my Honors Thesis.

Professor Bob Koester for the knowledge you shared with me, the time you were willing to spend, and the encouragement and guidance you provided along the way.

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And Jeff Culp and Walter Grondzik whose critiques challenged our design, and integration strategies to their maximum.

Thank you all for taking the time to help me produce a piece of work to be proud of.
# CONTENTS

**Author's Statement** 6

1.1 Photovoltaics 8

- Photovoltaic Metrics 10

1.2 Photovoltaic Conclusion 12

2.1 Water Treatment + Storage 14

- Water Storage Metrics 20

2.2 Water Treatment + Storage Conclusion 36

3.1 Natural Ventilation 38

- Cooling Metrics 42

3.2 Natural Ventilation Conclusion 48

4.1 Conclusion 50

Appendix 52

Index 58

Glossary 80

Notes 84

Bibliography 88
This Honors Thesis is an extension of the 2011-2012 International Sustainable Laboratory Student Design Competition hosted by the Association of Collegiate Schools of Architecture (ACSA). The competition enables architecture students from around the world to provide new and innovative thinking in the creation of energy-efficient and environmentally-sustainable laboratories. The site for the competition is located on the proposed Salt River Bay Marine Research and Education Center on the island of St. Croix in the U.S. Virgin Islands (full program attached).

During the 2012 spring semester at Ball State University, Ashley Stier, Joshua Stowers, and I participated as a team in the ACSA competition. Together we designed a marine biology studies campus as a way to represent an application of some of the green and sustainable practices developed through my Honors Thesis (competition boards attached).

The focus of this Honors Thesis is to present research on universal green and sustainable practices. A secondary focus is to offer an application of the research in the form of mathematical proof, and to show that this project is able to successfully support the requirements of marine laboratories, in the climate of the U.S. Virgin Islands (USVI).

There are many different topics this thesis could have addressed, but I chose to center attention on three: photovoltaics, water treatment and storage, and natural ventilation. These components are very important to a healthy green building and tend to blend into other issues such as waste management and energy consumption.

Power from the sun is able to be captured anywhere around the world, and the USVI, located near the equator, is an ideal location for solar collection. With almost equal day and night cycles year round, plenty of energy will be able to be sourced from the sun for the laboratory and the rest of the campus.

Water collection and treatment on an island surrounded by salt water is a vital task. Studying different methods to harvest and supply potable water to a campus of sixty researchers provides efficient strategies and back-up plans for times of drought or water deficiencies.

Natural ventilation is a simple way to cool a space without using any electricity. Because the competition site is located on a bay with constant winds, it provides the perfect chance to take advantage of the prevailing breezes. Constant summer-like weather in the USVI allows occupants the opportunity for natural ventilation year round, with no need for heating.

Metrics regarding each of the green and sustainable practices show that the group project can successfully maintain itself with regards to the three topics of focus. These equations can also be easily applied in future projects.

Conclusions present how the research aspect of the Honors Thesis guided my group to choose the most appropriate systems that best suit the needs and requirements of the laboratory campus.

Having completed this Honors Thesis project, I realize that complex systems are not necessarily the best way to solve complex problems, and that photovoltaics, water treatment, and natural ventilation do not just influence energy, water usage, and cooling. These three simple systems impact much more in a building than what was initially expected.

Author's Statement
Figure A.1 Sustainable laboratory entry view
1.1 PHOTOVOLTAICS

When exposed to direct sunlight, photovoltaic solar cells provide electricity that can be used in real time or stored in batteries for later use. In areas not connected to a power grid, electricity must be stored by batteries for use at night, times of peak energy usage, and days in which the sun is not available. The electrical current produced by a solar cell is dependent on how much light strikes it. In order to maximize solar gain, the cells are combined to create larger panels, which can be arranged together to form arrays (Figure 1.1).

**How Photovoltaics Work**

Photovoltaic (PV) cells are made up of positive and negatively charged layers that transform light into electrical energy. Two semi-conductive layers that make up a PV cell absorb or reflect small particles of solar energy called photons. The negatively charged layer absorbs photons that release electrons from their silicon binding. These electrons are then transferred to the positively charged layer, creating a voltage differential (Figure 1.2). When the two layers are connected to an external load, such as a battery, an electrical circuit is produced and more electrons are then released from the negative layer, continuing the cycle.

**Main Types of Photovoltaics**

There are three main types of Photovoltaic cells: monocrystalline silicon, polycrystalline silicon, and amorphous silicon cells (Figure 1.3). Some of these cells are more efficient than others (Table 1.1), but with high efficiency comes high cost.

Monocrystalline silicon is the most commonly used material for solar cells. It is very efficient, but also quite costly. Monocrystalline silicon is refined from one large crystal and polished to have a smooth, perfect finish that allows it to efficiently absorb sunlight. The energy and expense used to cultivate the crystal is a counter-productive action, but these cells have the highest level of efficiency.

Polycrystalline silicon, while less expensive, has a lower level of efficiency. It consists of many small crystals that are densely packed together, instead of a singular crystal. In order to receive the same output as monocrystalline silicon, more polycrystalline silicon cells are required. This also requires extra square footage in optimal locations, preferably tilted towards the sun, or located on the south side of a building, to place the panels upon.

Amorphous silicon cells are made up of randomly arranged atoms that can be compacted into a very thin, inexpensive film. These cells are much less efficient

**Figure 1.1** The larger the area of a solar array, the more electricity will be produced.

**Figure 1.2** Photons absorbed by the PV release electrons that transfer to upper layers, and then through to be stored or used in an external load.
and require more surface area to achieve the same amount of energy as its crystalline counterparts\textsuperscript{4} and have a shorter production. Amorphous silicon PVs are beneficial as \textbf{building-integrated photovoltaics (BIPV)} because of their thinness and flexibility. 

BIPVs are primarily incorporated into the building envelope, within glazing, shingles and other applications.

\textbf{New Types of Photovoltaics}\textsuperscript{6}

Scientists continue their research to produce more economical and efficient PV cells than the currently popular silicon cells (Table 1.1). Grätzel cells and CIGS cells are the most advanced new photovoltaics, but they are still being tested to maximize their life spans and minimize their material make-up.

Grätzel cells are dye-sensitized cells that imitate photosynthesis. Their creation is an attempt to replace the use of silicon with titanium dioxide\textsuperscript{5}. The Grätzel cells are efficient and inexpensive to produce, and are made from recyclable materials\textsuperscript{1}, but they are still being studied to improve their lifespan and organize their structure\textsuperscript{6}. Because of their make-up, these solar cells have great potential for use in countries where energy is expensive.

Copper-indium-gallium-selenide (CIGS) cells are still very new, but have been shown to be quite expensive and very efficient. Less material and square footage of CIGS cells are required to convert the same amount of electricity as silicon-based counterparts\textsuperscript{7}. They are made up of four layers that are applied to an aluminum foil base, and can be either rigid, glass backed cells, or they can have flexibility\textsuperscript{8}, increasing their range of applications.

\begin{table}[h]
\centering
\begin{tabular}{|l|c|c|}
\hline
\textbf{Cell} & \textbf{Module} \\
\hline
Silicon & & \\
Monocrystalline & 24.7\% & 22.7\% \\
Polycrystalline & 19.8\% & 15.3\% \\
\hline
Thin Film & & \\
Amorphous silicon & 1.0.1\% & 8.2\% \\
\hline
New Types of Cells & & \\
Grätzel cells & 8.2\% & 4.7\% \\
CIGS cells & 19.2\% & 16.6\% \\
\hline
\end{tabular}
\caption{Efficiency records of different types of PV cells and modules.}
\end{table}


\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{solar_cell_efficiency_records}
\caption{From left to right: Monocrystalline PV have a consistent dark blue or black coloration. Polycrystalline PV have varying colors, and crystalline structure resembles granite stone, and CIGS cells are naturally completely black.}
\end{figure}


In order to figure how many solar panels are necessary to power a building, the total square footage of space, type of solar panel, its efficiency, and maximum amount of power used by the facility are required.

**Solar Radiation**

*Solar Radiation in San Juan Puerto Rico*

5.02 kWh/m²/day

**Chosen Solar Panel**

The SunPower E20/327 panel was chosen for this application because of its high efficiency, almost twice as much as thin film solar panels. (Figure 1.4) These cells are a premium type of monocrystalline silicon that have been proven to be the most efficient in the world.

**Panel Efficiency**

*SunPower E20 Panel Efficiency*

20%

**Derate Factor**

Derate factor is a reduction factor that accounts for various conditions, including: transformers, manufacturing inconsistencies, panel and wiring connections, wire resistances, accumulation of dirt, shading, age, maintenance time (when off), and whether or not the cell tracks the sun. All factors are standard except for: shading (for the smaller roofs between modules), and suntracking. Derate factors are based on a per-year basis, and are only relevant for one year (because of the age factor). Derate factor is for the first year of operation, reduction for age is assumed later in the calculations.

---

*Figure 1.4 The SunPower E20 solar panel, with an efficiency of 20%. This is one of the most efficient solar panels on the market.*

Total Solar Gains

Total Roof Area

Rounded Roof Area
(reduced for trim work, gutters, panel edges, etc)
Total area reduced by 10%, then rounded down to the next simplest number.

\[
5.02 \text{ kWh/m}^2/\text{day} \times 0.02 \text{ panel efficiency} = 1.004 \text{ kWh/m}^2/\text{day}
\]

\[
1.004 \text{ kWh/m}^2/\text{day} \times 0.72 = 0.722 \text{ kWh/m}^2/\text{day}
\]

\[
0.722 \text{ kWh/m}^2/\text{day} \times 5,100 \text{m}^2 \text{ collection area} = 3,686 \text{ kWh/m}^2/\text{day}
\]

\[
3,686 \text{ kWh/m}^2/\text{day} \times 365 \text{ days/year} = 1,345,641 \text{ kWh/year}
\]

1,345,641 kWh/year minimum solar collection

1,345,641 kWh/year \times .10 \text{ cloud coverage and dark days} = 1,210,000 \text{ kWh/year}

\approx 1,200,000 \text{ kWh/year assumed for worst case year}

Total Design Collection = 1,200,000 kWh/year
**PHOTOVOLTAICS CONCLUSION**

After choosing to use the SunPower E20 solar panels, it was necessary to figure out if the amount of kilowatt hours collected will supply required power to the building. The next step was to determine what application the power from the PVs will go towards within the building.

### Building Electricity Need Breakdown

#### Lighting

<table>
<thead>
<tr>
<th>Category</th>
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</tr>
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<tbody>
<tr>
<td>Laboratories</td>
<td>84,056 + 5,293 + 8,780 + 1,891 + 5,050 + 2,455 + 52,927 + 8,680</td>
</tr>
<tr>
<td>Wet Labs</td>
<td>+ dry labs</td>
</tr>
<tr>
<td>Teaching Labs</td>
<td>+ administration</td>
</tr>
<tr>
<td>Library/Computer</td>
<td>+ classrooms + fitness/lecture/nursing</td>
</tr>
<tr>
<td>Exterior</td>
<td>+ housing/dining</td>
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<tr>
<td>Total</td>
<td>= 170,000 kWh/year</td>
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</tbody>
</table>

#### Plug Loads

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<tr>
<td>Housing</td>
<td>36,400 + 14,851 + 194</td>
</tr>
<tr>
<td>Student Housing</td>
<td>+ faculty housing + misc.</td>
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<tr>
<td>Total</td>
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</table>

<table>
<thead>
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<table>
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<table>
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</tr>
</thead>
<tbody>
<tr>
<td>Water Pumps</td>
<td>1,300 kWh/year</td>
</tr>
<tr>
<td>Total</td>
<td>= 1,300 kWh/year</td>
</tr>
</tbody>
</table>

### Total Electricity Need

\[
800,000 + 51,000 + 30,000 + 170,000 + 38,000 + 1,300 = 1,090,300 \text{ kWh/year}
\]

\[
1,908,231 \text{ kWh/year} \times 365 \text{ days} = 3,009 \text{ kWh/day} \approx 3,000 \text{ kWh/day}
\]

### Total Electricity Collected

\[
1,210,000 \text{ kWh/year} = 3,686 \text{ kWh/day}
\]
Building 'Grid' Schematic

Battery Storage

Battery system is based on storage of a one 24 hour cycle, plus 3 days of emergency backup supply.

The ideal 3,000 kWh/day needed + 2,200 kWh/3 day emergency backup = 5,200 kWh of usable storage

Damage can be done to the battery if too much energy is pulled out of it. In order to avoid this, only 50% of battery capacity will be considered usable. 50% more energy must be stored in order to contain a full day’s worth plus three days of back up.

5,200 kWh x 2 = 10,400 kWh total battery capacity

With this capacity, the batteries will be able to supply the building with a total of four days of energy loads in case a time of zero energy collection arises.

PV Application

Because the sun is so prevalent in the USVI, solar panels were chosen as the only means of electrical production. Wind turbines, and hydropower were considered, but these methods effected the environment in a negative manner, and unnecessarily extended the footprint on the site.
2.1 WATER TREATMENT + STORAGE

Most fresh water needs some type of treatment before it can be potable. Some problems that must be resolved include bacteria levels, color, odor, taste, or pH levels (hardness). The source of the water dictates what type of treatment is most suitable, so an analysis of the water must be done before an appropriate purification method can be chosen. How water is stored is another decision that must be made. Factors such as how much space is available and the delivery method can help determine how water will be collected.

