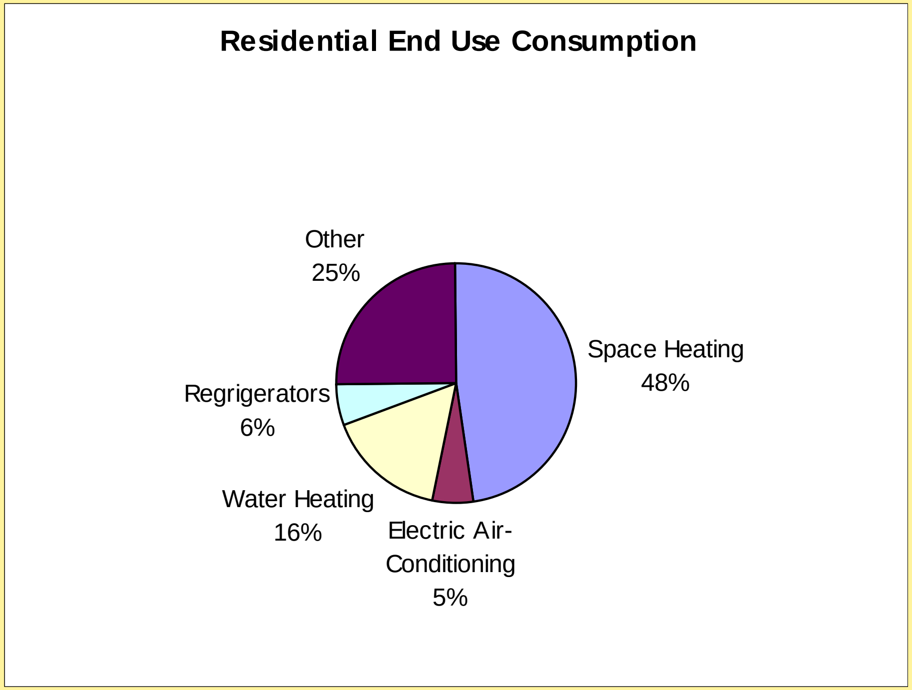
Simulation of Seasonal Solar Thermal Energy Storage

James T. McLeskey, Jr.[1]
Marshall Sweet[1]
Luca Terziotti [1]
David Stets[2]

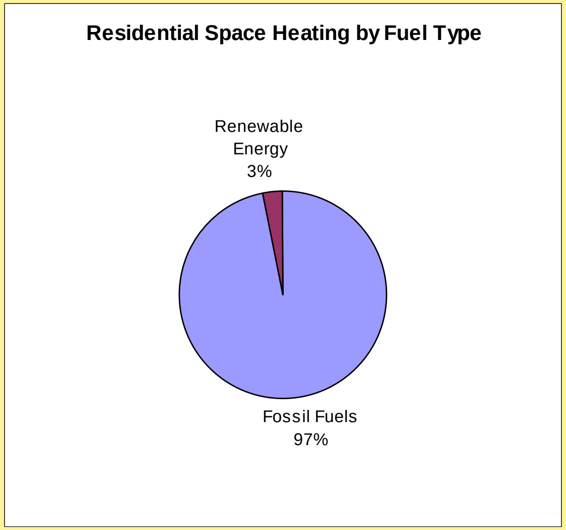
October 2010

[1]Dept. of Mechanical Engineering
Virginia Commonwealth University
[2]Richmond BySolar

Motivation