Importance of Rain Water Collection

Collecting rain water not only provides the occupants of a building with a source of water, but also averts the water from running off the building, collecting toxins from paved surfaces, and ultimately entering sewage drains, multiplying the amount of water that treatment plants will have to process. If buildings and other paved surfaces did not exist on site, rainwater would simply soak into the ground, feeding plants, and charging aquifers. When a building exists on a site, to take responsibility for its existence, occupants should use the water to their advantage for showering or irrigation which greatly reduces runoff levels. It is imperative for climates prone to droughts, or lacking in other fresh water sources to consider collecting and filtering water. It provides a possibility for architectural design opportunities in the way of bioswales and native plantings that can naturally filter the water.

Water Treatment Strategies

Bioswales, or vegetated swales, are a form of bioretention used to partially treat water quality, lessen flooding potential, and carry stormwater away from buildings. They are commonly seen as parking lot islands and medians, but are also used along highways and around any other densely paved area that produces runoff (Figure 2.1). The size of the bioswale determines how much water can be stored or filtered, and must be taken into consideration when designing.

Typically, native flora are the primary plantings within a bioswale. The advantage of the native plantings is that they are able to withstand the harshest climates their environments undergo. Their structures are also characteristically durable and are able to easily filter out toxins from water that foreign species may not be able to handle.

Ecological Wastewater Treatment Systems

are designed to mimic the functions of wetlands by using microorganism metabolism to remove pollutants. They are very similar to bioswales in that they use native plants, but also take advantage of other organisms such as bacteria, algae, and snails to aid in decomposition.

Living Machine® is a specific type of ecological wastewater treatment filtration device created by Worrell Water Technologies. It uses plants and microorganisms to turn wastewater into clean water without the use of chemicals. Living Machines® are versatile and do not require much space. They can be used indoors or out, depending on the climate. All Living Machines® are different in how they look, but they share the same series of steps to filter the water (Figure 2.2).

• Setting Tank - water collects here so larger sediment can settle to the bottom. Filters are used for bigger installations to clear out large amounts of deposits.

Figure 2.1 This is an example of how a bioswale can be layered. Typically, they are seen surrounded by expanses of hardscape, so the water has an alternative place to go other than sewers.

• Control System – the flow of water is managed through a central control system.
• Wetlands Installations – works similarly to bioswales, with added microorganisms, and gravel that work together to remove toxins from the water. These are highly designed ecosystems, and used as an architectural feature within a space.
• Disinfection System – ozone, ultraviolet or chlorine are used to kill any leftover pathogens in the water. This is an optional step depending on how the water will be reused.
• Reuse System – cleaned water is stored and kept in tanks for use for flushing toilets, hand washing, bathing, cleaning, irrigation, ponds, etc.

Living Machines® have high return rates, approximately 95% of the water that runs through is reusable, and very little is lost in the filtration process.

Reverse Osmosis can be used to desalinate, or remove salt, from seawater and wastewater treatment. According to the U.S. Environmental Protection Agency, this process, along with solar stills, are the only systems that may be classified as water “purifiers”; all other systems are water “treatment” devices due to the limited amount of impurities they remove from the water.

Reverse osmosis involves putting pressure on a tank of saltwater solution that forces the solution towards what is called a reverse osmosis membrane. These membranes have very small pores that are only large enough to allow water molecules through. As pure water passes through the filter, contaminants move down a drain which are later cleaned out (Figure 2.3). The salt gets left behind as well as metal ions, organic substances, bacteria and sludge. Reverse osmosis also filters out natural minerals in water, so if it is to be used for drinking, care must be taken to get proper nutrient intake in other ways. Reverse osmosis is one of the most efficient water filtration devices when it comes to contaminant removal, but cannot remove flavor from the water or microorganisms small enough to pass through the filter. It is a slow process, and only produces about 15 gallons of water per day per filter. It also requires 3-5 gallons of untreated water to produce a single gallon of purified water, a low return rate.

Ultraviolet (UV) light, when strong enough, can kill all microorganisms, bacteria and fungi in the water for a complete disinfection. Before UV can be used, all large particles must be filtered out because they block the UV light. Unlike chlorine additives used to kill bacteria, UV does not introduce any chemical additives to the water, but there is no long-lasting effect for UV exposure, so the system must be located nearby the source of use.
Ozone ($O_3$) can be used to purify water with only a small amount of energy and little maintenance. The ozone oxidizes organic and inorganic poisonous compounds and destroys viruses, bacteria, fungi and microorganisms. During the process $O_3$ is broken down into oxygen ($O_2$) and can be released into the atmosphere.

Solar Stills can provide the cleanest drinking water for the least expense, by doing one simple task: evaporating water. Instead of removing impurities from water, the sun heats the water and removes it from the impurities. A simple solar still is a large basin, typically made of a dark color to absorb the sun's rays. The basin is covered with an inclined glass pane that will stop the evaporating water from escaping into the atmosphere, but allows solar radiation to pass through that the darkened base absorbs. As the water heats, the steam content between the water and the glass will increase, and all the heat trapped inside the basin causes pure water to evaporate away from its contaminants. As the water evaporates, any salts, microbes, heavy metals, nitrates, and microorganisms are left behind. The water condenses on the glass, moves down the cover to a collection tank, and can be consumed immediately (Figure 2.4). The return rate of solar stills is promising. For every 1,000 square inch of cover surface, it will produce about 1 gallon of pure water on a sunny day, so a 4 foot by 8 foot solar still should produce 2 to 4 gallons of water a day.

Water Storage Strategies

Water may not all be consumed at the time it is collected so an efficient method to store extra water must be considered. Different water storage devices may be better suited than others depending on the size of the population served, the topography, and the climate of location.

Water Towers

Water towers are seen in small towns located on high elevation. The reason water towers are placed above many of the surrounding buildings, is to use gravity to create water pressure. To do this, towers rely on three main parts: the tower, the tank, and the pump.

Figure 2.4 Contaminated water sitting in a dark basin, is evaporated by the sun. The glass covering captures pure, condensed water that slides down, and is collected. Over time, salts and other microorganisms can build up to a point of saturation, and must be cleaned or flushed out periodically.

Towers provide 0.43 pounds per square inch (psi) of pressure for every foot of height. Most household appliances require at least 20-30psi, so the higher the towers the more pressure can be provided.

Tanks are typically the largest part of the tower, and the largest can hold approximately 1,500,000 gallons of water. A water tower’s tank is sized to hold about a day’s worth of water for the community served by the tower. Larger communities may require more than one tower, depending on water needs.

Pumps are needed to pull water from the water treatment plant up into the tank. In order to reduce the energy used by the pump, during peak water usage hours, the tank will drain, relying only on gravity pressure to distribute the water. This saves the pump from having to feed water up into the tank only to have it instantly drain out again. The pump will refill the tank at times of low demand.

If the community ever demands more water than the pump can supply, many water towers will have water from the treatment plant.
bypass the tank, to be fed directly to users\(^\text{10}\) (Figure 2.5).

**Distribution Methods of Water Towers**

The height of the water tower itself is designed to create enough pressure for all its users. In cities with tall buildings, however, a water tower cannot provide enough pressure to serve the highest occupancies. In these cases, tall buildings have their own pumps and their own water towers\(^\text{10}\) (Figure 2.6).

**Aboveground Tanks**

Aboveground water storage tanks come in many different materials, colors, and sizes that can blend well with their surroundings. They are also very easy to install, and are less expensive than underground tanks\(^\text{11}\).

**Metal + Steel Tanks** are coated with polyethylene linings that ensure water quality and prevent corrosion. Many colors and shapes are available, making them a popular choice for different applications. If cracks in the tanks appear, they are easily repaired\(^\text{11}\).

**Fiberglass Tanks** are a durable selection for aboveground water tanks, but are relatively a more expensive choice. They are corrosion resistant, sturdy, rarely crack, and can withstand harsh weather conditions. Fiberglass tanks also can be placed underground without the effects of the aboveground tanks\(^\text{11}\).

**Bladders** can store between 2,000 - 20,000 liters of water depending on the dimensions of the sac. They may appear to be less durable than other storage systems, and do require a space free of rocks and other debris, but they are made of highly puncture resistant material. Water bladders are designed to be located in the sub-floor space of a building, with all pipes directed into valves on the sac. All rainwater is able to be collected with this method and any overflow is diverted to outside drains to avoid overfilling\(^\text{11}\).
Underground Tanks

Underground water storage tanks provide a safe method to collect potable water. This is a space saving solution above ground, but also requires much soil to be displaced. High pressure, or flow, is also necessary for sufficient water supply to reach its destination. Because of this, underground tanks demand more energy than water towers or aboveground systems.

Concrete Tanks can be delivered or poured on-site. They have enough strength to be installed under driveways or serve as platforms for sheds or other small structures. Unfortunately, because they are located underground, they are very difficult to repair if cracks occur.

Plastic Tanks are made of a very lightweight material, which allows for simple site preparation and installation. They are made from polyethylene plastic that is UV treated and is appropriate for potable water without passing along a plastic taste to the water. Plastic tanks can also be installed aboveground and are available in different colors shapes and sizes.

Water Distribution Systems

‘Dry’ Distribution Systems

Pipes run from the gutter system directly into the storage tank. After a rain event the pipes drain and do not hold water. This is beneficial because water does not stand idle providing breeding grounds for mosquitoes (Figure 2.7).

‘Wet’ Distribution Systems

Pipes from the gutter system run underground, and then up into the tank farther away from the collection source. The distance requires long runs of underground pipes that, even during times without rain, retain water that can serve as breeding grounds for mosquitoes if not properly screened. One way to improve water quality and save water is by converting the ‘wet’ system into a ‘dry’ one by implementing In-Ground Water Diveters. (Figure 2.8).
It is necessary to know how much rainwater a building will be able to collect in order to determine how much storage space will be necessary to contain any left-over water. It is also required to know approximately how much water will be used at any given day at any given time to be sure the amount of water stored will be sufficient to supply the demand during peak water usage hours.

Water Metric Flow Chart

Collection Area

| Collection Area |
|-----------------|-----------------|
| Building        | Area in ft²     | Area in in²|
|                 |                 |            |
| Housing         | 17,500          | 2,520,000  |
| Laboratory      | 44,491          | 6,406,704  |
| Total           | 61,991 ft²      | 8,926,704 in² |

Table 2.1

Figure 2.9 Flow chart depicting the course water takes in order to determine storage tank size.
## Rainfall

**St. Croix Average Monthly**

*From January 1, 1972 - December 31, 2001*

<table>
<thead>
<tr>
<th>Month</th>
<th>Average (in)</th>
<th>High (in)</th>
<th>Low (in)</th>
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</thead>
<tbody>
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<td>2.06</td>
<td>3.74</td>
<td>.54</td>
</tr>
<tr>
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<td>.18</td>
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<td>September</td>
<td>5.28</td>
<td>21.39</td>
<td>1.07</td>
</tr>
<tr>
<td>October</td>
<td>5.44</td>
<td>16.2</td>
<td>1.55</td>
</tr>
<tr>
<td>November</td>
<td>6.21</td>
<td>16.34</td>
<td>1.11</td>
</tr>
<tr>
<td>December</td>
<td>3.41</td>
<td>9.07</td>
<td>1.38</td>
</tr>
</tbody>
</table>

*Table 2.2* Average monthly rainfall for St. Croix. These numbers will help determine how much water can be collected on an average year for the facilities.


---

**Average Annual Rainfall for St. Croix**

![Average Annual Rainfall Chart](chart.jpg)

Figure 2.10
WATER STORAGE METRICS

Collections

1 Gallon = 233 in³
7.5 Gallons = 1 Cubic Foot

\[ 7.5 \times 233 \text{ in}^2 = 1747.5 \text{ in}^2 \]

1 Cubic Foot = 1747.5 in³

Rainfall Total (in) \times \text{Roof Area (in}^2) = \text{Total Rainfall Collected (in}^3)\]

Total Rainfall Collected (in) ÷ 233 in³ = Total Gallons Collected

Total Gallons Collected \times 7.5 \text{ Gallons} = \text{Total Cubic Feet Collected}

<table>
<thead>
<tr>
<th>Month</th>
<th>Average (gal / cuft)</th>
<th>High (gal / cuft)</th>
<th>Low (gal / cuft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>78,923 / 591,923</td>
<td>143,287 / 1,074,626</td>
<td>20,688 / 155,160</td>
</tr>
<tr>
<td>February</td>
<td>70,877 / 531,578</td>
<td>162,060 / 1,215,450</td>
<td>6,896 / 51,720</td>
</tr>
<tr>
<td>March</td>
<td>66,663 / 499,973</td>
<td>158,995 / 1,192,463</td>
<td>18,390 / 137,925</td>
</tr>
<tr>
<td>April</td>
<td>70,877 / 531,578</td>
<td>312,691 / 2,345,183</td>
<td>0 / 0</td>
</tr>
<tr>
<td>May</td>
<td>141,371 / 1,060,283</td>
<td>537,518 / 4,032,683</td>
<td>8,429 / 63,418</td>
</tr>
<tr>
<td>June</td>
<td>83,520 / 626,400</td>
<td>299,983 / 2,249,873</td>
<td>3,831 / 28,733</td>
</tr>
<tr>
<td>July</td>
<td>110,722 / 830,415</td>
<td>234,087 / 1,755,653</td>
<td>18,773 / 140,798</td>
</tr>
<tr>
<td>August</td>
<td>141,371 / 1,060,283</td>
<td>437,140 / 3,278,550</td>
<td>53,687 / 402,653</td>
</tr>
<tr>
<td>September</td>
<td>202,288 / 1,517,160</td>
<td>819,494 / 6,146,205</td>
<td>40,994 / 307,455</td>
</tr>
<tr>
<td>October</td>
<td>208,417 / 1,563,128</td>
<td>620,655 / 4,654,913</td>
<td>59,384 / 445,380</td>
</tr>
<tr>
<td>November</td>
<td>237,918 / 1,784,386</td>
<td>626,019 / 4,695,143</td>
<td>42,526 / 318,945</td>
</tr>
<tr>
<td>December</td>
<td>130,644 / 979,830</td>
<td>347,490 / 2,606,175</td>
<td>52,871 / 396,533</td>
</tr>
</tbody>
</table>

Table 2.3 The average rainfall for St. Croix is 40.29 inches per year. These average monthly numbers will help determine how much water can be collected on an average year for the facilities.
Figure 2.11

Average Annual Rainfall Collection From All Roof Surfaces

Collection in Thousands of Gallons

- Average
- High
- Low

Figure 2.12

Average Annual Rainfall Collection From All Roof Surfaces

Collection in Ten-Thousands of Cubic Feet

- Average
- High
- Low
## Water Consumption of the Campus

Each part of the campus uses different amounts of water throughout a given day. An average total water usage must be found to determine if what is being collected is sufficient for the water demands, and to choose an accurate size for the collection tanks.

### Laboratories

<table>
<thead>
<tr>
<th>Research Labs (x12)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Tanks</td>
<td></td>
</tr>
<tr>
<td>200 Avg. Gallons per Tank</td>
<td></td>
</tr>
<tr>
<td>0.2 Rate of Exchange / 2 weeks</td>
<td>( (5 \times 200 \times 0.2) \div 14 = 14 \text{ Estimated Gallons Used per Day} \times 12 \text{ Labs} \quad 168 \text{ Estimated Gallons Used per Day} )</td>
</tr>
</tbody>
</table>

### Touch Tanks for community outreach exhibits

| 18,000 Total Gallons per Tank |  |
| 0.2 Rate of Exchange / 2 weeks | \( (18,000 \times 0.2) \div 14 = 257 \text{ Estimated Gallons Used per Day} \) |

### Misc. Uses

| 0.1 % for Cleaning and experiments |  |
| \( (14 + 257) \times 0.1 = 27 \text{ Estimated Gallons Used per Day} \) |  |

\( 168 + 257 + 27 = 452 \text{ Total Estimated Gallons Used per Day} \)
## Water Consumption of the Campus Continued

### Housing

<table>
<thead>
<tr>
<th>Activity</th>
<th>Gallons per Brush (12 oz.)</th>
<th>Occupants</th>
<th>Times per Day</th>
<th>Estimated Gallons Used per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brushing Teeth</td>
<td>.1</td>
<td>60</td>
<td>2</td>
<td>( .1 \times 60 \times 2 = 12 )</td>
</tr>
</tbody>
</table>

**Showers**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Gallons per Shower</th>
<th>Occupants</th>
<th>Time per Day</th>
<th>Estimated Gallons Used per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Showers</td>
<td>30</td>
<td>60</td>
<td>1</td>
<td>( 30 \times 60 \times 1 = 1800 )</td>
</tr>
</tbody>
</table>

**Misc. Uses**

<table>
<thead>
<tr>
<th>Activity</th>
<th>% Safety Factor</th>
<th>Time per Week</th>
<th>Estimated Gallons Used per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Misc. Uses</td>
<td>0.1</td>
<td>( (360 + 1800) \times 0.1 )</td>
<td>( 216 )</td>
</tr>
</tbody>
</table>

**Laundry**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Gallons per Wash</th>
<th>Occupants</th>
<th>Time per Week</th>
<th>Estimated Gallons Used per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laundry</td>
<td>25</td>
<td>60</td>
<td>( (25 \times 60 \times 1) \div 7 )</td>
<td>( 214 )</td>
</tr>
</tbody>
</table>

\[
12 + 1800 + 216 + 214 = 2242 \text{ Total Estimated Gallons Used per Day}
\]
### Water Consumption of the Campus Continued

#### Campus Wide + Dining

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toilets</td>
<td>Gallons per Flush</td>
<td>1.28</td>
</tr>
<tr>
<td></td>
<td>Occupants</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Times per Day (Average)</td>
<td>5</td>
</tr>
</tbody>
</table>

\[ 1.28 \times 60 \times 5 = 384 \text{ Estimated Gallons Used per Day} \]

#### Dining

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gallons per Guest</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>On-Site Guests</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Meals per Day</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Visiting Guests</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>% &quot;Smart Kitchen&quot; Reduction</td>
<td>0.7</td>
</tr>
</tbody>
</table>

\[ (((60 \times 3) + 0) \times 9) \times 0.7 = 1,134 \text{ Estimated Gallons Used per Day} \]

\[ 384 + 1,134 = 1,518 \text{ Total Estimated Gallons Used per Day} \]

### Totals:

<table>
<thead>
<tr>
<th></th>
<th>Gallons / Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory</td>
<td>456 Gallons / Day</td>
</tr>
<tr>
<td>Housing</td>
<td>2,410 Gallons / Day</td>
</tr>
<tr>
<td>Campus + Dining</td>
<td>1,518 Gallons / Day</td>
</tr>
<tr>
<td><strong>Total Consumption</strong></td>
<td><strong>4,384 Gallons / Day</strong></td>
</tr>
</tbody>
</table>
Campus Daily Fresh Water Needs

Given that:

The campus requires 4,384 gallons of water per day.

And that:

384 gallons, all toilet and cleaning water is taken from the Living Machine®.

Then:

4,000 gallons of rainwater is needed to supply the campus daily.

4,384 Total Gallons - 384 Toilet Gallons = 4,000 Rainwater Gallons

Campus Monthly Fresh Water Needs

*Fresh Water Need × Days per Month = Monthly Water Demands*

**Monthly Fresh Water Needs**

<table>
<thead>
<tr>
<th>Month</th>
<th>Days</th>
<th>Month Average (Gal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>31</td>
<td>129,580</td>
</tr>
<tr>
<td>February</td>
<td>28</td>
<td>117,040</td>
</tr>
<tr>
<td>March</td>
<td>31</td>
<td>129,580</td>
</tr>
<tr>
<td>April</td>
<td>30</td>
<td>125,400</td>
</tr>
<tr>
<td>May</td>
<td>31</td>
<td>129,580</td>
</tr>
<tr>
<td>June</td>
<td>30</td>
<td>125,400</td>
</tr>
<tr>
<td>July</td>
<td>31</td>
<td>129,580</td>
</tr>
<tr>
<td>August</td>
<td>31</td>
<td>129,580</td>
</tr>
<tr>
<td>September</td>
<td>30</td>
<td>125,400</td>
</tr>
<tr>
<td>October</td>
<td>31</td>
<td>129,580</td>
</tr>
<tr>
<td>November</td>
<td>30</td>
<td>125,400</td>
</tr>
<tr>
<td>December</td>
<td>31</td>
<td>129,580</td>
</tr>
</tbody>
</table>

Table 2.4 Monthly fresh water needs for the facilities in St. Croix. These numbers will determine how much water needs to be collected by the roof in order provide sufficient fresh water needs for the occupants.
WATER STORAGE METRICS

Campus Yearly Fresh Water Needs

4,000 Gallons/Day × 365 Days = 1,460,000 Gallons/Year

Monthly Fresh Water Surplus / Deficit

# Gallons Collected – Monthly Demand = (+)Surplus or (-)Deficit in Gallons

(Average/High/Low Calculated Respectively)

<table>
<thead>
<tr>
<th>Month</th>
<th>Average (Gal)</th>
<th>High (Gal)</th>
<th>Low (Gal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>-50,657</td>
<td>13,707</td>
<td>-108,892</td>
</tr>
<tr>
<td>February</td>
<td>-46,163</td>
<td>45,020</td>
<td>-110,144</td>
</tr>
<tr>
<td>March</td>
<td>-62,917</td>
<td>29,415</td>
<td>-111,190</td>
</tr>
<tr>
<td>April</td>
<td>-40,906</td>
<td>231,400</td>
<td>-125,400</td>
</tr>
<tr>
<td>May</td>
<td>11,791</td>
<td>407,938</td>
<td>-121,151</td>
</tr>
<tr>
<td>June</td>
<td>-41,880</td>
<td>174,583</td>
<td>-121,569</td>
</tr>
<tr>
<td>July</td>
<td>-18,858</td>
<td>104,507</td>
<td>-110,807</td>
</tr>
<tr>
<td>August</td>
<td>11,791</td>
<td>307,560</td>
<td>-75,943</td>
</tr>
<tr>
<td>September</td>
<td>76,888</td>
<td>694,094</td>
<td>-84,406</td>
</tr>
<tr>
<td>October</td>
<td>78,837</td>
<td>491,075</td>
<td>-70,196</td>
</tr>
<tr>
<td>November</td>
<td>112,518</td>
<td>500,619</td>
<td>-82,874</td>
</tr>
<tr>
<td>December</td>
<td>1,064</td>
<td>217,910</td>
<td>-76,709</td>
</tr>
<tr>
<td>Total</td>
<td>17,892 Gal</td>
<td>3,176,719 Gal</td>
<td>-1,199,281 Gal</td>
</tr>
</tbody>
</table>

Table 2.5 Based on the rainwater collections (Table 3.4) and monthly freshwater needs (Table 3.5) tables, the total amount of water that will be left over, or deficient per month can be calculated.
**Average Monthly Gains**

![Bar Chart: Average Monthly Gains](chart1.png)

*Figure 2.13* Average monthly rainwater collection chart. Half of the year looks to be in deficit, but the surplus from the positive months will be able to handle the shortages.

**Water Collection vs Usage per Month**

![Line Chart: Water Collection vs Usage](chart2.png)

*Figure 2.14* The dark blue line represents how much water is consumed by occupants on a monthly basis. The green and red lines represent record high and low rainfalls and collection rates respectively. Average collection is shown by the light blue line.
Living Machine®

90% return on the water coming from the Living Machine®

\[ \text{Monthly Needs} \times 0.9 = \# \text{Gallons Retrieved from the Living Machine®} \]

<table>
<thead>
<tr>
<th>Month</th>
<th>Average (Gal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>116,622</td>
</tr>
<tr>
<td>February</td>
<td>105,336</td>
</tr>
<tr>
<td>March</td>
<td>116,622</td>
</tr>
<tr>
<td>April</td>
<td>112,860</td>
</tr>
<tr>
<td>May</td>
<td>116,622</td>
</tr>
<tr>
<td>June</td>
<td>112,860</td>
</tr>
<tr>
<td>July</td>
<td>116,622</td>
</tr>
<tr>
<td>August</td>
<td>116,622</td>
</tr>
<tr>
<td>September</td>
<td>112,860</td>
</tr>
<tr>
<td>October</td>
<td>116,622</td>
</tr>
<tr>
<td>November</td>
<td>112,860</td>
</tr>
<tr>
<td>December</td>
<td>116,622</td>
</tr>
<tr>
<td>Yearly</td>
<td>1,373,130 Gal</td>
</tr>
</tbody>
</table>

Table 2.6 Average monthly rainfall for St. Croix. These numbers will help determine how much water can be collected on an average year for the facilities.

Figure 2.15
Gray Water Usage

Toilet Usage \((\text{Gal/flush} \cdot \text{flushes}) \times \text{Days per Month}\ = \text{Gray Water Usage (Gal)}\)

\[
(1.28 \text{ Gal} \times (60 \text{ people} \times 5 \text{ times a day})) \times \text{Days per Month} = \text{Gray Water Usage (Gal)}
\]

Flushes = occupants \(\times \#\text{ of flushes per occupant}

<table>
<thead>
<tr>
<th>Month</th>
<th>Average (Gal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>11,904</td>
</tr>
<tr>
<td>February</td>
<td>10,752</td>
</tr>
<tr>
<td>March</td>
<td>11,904</td>
</tr>
<tr>
<td>April</td>
<td>11,520</td>
</tr>
<tr>
<td>May</td>
<td>11,904</td>
</tr>
<tr>
<td>June</td>
<td>11,520</td>
</tr>
<tr>
<td>July</td>
<td>11,904</td>
</tr>
<tr>
<td>August</td>
<td>11,904</td>
</tr>
<tr>
<td>September</td>
<td>11,520</td>
</tr>
<tr>
<td>October</td>
<td>11,904</td>
</tr>
<tr>
<td>November</td>
<td>11,520</td>
</tr>
<tr>
<td>December</td>
<td>11,904</td>
</tr>
<tr>
<td>Yearly</td>
<td>140,160 Gal</td>
</tr>
</tbody>
</table>

Table 2.7
WATER STORAGE METRICS

Gray Water Discharge

Living Machine® Return – Gray Water Usage = Gray Water Discharge

<table>
<thead>
<tr>
<th>Month</th>
<th>Average (Gal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>104,718</td>
</tr>
<tr>
<td>February</td>
<td>94,584</td>
</tr>
<tr>
<td>March</td>
<td>104,714</td>
</tr>
<tr>
<td>April</td>
<td>101,340</td>
</tr>
<tr>
<td>May</td>
<td>104,718</td>
</tr>
<tr>
<td>June</td>
<td>104,718</td>
</tr>
<tr>
<td>July</td>
<td>104,718</td>
</tr>
<tr>
<td>August</td>
<td>104,718</td>
</tr>
<tr>
<td>September</td>
<td>101,340</td>
</tr>
<tr>
<td>October</td>
<td>104,718</td>
</tr>
<tr>
<td>November</td>
<td>101,340</td>
</tr>
<tr>
<td>December</td>
<td>104,718</td>
</tr>
<tr>
<td>Yearly</td>
<td>1,232,970</td>
</tr>
</tbody>
</table>

Table 2.8

![Gray Water Discharge](image)

Figure 2.16
**Maximum and Minimum Storage Needs**

Total Deficit = Sum of all Negative Monthly Fresh Water Collection  
Total Surplus = Sum of all Positive Monthly Fresh Water Collection

<table>
<thead>
<tr>
<th>January - July Deficit</th>
<th>August - December Surplus</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Month</strong></td>
<td><strong>Average (Gal)</strong></td>
</tr>
<tr>
<td>January</td>
<td>-50,657</td>
</tr>
<tr>
<td>February</td>
<td>-46,163</td>
</tr>
<tr>
<td>March</td>
<td>-62,917</td>
</tr>
<tr>
<td>April</td>
<td>-40,906</td>
</tr>
<tr>
<td>May</td>
<td>11,791</td>
</tr>
<tr>
<td>June</td>
<td>-41,880</td>
</tr>
<tr>
<td>July</td>
<td>-18,858</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>-263,206 Gal</strong></td>
</tr>
</tbody>
</table>

| Table 2.9              |                           |                          |                          |

Yearly Total (Deficit + Surplus) = \(-263,206 \text{ Gal} + 281,098 \text{ Gal}\)  
\[= 17,892 \text{ Total Gal}\]
# Tank Storage Calculations

## Given:

Maximum average surplus for storage = 281,098 Gal

Chosen storage goal = 300,000 Gal

Gallons per cubic foot = 7.481

## Restrictions:

Module size for tank type A restricted to 20ft diameter and 48ft tall.

Module size for tank type B restricted to 8ft diameter.

Module size for tank type C restricted to 10ft tall.

## Tank Type A (Labs)

<table>
<thead>
<tr>
<th>Tank Diameter (Restricted)</th>
<th>20 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tank Height</td>
<td>42 ft</td>
</tr>
<tr>
<td>Area ($\pi r^2$)</td>
<td>13,188 ft³</td>
</tr>
<tr>
<td>Gallons per tank</td>
<td>98,653 Gal</td>
</tr>
</tbody>
</table>

*Guess and Check*

$$
\pi \times (10 \text{ft})^2 = 13,188 \text{ ft}^3
$$

$$
13,188 \text{ft}^3 \times 7.481 \text{ Gal/ft}^3 = 98,653 \text{ Gal}
$$

## Tank Type B (Labs)

<table>
<thead>
<tr>
<th>Tank Diameter (Restricted)</th>
<th>8 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tank Height</td>
<td>25 ft</td>
</tr>
<tr>
<td>Area ($\pi r^2$)</td>
<td>1,256 ft³</td>
</tr>
<tr>
<td>Gallons per tank</td>
<td>9,396 Gal</td>
</tr>
</tbody>
</table>

*Guess and Check*

$$
\pi \times (4 \text{ft})^2 = 1,256 \text{ft}^2
$$

$$
1,256 \text{ft}^2 \times 7.481 \text{ Gal/ft}^2 = 9,396 \text{ Gal}
$$
Tank Storage Calculations

**Tank Type C (Housing)**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tank Diameter</td>
<td>22 ft</td>
</tr>
<tr>
<td>Tank Height (Restricted)</td>
<td>42 ft</td>
</tr>
<tr>
<td><strong>Area (π r²)</strong></td>
<td>3,799 ft³</td>
</tr>
<tr>
<td>Gallons per tank</td>
<td>28,421 Gal</td>
</tr>
</tbody>
</table>

Guess and Check

\[ \pi \times (11\text{ft})^2 = 3,799 \text{ ft³} \]

\[ 3,799\text{ft}^3 \times 7.481 \text{ Gal/ft}^3 = 28,421 \text{ Gal} \]

**Totals:**

- **Tank Type A**
  
  2 Tanks x 98,653 Gal = 197,306 Gal

- **Tank Type B**
  
  3 Tanks x 9,396 Gal = 28,187 Gal

- **Tank Type C**
  
  3 Tanks x 28,421 Gal = 197,306 Gal

**Total Storage Capacity (A + B + C)** = 310,756 Gal of Rain Water Collection

*Note: Pressure tanks located in ceilings below roof level, plus the living machine system tanks (output should equal approximately daily total usage times the percent return (4,375x0.95=4100 Gallons...) are also units for water storage. But if these systems are considered in-line operational tanks, it can be assumed that they are figured as additional storage not intended for calculated use.*
2.2 WATER CONCLUSION

For any fully sustainable building, it is required that it be able to filter and collect its own water without supplement from a water treatment plant. With an average annual rainfall of 40.29 inches per year, sufficient water supply should be collected by the facilities. Draughts, and dry seasons are common in St. Croix, so in case the rainwater supply is depleted, a back-up system of solar stills are provided so potable water can be made from sea water.

Water Storage Systems

1. Rainwater collection tanks
   - Aboveground, steel tank
2. Living Machine®
   - In-process storage system
3. Pressurized storage tanks

Treatment Methods

Rainwater
   - Carbon filtration

Gray water
   - Living Machine®

Black water
   - Living Machine®

Saltwater
   - Solar stills - these will be used as a back-up ocean-water filtration device in case of a dry year.

Conclusion

Three methods of water storage systems are necessary for the different types of water being filtered. Rainwater is collected in above-ground steel tanks located in a storage room within the main building. It was decided an above-ground tank would be best placed inside the facility to avoid harsh weather common during hurricane season in the USVI. This method will also prevent any untimely damage that might be done to the tanks. This rainwater will be filtered by a carbon filtration system while it is en-route to the tap to clean out any microorganisms.

Gray water and black water will be filtered by a Living Machine® that will include the disinfection system step that will purify the water enough to be potable.

Solar stills will be used in case of emergencies if the collection of fresh water is depleted. Salt water from the
sea will be decontaminated, and will be able to provide potable water to the campus in times of need. Water from each of these systems will be delivered to the tap by being pumped up into pressurized storage tanks located under the butterfly roofs of the buildings, and above the ceiling of the upper levels (Figure 3.8). These pressurized water tanks act as miniature water towers, so after water is pumped up all distribution is reliant upon the pressure given by the height of the tank.

Figure 2.15 Laboratory and water storage section cut. Blue highlighted tanks were designed to store the water required by the laboratory campus. The water will be pumped up to the pressurized water tanks under the butterfly roofs. From this point, gravity will provide pressure to supply water at the tap.
3.1 NATURAL VENTILATION

Before mechanical heating and cooling systems existed, natural ventilation was the only way buildings and homes received fresh, circulating air. Because of people's current dependence on HVAC systems and the need for airtight buildings, infiltration can occur through holes and cracks in a wall or around windows and doors. In order to design sustainable buildings, natural ventilation must be restored to supply and remove air through an indoor space without using any mechanical systems. There are multiple techniques that can be used to achieve good natural ventilation that all depend on a building's layout and its location.

Natural Ventilation Strategies

Cross Ventilation

Cross ventilation is dependent upon the wind and how it interacts with a building's façade. Openings such as windows and doors are factors that control how much air is able to circulate in a space. Along the windward side of a building where the wind first impacts the façade, a zone of high pressure is created that pushes air through the building. A zone of low pressure is created on the leeward façade due to the alternate paths wind finds as it moves around the structure. Cross ventilation relies upon placement of the apertures on both windward and leeward façades and how the wind flows through them. The orientation of the apertures on the site in relation to the prevailing wind flow is an important aspect to consider. Cross ventilation is best suited for buildings with a narrow, open floor plan with the long façade facing perpendicular to the prevailing winds. Cross ventilation tends to be most effective for buildings with depths of up to five times the ceiling height.

Cross Ventilation Design Considerations

- The area of the inlet must be equal to or 25% smaller than the outlet aperture.
- Single-loaded corridors present better airflow than double-loaded corridors, allowing for fully open inlets and outlets that are not blocked from walls opposite the walkway.
- Air flows in a path of least resistance areas where fresh air does not flow are common and must be checked.
- Cross ventilation will have major influences on site planning and aesthetics of a building.
- Consider security, privacy, and noise transfer.
- Narrow buildings with the long façade perpendicular to the wind direction, and well-placed apertures will maximize efficiency.
- Louvers, balconies, and other building elements must be considered when designing with cross ventilation so they aid the system and do not block airflow or cause turbulence.

Figure 3.2 Air must have an unobstructed pathway to flow through.

Figure 3.3 A simple rule of thumb for designing cross ventilation: it is most effective with depths of up to five times its ceiling height.

Stack Ventilation Design Considerations

- Pressure in the stack must remain high so air is always moving up and fresh air is being pulled in.
- In order to avoid blocking positive pressure flow, exhausts should be placed on the leeward side where the negative pressures will draw air out.
- Operable vents or louvers may be necessary on different faces of a building to respond to changing wind directions.

Stack Ventilation

Stack Ventilation creates air movement by drawing naturally rising and warming air from low elevations in a space up through a stack or chimney where it is released at the top. In order for stack ventilation to work, incoming air must be cooler than the internal ambient temperature of the space, and works best in spaces with high ceilings. To aid in the movement of warm air through the stack, a transparent cap with a darkly colored material with absorptive properties will heat the air at the top of the stack, kick-starting the movement of cool and warm air down below (Figure 3.4).

Figure 3.4 A rotating fan at the top of a stack can aid the air being pulled through the outlet.
Hybrid Ventilation

When environmental conditions are not ideal, or too unpredictable to maintain a comfortable indoor setting, some spaces in a building require a regulated environment and mechanical systems may be required to supplement natural ventilation. Combining mechanical and natural ventilation techniques is known as hybrid ventilation and there are several ways to approach it. This method will result in slightly greater energy use, but if the environmental conditions do not provide comfortable indoor air conditions this will be necessary.

Hybrid Ventilation Design Considerations

- Divide the building into zones for natural ventilation and zones for mechanical ventilation.
- Systems are available that switch from mechanical to natural ventilation when weather conditions are more favorable.

Hybrid Ventilation Strategies

Operable windows are one of the simplest ways to provide occupants with personalized ventilation for the lowest cost. When operable windows are implemented in mechanically ventilated buildings, both systems must work together in order to be a true hybrid system. Triggers that shut air conditioners off when windows are opened prevent the systems from working against each other.

Integral building openings, such as mechanized louver systems, are beneficial when used in situations where operable windows are unrealistic to rely upon. These are best placed in public spaces in which no one person controls the temperature, and can be adjusted to allow more or less air in, and may double as a shading device.

Air handling units (AHU) provide ventilation through a system of air supply ducts when heating or cooling is required (Figure 3.5). When the mechanical units are not necessary, air naturally flows into the building and bypasses the AHU.

Low-pressure air-conditioning has low air velocities in the ducts the air travels through. Because of the minimal pressure, the mechanical system can make use of natural forces such as wind or a passive stack to reduce the energy consumed by the fans.

Thermal masses such as concrete and masonry that are exposed to the outdoors can be used during the daytime to store heat and release it into the space at night (Figure 3.6). Due to cooler nighttime air temperatures, thermal mass will also store the coolth of cold air, absorbing heat during the day, lessening the need for mechanical cooling.

Natural light can prevent much unnecessary cooling loads created by artificial light sources. Taking advantage of natural light also will lower total electrical consumption of the building (Table 3.1).
Figure 3.6 Thermal mass collects warm air during the day, and heats a space in the winter. In the summer, the mass stores the coolth of cool air at night releasing it into a space. Proper shading prevents excess heating in the summer.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Light Level</th>
<th>Light Source</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parking</td>
<td>3-5 FC</td>
<td>HID</td>
<td>0.07 W/sf</td>
</tr>
<tr>
<td>Computer</td>
<td>25 FC</td>
<td>Fluorescent</td>
<td>0.5 W/sf</td>
</tr>
<tr>
<td>Office</td>
<td>50 FC</td>
<td>Fluorescent</td>
<td>1.0 W/sf</td>
</tr>
<tr>
<td>Display</td>
<td>100 FC</td>
<td>Incandescent</td>
<td>2.0 W/sf</td>
</tr>
</tbody>
</table>

Table 3.1 How much energy, in Watts per square foot, different types of light sources use compared to the level of light they produce. All the light energy finally dissipates into the surrounding space as heat.

In order to determine how much cooling a space will need, it is necessary to know the difference between maximum outdoor temperatures and ideal interior temperatures. To figure how much energy will be needed to cool a space, energy used by the air conditioner should be multiplied by the number of degrees that require cooling each month.

**Monthly Cooling Degree Days for Charlotte Amalie VI Harry S. Truman Airport, U.S. Virgin Islands**

<table>
<thead>
<tr>
<th>Month</th>
<th>CDD (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>17</td>
</tr>
<tr>
<td>February</td>
<td>21</td>
</tr>
<tr>
<td>March</td>
<td>27</td>
</tr>
<tr>
<td>April</td>
<td>33</td>
</tr>
<tr>
<td>May</td>
<td>52</td>
</tr>
<tr>
<td>June</td>
<td>86</td>
</tr>
<tr>
<td>July</td>
<td>95</td>
</tr>
<tr>
<td>August</td>
<td>100</td>
</tr>
<tr>
<td>September</td>
<td>79</td>
</tr>
<tr>
<td>October</td>
<td>69</td>
</tr>
<tr>
<td>November</td>
<td>36</td>
</tr>
<tr>
<td>December</td>
<td>20</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>635</strong></td>
</tr>
</tbody>
</table>

Table 3.2 CDD, cooling degree days, are a measure of how much (in degrees), and for how long (in days), outside air temperature was higher than a specific base temperature. They are used for calculations relating to the energy consumption required to cool buildings.

Known:

- CDD for each month of the year
- 3093 sqft = One floor of one module of the lab building
- 1kWh = 3400 BTUH
- COP for Energy Star rated air conditioner = 5.0
- R-24 = R-values for exterior walls (Figure 3.7)

Converting kWh to BTUH

\[ 1 \text{kWh} = 3,400 \text{ BTU/h} \]

\[ 3,400 \text{ BTU/h} \times 5 = 17,000 \text{ BTU/h} \]

\[ 1 \text{kWh} = 17,000 \text{ BTU/h} \]

BTUH per °F

\[ \frac{\text{Square footage}}{R - \text{Value}} = \text{BTUH}/^\circ\text{F} \]

\[ \frac{3093 \text{ sqft}}{R - 24} = 128.9 \approx 129 \text{ BTU}/^\circ\text{F} \]
### Flow Rate (BTUH)

\[ BTUH/°F \times CDD = Flow \ Rate \ (BTUH) \]

\[ 129 \ BTU/°F \times CDD = Flow \ Rate \ (BTUH) \]

<table>
<thead>
<tr>
<th>Month</th>
<th>CDD x 129 BTU/°F</th>
<th>Flow Rate/hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>17</td>
<td>2,193</td>
</tr>
<tr>
<td>February</td>
<td>21</td>
<td>2,709</td>
</tr>
<tr>
<td>March</td>
<td>27</td>
<td>3,483</td>
</tr>
<tr>
<td>April</td>
<td>33</td>
<td>4,257</td>
</tr>
<tr>
<td>May</td>
<td>52</td>
<td>6,708</td>
</tr>
<tr>
<td>June</td>
<td>86</td>
<td>11,094</td>
</tr>
<tr>
<td>July</td>
<td>95</td>
<td>12,225</td>
</tr>
<tr>
<td>August</td>
<td>100</td>
<td>12,900</td>
</tr>
<tr>
<td>September</td>
<td>79</td>
<td>10,191</td>
</tr>
<tr>
<td>October</td>
<td>69</td>
<td>8,901</td>
</tr>
<tr>
<td>November</td>
<td>36</td>
<td>4,644</td>
</tr>
<tr>
<td>December</td>
<td>20</td>
<td>2,580</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>635</strong></td>
<td><strong>81,915 BTUH</strong></td>
</tr>
</tbody>
</table>

Table 3.3
**COOLING METRICS**

**BTU per Month**

\[ BTUH \times 24\text{hrs} = \text{BTU/Month} \]

<table>
<thead>
<tr>
<th>Month</th>
<th>Flow Rate BTUH</th>
<th>( \times 24 \text{hrs} )</th>
<th>BTU/M</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>2,190.88</td>
<td></td>
<td>52,581</td>
</tr>
<tr>
<td>February</td>
<td>2,706.38</td>
<td></td>
<td>64,953</td>
</tr>
<tr>
<td>March</td>
<td>3,479.63</td>
<td></td>
<td>83,511</td>
</tr>
<tr>
<td>April</td>
<td>4,252.88</td>
<td></td>
<td>102,069</td>
</tr>
<tr>
<td>May</td>
<td>6,701.50</td>
<td></td>
<td>160,836</td>
</tr>
<tr>
<td>June</td>
<td>11,083.25</td>
<td></td>
<td>265,998</td>
</tr>
<tr>
<td>July</td>
<td>12,243.13</td>
<td></td>
<td>293,835</td>
</tr>
<tr>
<td>August</td>
<td>12,887.50</td>
<td></td>
<td>309,300</td>
</tr>
<tr>
<td>September</td>
<td>10,181.13</td>
<td></td>
<td>244,347</td>
</tr>
<tr>
<td>October</td>
<td>8,892.38</td>
<td></td>
<td>213,417</td>
</tr>
<tr>
<td>November</td>
<td>4,639.50</td>
<td></td>
<td>111,348</td>
</tr>
<tr>
<td>December</td>
<td>2,577.50</td>
<td></td>
<td>61,860</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>81,835.63</strong></td>
<td></td>
<td><strong>1,964,055</strong> BTU/M</td>
</tr>
</tbody>
</table>

**Table 3.9**

**BTU Per Month**

![Bar Chart: BTU Per Month](image3.9)
\[ \text{BTU/Month} \div \text{BTUH/kWh} = \text{kWh} \]

<table>
<thead>
<tr>
<th>Month</th>
<th>BTU/Month</th>
<th>+17,000</th>
<th>kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>52,581</td>
<td></td>
<td>3.09</td>
</tr>
<tr>
<td>February</td>
<td>64,953</td>
<td></td>
<td>3.82</td>
</tr>
<tr>
<td>March</td>
<td>83,511</td>
<td></td>
<td>4.91</td>
</tr>
<tr>
<td>April</td>
<td>102,069</td>
<td></td>
<td>6.00</td>
</tr>
<tr>
<td>May</td>
<td>160,836</td>
<td></td>
<td>9.46</td>
</tr>
<tr>
<td>June</td>
<td>265,998</td>
<td></td>
<td>15.56</td>
</tr>
<tr>
<td>July</td>
<td>293,835</td>
<td></td>
<td>17.28</td>
</tr>
<tr>
<td>August</td>
<td>309,300</td>
<td></td>
<td>18.19</td>
</tr>
<tr>
<td>September</td>
<td>244,347</td>
<td></td>
<td>14.37</td>
</tr>
<tr>
<td>October</td>
<td>213,417</td>
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<td>12.55</td>
</tr>
<tr>
<td>November</td>
<td>111,348</td>
<td></td>
<td>6.55</td>
</tr>
<tr>
<td>December</td>
<td>61,860</td>
<td></td>
<td>3.64</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1,964,055</td>
<td></td>
<td>116 kWh</td>
</tr>
</tbody>
</table>

Table 3.10

**kwh per Month Histogram**

Figure 3.10

Cooling Metrics

Rebecca L. Ackerman

47
3.2 NATURAL VENTILATION

Laboratories must be mechanically ventilated so experiments can be kept at a constant temperature, and no outside factors disturb lab work. Because much of the project’s program is laboratory, spaces need to be carefully planned out to create an efficient hybrid ventilation system with mechanical and naturally cooled zones.

Naturally Ventilated Areas

**Laboratories**

- 3 full stories of atrium/entrance: 4,406 sqft
- 6 - 2 story office + stair + rest room space: 12,000 sqft

**Housing**

- 9 - 2 story pods + rest rooms: 14,553 sqft

**Dining**

- 1 story dining area: 3,618 sqft

**Housing + Dining**

100% of the housing and dining buildings are naturally ventilated.

**Laboratories**

64,068 sqft total in the laboratory building.

4,406 sqft + 12,000 sqft = 16,406 sqft of the laboratory building is naturally ventilated.

64,068 sqft - 16,406 sqft = 47,662 sqft of the laboratory building is mechanically ventilated.

~26% of the laboratory building is naturally ventilated.

**Conclusion**

Cross ventilation is the best choice for this building in the location it is in. Prevailing winds come from the east, and the building is easily able to take advantage of it with a north-south axis (Figure 3.8). Stack ventilation could have been considered for these buildings, but the building is not tall enough for an effective stack. The spaces that need to be naturally ventilated are located on a single-loaded corridor, and have a narrow shape, so cross ventilation for the main entrance, offices, stairways, rest rooms, housing facilities, and dining hall are the best choice. Louver and vent systems that act together with a small plenum space in the housing units are available to provide cooling even during rainy weather (Figure 3.9).
Figure 3.11 The majority of annual prevailing winds comes from the east. It is best to place a building’s axis perpendicular to the prevailing winds to best take advantage of them.

Source: Climate Consultant 5.0, VIR_Charlotte_Amalie-Harry_S_Truman.AP.785430_TMY3.epw.

Figure 3.12 Above: fluid mapping table image determining if the vents and plenum space in the housing building will provide sufficient natural cooling. Right: Similar ventilation diagram, showing the context of the housing building.
4.1 CONCLUSION

This project began as three individual endeavors in the fall of 2011. Classmates Ashley Stier, Joshua Stowers, and I each completed a first pass of what we envisioned the design of a sustainable laboratory campus in St. Croix to look like (Figure 5.1). At the beginning of the Spring 2012 semester, we joined together to develop and submit the design of a more complete, functional campus plan for the ACSA competition. This Honors Thesis served as a tool for me to better understand green and sustainable practices, as well as a guideline for our team's competition entry. By applying my Honors Thesis to the competition project, I was able to utilize my research in a setting that helped our team to draw conclusions for our final laboratory design.

When determining which systems to use in our building, there was a great deal of push and pull between research and design. Some systems required a preliminary design before engaging research, while others needed more research to guide the design.

The water treatment and storage metrics were able to be completed first because the water needs of the residents, and available annual rainfall were known before any design began. With this research, we were able to plan a design to satisfy the balance of 100% of the water supply/demand conditions.

A rough design phase for natural ventilation was finished before any metrics were examined, and after some testing on the fluid-mapping table, and re-designing, we were able to run the qualitative flows and quantitative estimates of performance metrics to ensure the design was as effective as possible.

Design, primarily of the roof area, guided the potential location and quantity of photovoltaics that could be placed for electrical energy production. After studies and calculations, it was determined that sufficient energy from the sun is available to power the campus. One problem we encountered was in regards to periodic excesses of energy the PV cells would collect. Storing all the energy in battery backups is not possible in any known system, so we had to come up with an alternative storage and distribution system for energy collected by the PV cells (see section 1.2 Photovoltaics Conclusion).

While focusing on photovoltaics, water treatment, natural ventilation, electricity and waste management came up as important issues. To figure how many PV panels were needed, we had to determine approximately how much energy would be used on a daily basis by the campus. When dealing with ventilation, we needed to know how much energy an air conditioner would consume, and check back with our photovoltaic metrics to be sure the power we would collect would be enough for their loads.

Water is a management challenge; its treatment is not only for rainwater or saltwater, and we had to consider how greywater and blackwater would be filtered and disposed of especially because the laboratory site is not located near a wastewater treatment plant.

I originally proposed a ten-page research paper solely focusing on natural ventilation techniques. I quickly discovered, however, that aspects of natural ventilation effect energy consumption that in turn, affects energy collection. This required me to expand my studies and elaborate upon some of the other systems in a building that interact with the natural ventilation system. This expansion made me understand that each system does not stand on its own, and it is important to recognize all aspects of a building. I learned that each system interacts with each other and collectively can have a strong impact on the environment and the design process.
Figure 5.1 Left: Snapshots of the fall 2011 individual entries for the ACSA Sustainable Laboratory Student Design Competition. Entries in alphabetical order from top to bottom: Rebecca Ackerman, Ashley Stier, Joshua Stowers.

Below: Snapshot of the spring 2012 group entry for the ACSA Sustainable Laboratory Student Design Competition.

Sources: Rebecca L. Ackerman, SYM{bio}/SIS, Ball State University, 2011.
Ashley R. Stier, earthen RESPONSE, Ball State University, 2011.
Joshua M. Stowers, St. Croix Marine Ecological Research Facility, Ball State University, 2011.
Rebecca L. Ackerman, Ashley R. Stier, and Joshua M. Stowers, 2011-2012 ACSA Sustainable Laboratory Competition, Ball State University, 2012.
APPENDIX

SENIOR HONORS THESIS / CREATIVE PROJECT PROPOSAL

Rebecca Ackerman
Major: Architecture   Minor: Spanish
Expected Graduation Date: May 2012

Fall semester 2011 the ARCH 401 Architectural Design class is participating in a class wide competition sponsored by Cripe Architects + Engineers as their final project. The ‘Cripe Competition’ is a marker for all fourth year architecture majors to showcase their talents given a short, seven-week deadline.

This year, the Cripe Competition happens to be of a larger international competition. This international competition is the 2011-2012 International Sustainable Laboratory Student Design Competition hosted by the Associate of Collegiate Schools of Architecture (ACSA) (program attached). The ACSA hosts a different themed competition each year under similar goals of "innovative thinking" and "the creation of energy-efficient and environmentally-sustainable laboratories". This year, the site is located in the U.S. Virgin Islands on the island of St. Croix. Participants must design laboratories, housing facilities, and a community outreach center for scientists, students, and St. Croix residents, while remaining conscious of the sustainable aspects required, and unfamiliar environmental challenges of St. Croix.

Fall semester, students will be using the guidelines from the international competition to complete a first pass at what they believe the laboratory should look like, and how it should function. It is also a requirement that students work individually for this semester, no team projects will be accepted. At the end of fall semester these final drafts of the laboratories will be submitted and judged by Ball State faculty and alumni, and winners of the 2011 Cripe Competition will be announced.

Spring semester, students will be given the option to continue to develop their Cripe Competition projects in order to submit it to the 2011-2012 International Sustainable Laboratory Student Design Competition in May 2012. In order to fulfill the demands of the project and have a fully developed program, teams will be allowed to form, and enter the competition together. For the spring semester, I plan to continue developing my Cripe Competition entry, and submit it in the international competition in May. I also plan to collaborate with two partners, Ashley Stier and Joshua Stowers. We will combine our first iterations together, and each study one specific aspect of the building in order to create a balanced symbiosis of systems, structure, and sustainability.

My topic of interest will be passive cooling systems the building will require. I will do an extensive study on these issues in regards to the climate of St. Croix, and report on their benefits and drawbacks. With this study, I will complete a collection of diagrams and explanations showing how each passive cooling system works. This will consist of a research paper to be approximately 10 pages. I will use this study in order to inform my design project for the international competition, and apply it to a broader scale in which the other members of my team will also participate.

With my studies, I hope to communicate the different passive cooling systems available for different climates in order for other architects and builders to easily see, and choose which system may best help their designs.
**SOLAR ENERGY COLLECTION**

**TOTAL SOLAR COLLECTION**
- Lab: 66,600 kWh/yr
- Office: 52,900 kWh/yr
- Total: 119,500 kWh/yr

**ENERGY STORED**
- Lab: 7,000 kWh/yr
- Office: 9,000 kWh/yr
- Total: 16,000 kWh/yr

**PLUG LOADS**
- Lab: 200 kWh/yr
- Office: 150 kWh/yr
- Total: 350 kWh/yr

**PERMANENT LOADS**
- Lab: 500 kWh/yr
- Office: 400 kWh/yr
- Total: 900 kWh/yr

**WATER PUMPS**
- Lab: 100 kWh/yr
- Office: 150 kWh/yr
- Total: 250 kWh/yr

**TOTAL ENERGY CONSUMPTION**
- Lab: 7,231 kWh/yr
- Office: 9,000 kWh/yr
- Total: 16,231 kWh/yr

**PARAMETERS / FEATURES**

**SOLAR BES**

**BEST PRACTICES**

**SUSTAINABLE LAB**

**ENERGY STAR RATED**

**ADDITIONAL ENERGY DESIGN FEATURES**

**LIGHTING**
- Dimmable lighting systems for meeting spaces
- LED task lighting

**MECHANICAL SYSTEMS**
- High-efficiency HVAC systems
- Variable air volume (VAV) systems
- Ceiling-level supply/return air distribution
- Ceiling-level return air grilles

**WATER CONSERVATION MEASURES**
- Drought-tolerant landscape materials
- Water-efficient landscaping fixtures
- Low-flow toilets
- Water-saving fixtures in restrooms

**WATER CONSUMPTION**

**WATER INDICATORS**

**WATER COLLECTION**

**TOTAL WATER COLLECTION**
- Lab: 1,243,594 gallons
- Office: 1,960,298 gallons
- Total: 3,168,592 gallons

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SUSTAINABLE LAB COMPETITION
2011-2012 INTERNATIONAL SUSTAINABLE LABORATORY STUDENT DESIGN COMPETITION

INTRODUCTIONS
The Association of Collegiate Schools of Architecture (ACSA) is pleased to announce the International Sustainable Laboratory Student Design Competition for the 2011-2012 academic year. Inspired by the success of the Laboratories for the 21st Century (Lab21-B1) Student Design Competition (2003–2004), the International Institute for Sustainable Laboratories (IISL) is hosting the International Sustainable Laboratory Student Design Competition with the Office of Insular Affairs (OIA) of the U.S. Department of the Interior and in collaboration with the Association of Collegiate Schools of Architecture and the Joint Institute for Caribbean Marine Studies (JICMS).

The competition will enable architecture and engineering students from around the world to provide new and innovative thinking in the creation of energy-efficient and environmentally-sustainable laboratories.

The competition will focus on the proposed Salt River Bay Marine Research and Education Center (MRBCEC), to be located within Salt River Bay National Historial Park and Ecological Preserve (SRB) a unit of the National Park Service (NPS) on the island of St. Croix in the U.S. Virgin Islands (USVI).

THE IMPORTANCE OF SUSTAINABLE DESIGN
Sustainably designed buildings seek to reduce or eliminate their impact on the environment through reduced energy use and resource efficiency. The building industry — encompassing facility design, construction, engineering, and facility operations — is seeking to develop, redevelop, and retrofit buildings that are healthy, environmentally responsible, and cost-effective. The goal is to minimize natural resource consumption while enhancing social and economic benefits.

INNOVATION
The competition seeks to explore and develop ideas, systems, and applications utilizing sustainable design for the Marine Research and Education Center laboratory and campus, based on the actual building program of the facility and the project goals of the partners.
“As a building type, the laboratory demands our attention. What the cathedral was to the 14th century, the main station was to the 19th century, and the office building was to the 20th century, the laboratory is to the 21st century. That is, it is the laboratory that embodies, in both program and technology, the spirit and culture of our age and attracts some of the greatest intellectual and economic resources of our society.” — Ivan Pondner, FAIA, 1950-2002

The competition organizers are combining efforts to make the public more aware of the important role that energy-efficient and environmentally sustainable laboratories serve in the educational, economic, and social success of our communities and nations. This collaborative competition will enable students to advance building innovations within the limitations of conventional industry practices — and use their untapped creativity to shape the future of sustainable laboratory design, engineering, and operation.

COMPETITION PHILOSOPHY

Laboratories, as a building type, must provide spaces that enable students to conduct experiments with high standards and controls, thereby ensuring that the results of experiments are authentic, replicable, and long-lasting. The complementary needs for safe, control, and safety have driven the evolution of the modern laboratory into today’s complex and sophisticated structures.

All laboratories — from intramural to research and testing facilities — should provide an environment that functions, attracts, engages, and motivates students to their highest level of creativity and intellect. The competition encourages participants to break through traditional thinking to creating buildings that do much more.

Given the impact of the built environment on the ecological health of our planet, sustainable design is one of the most critical issues challenging building designers. For laboratories, this is especially true, given that lab facilities are among the largest energy users among buildings. Architects and engineers, therefore, must embrace the ethic of sustainable design and engineering to create buildings not only of beauty and integrity, but also of ecological soundness and performance.

Based on this vision, the 2011-12 International Sustainable Laboratory Student Design Competition will promote in participating students an awareness of the challenge of creating laboratories sustainable in design, engineered systems, and operations.
MARINE RESEARCH ON ST. CROIX

Research has been an important activity within the U.S. Virgin Islands for more than a quarter century.

St. Croix, the southernmost of these islands, provides a rich environment for tropical marine research, especially on coral reef ecosystems. Marine research activities began on St. Croix in the late 1960s, providing some of the oldest available data on coral reefs. Some of the world’s leading marine researchers gathered data at two former marine laboratories on St. Croix: the West Indies Laboratory (WIL) on the east end of St. Croix, and the National Oceanic and Atmospheric Administration’s (NOAA) National Undersea Research Program’s habitats, the Hydrophi, then the Aquarius, which operated at Salt River Bay until Hurricane Hugo damaged both the National Oceanic and Atmospheric Administration and West Indies Laboratory facilities in 1989. The scientific records generated by investigators at these two facilities are one of the primary tools used for understanding, monitoring, and documenting of coral reef condition.

Under a cooperative agreement with the National Park Service, West Indies Laboratory produced the first marine research and assessments at Buck Island Reef National Monument (BIRNM), established on St. Croix in 1961. West Indies Laboratory researchers mapped, inventoried, and investigated the ecology, function, status, and trends of Buck Island marine resources, including coral geology, reef fish, marine invertebrates, sea turtles, seagrass, and coral reef habitats. Over time, Buck Island became one of the best-documented and studied marine ecosystems in the Caribbean and served as a pre-release field school for hundreds of West Indies Laboratory students.

The documentation of the long-term degradation of St. Croix’s marine resources was used in 2001 to support the expansion and designation of Buck Island Reef as a marine protected area. In addition, these data have guided resource managers in the recovery of degraded reefs, which are designated as a critical habitat in the U.S. Virgin Islands. These examples show how the National Park Service on St. Croix have benefitted from marine research and documentation, and the need for that capacity will only grow as resource management issues become more complex.

THE MARINE RESEARCH AND EDUCATION CENTER CONCEPT

In the mid 1990s, scientists and resource users had worked on St. Croix began to work with the National Park Service and the Office of the Governor to create St. Croix’s marine research capacity.

In 1999, the Department of the Interior entered into a memorandum of understanding with the newly-formed Joint Institute of Caribbean Marine Studies to aid in the understanding of the marine environment, including coral reef ecosystems, promote marine education and public awareness, and assist in the development of appropriate public policy within the Caribbean.

Through this agreement, the partners sought to:
- Foster collaborative research programs to understand and protect marine resources of the Caribbean
- Support marine education programs for school children and adults in the U.S. Virgin Islands
- Foster cooperation with other government, institutional, and private organizations to better understand marine issues in the Caribbean
- Enrich the learning environment and opportunities for the University of the Virgin Islands and other community students

In addition to focusing on acquiring the West Indies Laboratory site, the partners and the property owners could not reach agreement. In 2001, the National Park Service acquired property almost 100 acres on the east side of Salt River Bay. Given the combination of global and local threats to coral reefs and its resource management responsibilities, NPS approached the Office of Island Affairs and the Joint Institute for Caribbean Marine Studies about building the Marine Research and Education Center at Salt River Bay.
Sustainable Lab Competition
2011-2012 International Sustainable Laboratory Student Design Competition

The Marine Research and Education Center project includes research laboratories, classrooms, a lecture hall, teaching facilities, books and housing equipment, and opportunities for students and visiting researchers. The facility will serve undergraduate and graduate students through a variety of research and education programs provided by the Joint Institute for Caribbean Marine Studies.

In addition to providing research and education programs, the Marine Research and Education Center will enable the partners to strengthen undergraduate and graduate marine studies programs in the U.S. Virgin Islands by providing research and internship opportunities not available on St. Croix.

By coordinating with the competition sponsors, the Joint Institute for Caribbean Marine Studies is seeking to instill among tomorrow's planners, architects, and engineers a deep and shared appreciation for scientific research while promoting sustainability as integral to successful scientific endeavors.

The Location: Salt River Bay National Historical Park and Ecological Preserve

The Marine Research and Education Center will be located on a 9-acre site on the north-central coast of St. Croix. The former's Peninsula site east of Salt River Bay offers direct access to adjacent salt pond and mangrove ecosystems. The site has an extensive cultural history including the remains of two prehistoric villages of the indigenous Indians and a ball court constructed more than 2000 years ago.

The site was part of Columbus's many visits to the island. On November 14, 1493, Christopher Columbus's party came ashore at Salt River Bay. It is the only site within a U.S. territory visited by Columbus's party during his voyages.

Salt River Bay National Historical Park and Ecological Preserve is one of four co-managed National Park Service units; National Park Service shares the management responsibilities with the Government of the Virgin Islands. Within the park boundaries are more than 30 acres of mangrove estuaries, habitat, coral reefs, and a submarine canyon.

Salt River Bay National Historical Park and Ecological Preserve is one of the few co-managed National Park Service units; National Park Service shares the management responsibilities with the Government of the Virgin Islands. Within the park boundaries are more than 30 acres of mangrove estuaries, habitat, coral reefs, and a submarine canyon.

Several miles east of the site, the St. Croix East End Marine Park was established in 2003 as the U.S. Virgin Islands' first terrestrial marine park. It encompasses 60 square miles, including four square miles of marine areas off the northern and eastern coasts of St. Croix. Combined with the submerged lands within Salt River Bay National Historical Park and Buck Island Reef Natural Monument, these marine park areas protect one of the largest coral reef ecosystems in the Caribbean.

The Marine Research and Education Center will be within Salt River Bay's boundaries, so maximizing the impact of the facility on the park is an important project goal. Because a hotel and marina project was partially constructed during the 1970s (prior to Salt River Bay’s designation as a national park), Hermit’s Peninsula is considered a gray field — one previously disturbed but not so adversely affected that it is classified as a brown field.

Competition designs must consider the Salt River Bay National Historical Park and Ecological Preserve legislative mandate to study and preserve the park's historical and natural resources, as well as to advance the project's sustainability goals of net zero annual electricity use and net zero waste use (so that the project collects at least as much of each of these resources as it uses). Additional background information regarding the project partners' goals will be posted on the competition website by alliance during the competition.
SUSTAINABLE LAB COMPETITION
2011-2012 INTERNATIONAL SUSTAINABLE LABORATORY STUDENT DESIGN COMPETITION

COMPETITION CHALLENGE
For the competition, students are required to address the following in their submissions:
- Laboratory details incorporating the design and engineered systems for the marine research laboratory facility that is part of the Marine Research and Education Centers.
- A concept plan describing community and infrastructure, including on-site energy generation, potable water supply, wastewater disposal, or systems in place providing both new and existing resources to the research laboratories within the Marine Research and Education Centers, solid waste disposal, bio-digester, and water filtration system planning.

Teams of students from multiple disciplines, including but not limited to facility planning, architecture, engineering, and facility operations, are encouraged to collaborate to fulfill these requirements while addressing critical issues of the program. These include appropriate responses to climate and culture, defense to available natural resources, integration of design and systems, and the maintainability of the laboratory and campus long term operation and maintenance in a sustainable manner.

In addition, students should apply the following evaluation criteria when defining the concept and scope of their proposal:
- Minimal use of fossil energy consumption.
- Ecological sensitive water and waste water systems.
- Minimal or no impact to the marine and natural environments during construction.
- Architectural expression that embraces the ethic of sustainability and restoration.
- Integration of engineered solutions with sustainable and indigenous design strategies.
- Maintainability of building and its components.
- Relationship to the environment.
- Design for human performance.
- Design for flexibility and adaptability.
- Design for long-term sustainable operation and maintenance.
- Exceptional innovation.

REQUIREMENTS FOR MARINE RESEARCH AND EDUCATION CENTER DESIGN
The laboratory shall:
- Incorporate life cycle strategies that consider the living marine systems and that are site specific, restorative and adaptive. Because the marine of the Marine Research and Education Center is an unstable marine ecosystem within the U.S. Virgin Islands, the program is envisioned to continue adaptively. Because the marine and methods to achieve research and education goals change over time, designs are encouraged to include strategies that can adapt to changing needs.
- Utilize technologies that are appropriate for the remote nature of the site and that are maintainable/repairable for the lifespans of the building.
- Provide collaborative spaces that promote learning through teaching and research.
- Serve to reenergize the scientific community in the Caribbean.
- Provide storage for scientific and logistical needs/contracts.
- Accommodate 12 researchers and/or scientists.
- Include wet and dry laboratories that will support a flexible marine research program, a computer lab supporting these laboratories that also can be used for classroom instruction, classroom space accommodating a maximum of 40 undergraduate students at one time, and teaching laboratories to serve these students.

The campus shall:
- Be a local attraction and engage the local community, and support island culture.
- Minimize (if possible) the use of fossil fuels for energy use.
- Reduce the construction impacts of energy use, emissions, and waste.
- Promote local materials and modular construction.
- Demonstrate the sustainability ties between design, construction, operation, and maintenance.
**SUSTAINABLE LAB COMPETITION**

2011-2012 INTERNATIONAL SUSTAINABLE LABORATORY STUDENT DESIGN COMPETITION

**MARINE RESEARCH AND EDUCATION CENTER SPACE SUMMARY**

As the Marine Research and Education Center campus will comprise multiple buildings, competitors are encouraged to use creativity in designing the number of individual structures and the separation or combination of their functions. Below is the Marine Research and Education Center's actual building program that encompasses the functions of the facility. This program should be used as guidance in the submission but can be adapted for use by the teams.

<table>
<thead>
<tr>
<th>Program Space</th>
<th>Description</th>
<th>Total GSF</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Building s</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laboratory</td>
<td>Wet &amp; dry laboratories (dual use: marine research for 12 researchers/students)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Computer Lab</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Classroom space (for a maximum of 48 students)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Boating Laboratories</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Storage for scientific and biological research/outreach</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Laboratory &amp; Lab Support Spaces - TOTAL</td>
<td>15,000</td>
</tr>
<tr>
<td>Building Administration</td>
<td>Offices &amp; office support spaces</td>
<td>3,000</td>
</tr>
<tr>
<td>Lecture &amp; Teaching</td>
<td>Classroom, lecture, conference rooms</td>
<td>5,000</td>
</tr>
<tr>
<td>Community Outreach</td>
<td>K-12 education facilities, exhibits, &amp; touch tables</td>
<td>6,000</td>
</tr>
<tr>
<td>Collections</td>
<td>Collections archive/storage, object preparation, object cataloging</td>
<td>2,500</td>
</tr>
<tr>
<td>Living/Accommodation</td>
<td>Student residences (up to 48 residents), dining space (up to 48 residents), staff housing (4 residents), support for these spaces</td>
<td>20,000</td>
</tr>
<tr>
<td>Boat Dock/Dive Operations</td>
<td>Dock, Dive operations &amp; support spaces</td>
<td>3,000</td>
</tr>
<tr>
<td>Maintenance Building</td>
<td>Other support spaces including fuel storage, landscaping, etc.</td>
<td>5,000</td>
</tr>
<tr>
<td><strong>Building Totals</strong></td>
<td></td>
<td>60,000</td>
</tr>
<tr>
<td><strong>Site</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site Support</td>
<td>Seawater holding tanks, energy generation, composting, transportation, etc.</td>
<td></td>
</tr>
</tbody>
</table>
ENVIRONMENTAL CONSIDERATIONS

AMBIENT AIR TEMPERATURE

The average dry bulb temperature of St. Croix is 62°F with temperatures remaining relatively constant throughout the year with a typical swing of ±10°F. There is very limited seasonal variation in temperature with modest daily temperature swings (day-night).

WATER TEMPERATURES

Water temperature data will be provided on the competition website.

Figure 1: Interpolated bathymetry for Salt River Bay, based on the available soundings conducted in 1982 and 1977 from National Oceanic and Atmospheric Administration Geophysical Data System.
HUMIDITY
The relative humidity at St. Croix also has fairly limited seasonal variation, averaging approximately 70 percent and generally staying between a low of about 60 percent and a high of 90 percent.

WIND
A wind rose diagram plots the annual frequency of wind speed and direction, with the prevailing winds predominantly from the east and southeast and velocities most commonly in the range of 3 to 6 meters per second.

Solar Radiation and Cloud Cover
The solar radiation on site is relatively high, averaging 5.4 kilowatts-hours per square meter per day, with only 40 percent average annual cloud cover.

Figure 3 shows the sun path at the site, the park boundary, 100-year floodplain, and an archaeological zone on the site. The exhibit was developed by the partners during the Marine Research and Education Center's conceptual design process and is provided here as guidance for campus master planning purposes.
Figure 4: Psychrometric Chart

Figure 4 provides a graphic representation of comfort conditions, plotting dry-bulb temperature, wet-bulb temperature, and relative humidity. The Marine Research and Education Center program contains both museum storage and laboratory spaces which have both temperature and maximum relative humidity requirements of 60 percent.

SUSTAINABLE DESIGN METRICS

Green building rating systems provide an effective, holistic framework for both addressing the environmental impacts of building design and construction as well as setting concrete performance targets to refer to design. Additional sustainable design measures may be found on page 18 of this program.
SUSTAINABLE LAB COMPETITION
2011-2012 INTERNATIONAL SUSTAINABLE LABORATORY
STUDENT DESIGN COMPETITION

ENVIRONMENTAL CONSIDERATIONS

FACILITIES MAINTENANCE
Design and engineered systems must acknowledge the surrounding environment and occupants in regards to maintenance, accessibility, durability, and cost feasibility.

COMMUNITY AWARENESS AND IMPROVEMENTS
A key goal of the Marine Research and Education Center is the demonstration of environmentally responsible, sustainable development. A key element of sustainability is that the project be designed in response to local environmental challenges and in harmony with local conditions while supporting cultural awareness.

A 2005 survey identified air quality and sewage as the environmental area of greatest concern to St. Croix residents. The island is home to the Hovensa Refinery, the second largest oil refinery in the United States and one of the 10 largest oil refineries in the world. In 2011 the U.S. Environmental Protection Agency began a 3-month study of air pollution in response to community demands about the health impacts of airborne chemical releases from the refinery. Additional air quality threats are posed by the Richmond power plant near Christiansted, St. Croix, which produces electricity using oil-fired generators.

Highly published raw municipal sewage discharges have caused periodic fish kills and beach closures. The majority of homes on St. Croix are served by septic systems. Due to poor soil conditions, steep slopes, and limited regulations, untreated effluent from failing septic systems also poses an environmental challenge, both to human health as well as the marine ecosystems that are the focus of the Marine Research and Education Center. Erosion and sedimentation resulting from stormwater runoff caused by poor soils, steep slopes, and conventional development further stress the marine ecosystem. Additionally, the services conventionally provided by municipal systems in other locations are much more dependable and less reliable on St. Croix.

There is very limited fresh water supply from conventional sources. There is little ground water and obtaining municipal water from a desalination plant is energy intensive and expensive. Municipal desalination is among the most expensive in the U.S., and the supply is unreliable with frequent, unpredictable interruptions which pose a particular challenge to a research environment where reliability is critical.

An environmentally responsible facility on St. Croix should be designed to: directly address the local environmental challenges of air pollution, water pollution (both from sewage and stormwater), limited fresh water supply, and polluting, expensive, and unreliable electricity.
SUSTAINABLE LAB COMPETITION
2011-2012 INTERNATIONAL SUSTAINABLE LABORATORY
STUDENT DESIGN COMPETITION

- Integration of Solutions with Sustainability/Restorative Design Strategies
  Architectural design and engineered systems must reinforce the common commitment to sustainability and restoration both in form and function as well as support long-term sustainable operations.

- Maintainability of Products and Facility
  The delivery of a sustainably constructed and designed facility is only a first step toward meeting the objectives of this competition. The ability and durability of design, components, products, and systems must be readily accessible, cost-effective in their maintenance, and long-lasting in providing the service for which they were intended. The maintenance process must not have negative environmental impacts on the staff, building occupants, and the community.

- Design for Human Performance
  The design solution should support and enhance the learning process through spatial configurations that foster collaboration between students and their faculty and through spaces that achieve high levels of indoor environmental quality pertaining to exposure, thermal comfort, sound quality, concrete performance, and indoor air quality.

- Design for Research Functionality
  The laboratory shall be designed to incorporate elements needed for modern marine science research with appropriate adjacencies between the indoor laboratories, classrooms, and outdoor research spaces.

- Design for Flexibility and Adaptability
  The design solution should allow for changes in programmatic needs and associated laboratory configurations by using modular design and flexible distribution systems in order to reduce waste generation in the future, and disruption of the building functions, and incorporates lifecycle strategies that consider being aware systems that are sustainable restorative and adaptive.

- Extraordinary Innovation
  Space will be given to competition that incorporate particularly innovative ideas in their design solutions — ideas that advance results beyond the expectations of the sponsors.

DESIGN INNOVATION
The Marine Research and Education Center is a real project being developed by the Joint Institute for Caribbean Marine Studies in partnership with the U.S. government. Students should focus on their own innovative and original designs for the project.

Concepts and strategies contained in all submissions, not just winning submissions, have the opportunity of being applied at the actual Marine Research and Education Center campus. Students' contributions would be recognized if the cases.
SUSTAINABLE LAB COMPETITION
2011-2012 INTERNATIONAL SUSTAINABLE LABORATORY STUDENT DESIGN COMPETITION

SCHEDULE
February 15, 2012
Online competition opens to students.

March 22, 2012
Final entry submission deadline.

Summer 2012
Winners announced on competition website.

September/October 2012
Competition co-sponsors and selected students presented at the International Conference for Sustainable Laboratories.

March/April 2013
Winning entries displayed at 2013 International Conference for Sustainable Laboratories, San Francisco, CA.

Awards/Benefits
The design jury will meet in Summer 2012 to determine winning projects and award prizes. Winners and their faculty sponsors will be notified of the competition results.

All winning projects will be posted on the Association of Collegiate Schools of Architecture website at www.acsa.org and the International Institute for Sustainable Laboratories website at www.isslab.org. The top 5 teams will be invited to attend the ACSA Annual Conference, where a $4,000 cash prize will be awarded to winning students and their faculty sponsors.

Additional Benefits:
- College students and winning students have the opportunity to be selected for the annual Design and Exhibit Design competition.
- Students will receive a trip to the competition meeting site.
- All design concepts and strategies, including student design information if provided, will be presented at the International Conference for Sustainable Laboratories in Washington, D.C.
- Winning teams may be considered for interviews with competition sponsors and other organizations interested in the sustainable laboratory community.
- Winning teams and institutions may be invited to participate in the conference opening ceremony, present their projects during the technical sessions, and attend the conference social events at an evening reception and a photographic exhibition.

Sustainable Laboratories

Index
Rebecca L. Ackerman 71
SUSTAINABLE LAB COMPETITION
2011-2012 INTERNATIONAL SUSTAINABLE LABORATORY
STUDENT DESIGN COMPETITION

ELIGIBILITY
Students from all Associate or Collegiate Schools of Architecture around the world will be eligible to participate in the competition. Students may work individually or in teams and must work with a faculty sponsor on the submission. Teams must be limited to a maximum of five students. There will be no additional fee for eligible students to participate in the competition.

LANGUAGE
The official language of the competition is English.

REGISTRATION
A faculty sponsor is required to enroll students by completing an online registration form (available at www.arch.org/competition) by February 15, 2012. Faculty may complete a form for each individual student or for each individual student sponsoring a team. Students or teams wishing to enter the competition on their own must have a faculty sponsor who will complete the form. There is no entry or submission fee to participate in the competition. Each registered student and faculty sponsor will receive a confirmation email that will include information on how the student(s) will upload their submission online. Please add the email address competition @ arch.org to your address book to ensure that you receive all emails regarding your submission.

During registration the faculty will have the ability to add students, add teams, assign students to teams, and add additional faculty. Registration is required by February 15, 2012, but can be changed, edited, and added to until a student enters a final submission; after the registration is no longer editable, faculty may assign a "Faculty Representative" to a registered student. The "Faculty Representative" will have access to change, edit, and add to the registration.

FACULTY RESPONSIBILITY
Thefname of the competition at each level is left to the discretion of the faculty sponsor within the guidelines set forth in this document. Works on the competition may be structured over the course of one or two semesters (Fall 2011 and/or Spring 2012).

CODES
Refer to the International Building Code for information on standard requirements. Participants should follow the principles of universal and sustainable design.

SUBMISSIONS
All competition submission must include:
- four digital presentation boards for the laboratory proposal of 20" x 30" each. The digital boards should clearly show the students' responses and design solutions, with one board dedicated to each of the following: (a) laboratory model, (b) sustainable resolution and campus plan.
- a 500-word maximum design essay that supports the above mentioned digital presentation boards by describing the proposed research infrastructure.

Incomplete or undocumented entries will be disqualified. All drawings should be presented at a scale appropriate to the design solution and include a graphic scale and north arrow.
SUSTAINABLE LAB COMPETITION
2011-2012 INTERNATIONAL SUSTAINABLE LABORATORY
STUDENT DESIGN COMPETITION

DIGITAL PRESENTATION BOARDS
Submissions must be designed on no more than four 20" x 30" digital boards. The names of student participants, their schools, or faculty sponsors, must NOT appear on the boards. The digital boards should clearly show the students' responses and design solutions, with one board dedicated to each of the following: the laboratory model, sustainable resolution, and campus plan.

All boards are required to be uploaded through the Association of Collegiate Schools of Architecture website in Adobe Acrobat Expert (PDF) or image (JPEG) files. Participants should keep in mind that, due to the large number of entries, preliminary review does not allow for the hanging and shared display of presentation boards. Accordingly, participants should not use text graphics that cross over from board to board. The names of student participants, their schools, or faculty sponsors, must NOT appear on any of the submitted material.

The digital presentation boards must directly address the criteria outlined in the Evaluation Criteria section and must include (but are not limited to) the following elements:

For the laboratory:
• Plan and circulation patterns
• Flexibility and building sections
• Laboratory module layout
• Building materials and application
• Building systems and energy management strategies within the laboratory
• Control strategies for lighting, occupancy, and supply and exhaust, and energy management
• Large scale drawings (either orthographic or three dimensional)
• A three-dimensional representation in the form of either an axonometric perspective, or model photographs, one of which should illustrate the character of the project

For the campus:
• Site plan showing infrastructure systems such as energy generation, waste management and recovery, water management and recycling, transportation, and accessibility
• Plan for managing energy systems, such as energy distribution, throughout the campus

Please note that the digital presentation boards should graphically convey the design solution and context as much as possible, and not rely on the design essay to convey a basic understanding of the project.

DESIGN ESSAY
A 500 word maximum essay (in English) is required as part of the submission to support the campus schematic by describing the proposed campus infrastructure. Keep in mind that the digital presentation boards should graphically convey the design solution and context as much as possible and not rely on the design essay to convey a basic understanding of the project.

The names of student participants, their schools, or faculty sponsors, must NOT appear in the design essay. The essay is included in the final online submission, completed by the student(s) in a single copy/print out form.
ONLINE PROJECT SUBMISSION

The student is required to submit final entries through the Association of Collegiate Schools of Architecture competition website at www.acsa.org/competitions by 5 p.m. Eastern Time on May 22, 2012.

If the submission is from a team of students, all student team members will have the ability to upload the digital files. Once the final submit button is pressed, no additional edits, uploads, or changes can be made. Once the final submission is uploaded and submitted, each student will receive a confirmation email notification. The submission is not complete until the “complete this submission” button has been pressed. You may “save” your submission and return to complete it later. For team projects, any member of the team may submit the final project.

A final submission upload must contain the following:

- Completed online registration including all team members and faculty sponsors;
- Each of the four 20” x 30” boards uploaded individually as high-resolution Portable Document Format (PDF) documents or image (JPEG) files;
- A design essay (500 words maximum).

Winning projects will be required to submit high-resolution original files/images for use in competition publications and exhibit materials. Upon receipt, submissions become the property of Association of Collegiate Schools of Architecture and the International Institute for Sustainable Laboratories.
SUSTAINABLE LAB COMPETITION
2011-2012 INTERNATIONAL SUSTAINABLE LABORATORY
STUDENT DESIGN COMPETITION

Students are encouraged to research references that are related to St. Croix, laboratory spaces, sustainability/environmental systems, the design problem, and precedent projects. An integral part of the competition is to make students aware that research is a fundamental element of any design solution. Following are a few sample research reference websites, publications, and case studies:

PUBLICATIONS AND WEBSITES
The following resources provide specific information on laboratory design. Some of these are based specifically on sustainability in laboratory facilities but can be readily adapted to other types of buildings. They are essential for understanding the nature, scope, and objectives of the competition program:

- Marine Research and Education Center www.marine.mt.edu
- American Institute of Architects Center for Integrated Technology Design Guidelines for Planning and Design of Biomedical Research Laboratory Facilities Washington, DC: American Institute of Architects, 1999
- Lab21 Environmental Performance Criteria www.epa.gov/lab21guide/toolkit/adp.htm
- American Institute of Architects Center for Integrated Technology Design Guidelines for Planning and Design of Biomedical Research Laboratory Facilities Washington, DC: American Institute of Architects, 1999
- Whole Building Design Guide http://whole.org
- Department of Energy Building Database http://www.buildings.gov
- National Renewable Energy Laboratory's NREL's Climate Neutral Research Centers Online Tool www.nrel.gov/applying_technologies/climate_neutral
- NREL's Climate Action Planning Tool www.nrel.gov/applying_technologies/planning_tool

The following resources provide further information on sustainable design practices in general (i.e., practices that are applicable to wide range of building types, including laboratories). Students should refer to their own school libraries for many other sources of information on sustainable design issues:

- U.S. Green Building Council www.usgbc.org
- International Living Future Institute's Living Building Challenge www.lbi.org
SUSTAINABLE LAB COMPETITION
2011-2012 INTERNATIONAL SUSTAINABLE LABORATORY
STUDENT DESIGN COMPETITION

CASE STUDIES
In addition to the publications and websites previously listed, competitors are strongly encouraged to research, document, and analyze the projects listed below. This list is provided to encourage and promote the research and analysis of significant works of architecture relevant to the competition program and the integration of sustainable practices. An interest in all Association of Collegiate Schools of Architecture accredited student design competitions is an integral component of all design programs.

Centre for Clinical Sciences Research, Stanford University, Palo Alto, California
- Foster + Partners, London, England
  - Foster Catalog 2001, Munich, 2001
  - Architectural Record, 2001, 1, p. 110-117
  - GQ Document, 2001, n. 64, p. 66-73
  - Lubbock International, n. 114, p. 30-41

Faculty of Economics and Management, Maastricht University, Maastricht, the Netherlands
- Mecanoo Architects, Utrecht, the Netherlands
  - Mecanoo, Mecanoo: Mecanoo, Architecture - Context, Composition, Complexity, Boston
  - Architectural Record, 1996, 1, n. 119, p. 48-57

Forfältungsakademie Hausomstrei, Heim-Schragen, (Ost), Germany
- Kanda & Partners Architects, Paris, France
  - Mabran, 2000, Feb., n. 397, p. 66-101
  - Architectural Record, 1999, Dec., 1, n. 199, p. 204, 206, 208
  - Interiors & Architecture, 1999, June, n. 448, p. 96-101

Fred Hutchinson Cancer Research Center, Seattle, Washington
- Zimmer, Gouraud, Franco Partnership, Seattle, Washington
  - Architecture, 1994, 6, n. 3, p. 64-75
  - http://arch.114.gov/docs/ARCH94.00.pdf

Georgia Public Health Laboratory, Atlanta, Georgia
- Lord, Rock, and Sargent Architects, Atlanta, Georgia
  - Architectural Record, 1999, June, n. 187, n. 4, p. 66-101

Institute for Forestry and Nature Research (INEREN), Waynecites, the Netherlands
- Behnisch, Behnisch & Partner, Stuttgart, Germany
  - Hilland Jones, Peter, Centre for Forestry Research, 2000
  - Architectural Record, 2000, 1, n. 188, p. 96-103
  - Architectural Review, 2001, 1, p. 37, n. 50-91
SUSTAINABLE LAB COMPETITION
2011-2012 INTERNATIONAL SUSTAINABLE LABORATORY
STUDENT DESIGN COMPETITION
Sustainable Lab Competition
2011-2012 International Sustainable Laboratory Student Design Competition

Sponsors
The competition is being sponsored by the International Institute for Sustainable Laboratories and the Office of Insular Affairs of the U.S. Department of the Interior.

The International Institute for Sustainable Laboratories (I2S2) is devoted to the principles of sustainable laboratories— from design to engineering to operational practice. Through worldwide partnerships and the exchange of technical information, I2S2 helps to produce high technology facilities that address the rapid pace of science, medicine, research, and development in an ever-changing and dynamic world (www.i2s2.org).

The Office of Insular Affairs, U.S. Department of the Interior, has oversight of U.S. territories and assists territorial governments in addressing infrastructure and management needs related to water treatment and solid waste systems, roads, public buildings, hospitals, schools, and resource management issues (www.doi.gov/oi).

Project Partners
The Joint Institutes for Coastal Marine Studies (JICMS) is a consortium of four universities that will operate the MAEC. They include the University of North Carolina at Wilmington (UNCW), the University of the Virgin Islands (UVI); Rutgers, the State University of New Jersey (RU); and the University of South Carolina (USC).

National Park Service (www.nps.gov)

Government of the Virgin Islands (http://envir.gov/vi/)

Office of Insular Affairs, U.S. Department of the Interior (www.doi.gov/oi/)

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SUSTAINABLE LAB COMPETITION
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STUDENT DESIGN COMPETITION

ADMINISTERING ORGANIZATION
The competition is administered by the Association of Collegiate Schools of Architecture, a nonprofit organization founded in 1912 to enhance the quality of architectural education. School membership in ACSA has grown from 20 charter schools to more than 250 schools in several membership categories. Through these schools, more than 5,000 architecture faculty are represented in ACSA's membership. ACSA, unique in its representation role for professional schools of architecture, provides a major forum for ideas on the leading edge of architectural thought. Issues that will affect the architectural profession in the future are being examined today in ACSA member schools. ACSA is committed to the principles of renewal and sustainable design.

FOR ADDITIONAL INFORMATION
Additional questions on the competition program and submission should be addressed to:

For Information: Property Manager
Association of Collegiate Schools of Architecture
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Washington, DC 20006
Tel: 202-785-2324
info@acsaarch.org
GLOSSARY

AHU
(see AIR HANDLING UNIT)

AIR HANDLING UNIT (AHU)  A device used to condition and circulate air.

AMORPHOUS SILICON  A type of photovoltaic that is made up of randomly arranged atoms that can be compacted into very thin, inexpensive film.

AQUIFER  An underground layer of permeable rock that contains water and is often used to supply wells.

ARRAY  A grouping of many solar panels.

BIOSWALE (VEGETATED SWALE)  A form of bioretention used to treat water quality, lessen flooding potential, and carry stormwater away from buildings.

BIPV
(see BUILDING-INTEGRATED PHOTOVOLTAICS)

BLACKWATER  Wastewater containing fecal matter and urine.

BTU  British Thermal Unit. A unit of energy needed to heat one pound of water one degree Fahrenheit.

BUILDING-INTEGRATED PHOTOVOLTAICS (BIPV)  A type of photovoltaic that is incorporated into the building envelope.

CELL  A small part of a photovoltaic panel or array that collects the sun’s energy.

CIGS
(see COPPER-INDIUM-GALLIUM-SELENIDE CELLS)

COEFFICIENT OF PRODUCTIVITY (COP)  A factor applied to energy efficient appliances that show how much energy they save.

COP
(see COEFFICIENT OF PRODUCTIVITY)

COPPER-INDIUM-GALLIUM-SELENIDE CELLS (CIGS)  An efficient, inexpensive, flexible type of photovoltaic cell.

CROSS VENTILATION  A type of natural ventilation that relies on the wind, and is best applied to narrow buildings built perpendicular to wind flow.

ECOLOGICAL WASTEWATER TREATMENT SYSTEM  Man-made wetlands that take advantage of microorganisms and plants to filter our and decompose pollutants in water.

FC
(see FOOT CANDLE)
FLUID-MAPPING TABLE  A water table in which a plan or section model is placed upon, and dyed liquid run across to mimic the movement of air or wind.

FOOT CANDLE (FC)  A unit of luminance or light intensity.

GRÄTZEL CELLS  An efficient, inexpensive, photovoltaic cell that is dye-sensitized that imitates photosynthesis.

GREYWATER  Wastewater generated from household activities such as laundry, dish washing, and bathing.

HYBRID VENTILATION  A combination of mechanical and natural ventilation techniques.

INDOOR AIR QUALITY  Refers to the air quality within and around buildings, especially as it relates to the health and comfort of building occupants.

INTEGRAL BUILDING OPENINGS  A form of natural ventilation employing mechanical louver systems best used in situations in which no one person controls the temperature.

LIVING MACHINE®  A multi-step water filtration device technology that uses plants and microorganisms to turn wastewater into clean water without the use of chemicals.

LOW-PRESSURE AIR CONDITIONING  A ventilation system that makes use of natural forces to reduce the energy consumed by fans that power it.

MONOCRYSTALLINE SILICON  The most common type of photovoltaic cell. They are refined from one large crystal, with a very high level of efficiency.

OZONE (O₃)  A method of water purification that oxidizes and kills any organic or inorganic compounds found in water.

LEEWARD  The side of a building that is downwind.

PANEL  A small grouping of photovoltaic cells that more effectively collects energy from the sun.

PHOTON  Small particles of solar energy.

PHOTOVOLTAICS (PV)  Grouping of solar cells that when exposed to direct sunlight, collects energy from the sun.

POLYCRYSTALLINE SILICON  A type of photovoltaic cell that consists of many small, densely packed crystals.

POTABLE  Safe to drink.

PREVAILING WIND  Winds that blow predominantly from a single general direction.
PV (see PHOTOVOLTAICS)

REVERSE OSMOSIS A method of water purification used to desalinate, or remove salt from seawater.

R-VALUE A measure of thermal resistance of different building materials.

SINGLE LOADED CORRIDOR Rooms located only on one side of a corridor

SOLAR STILL A method of water purification that uses evaporation to remove water from impurities.

STACK VENTILATION A form of natural ventilation that creates air movement by drawing air through a space up through a stack, or chimney in a building.

TANK A vessel used for holding or storing water.

THERMAL MASS A method of natural ventilation in which large masses such as stone or concrete walls absorb daytime heat, or nighttime cold, and release it inside the building during the night or day, respectively.

TRANSPIRATION The loss of water vapor from the parts of plants.

ULTRAVIOLET LIGHT (UV LIGHT) A form of water purification that can kill all microorganisms and fungi in water for a complete disinfection.

UV LIGHT (see ULTRAVIOLET LIGHT)

VEGETATED SWALE (see BIOSWALE)

WATER TOWER A form of water storage and distribution that relies on height and pressure to supply surrounding areas with water.

WINDWARD The side of a building that is upwind.
NOTES

1.1 PHOTOVOLTAICS


PHOTOVOLTAIC METRICS


PHOTOVOLTAIC CONCLUSION

1. Aaron Blackford, e-mail message to electrical designer, April 13, 2012.


2.1 WATER TREATMENT + STORAGE


**Water Storage Metrics**


**Natural Ventilation**


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Sustainable Laboratories

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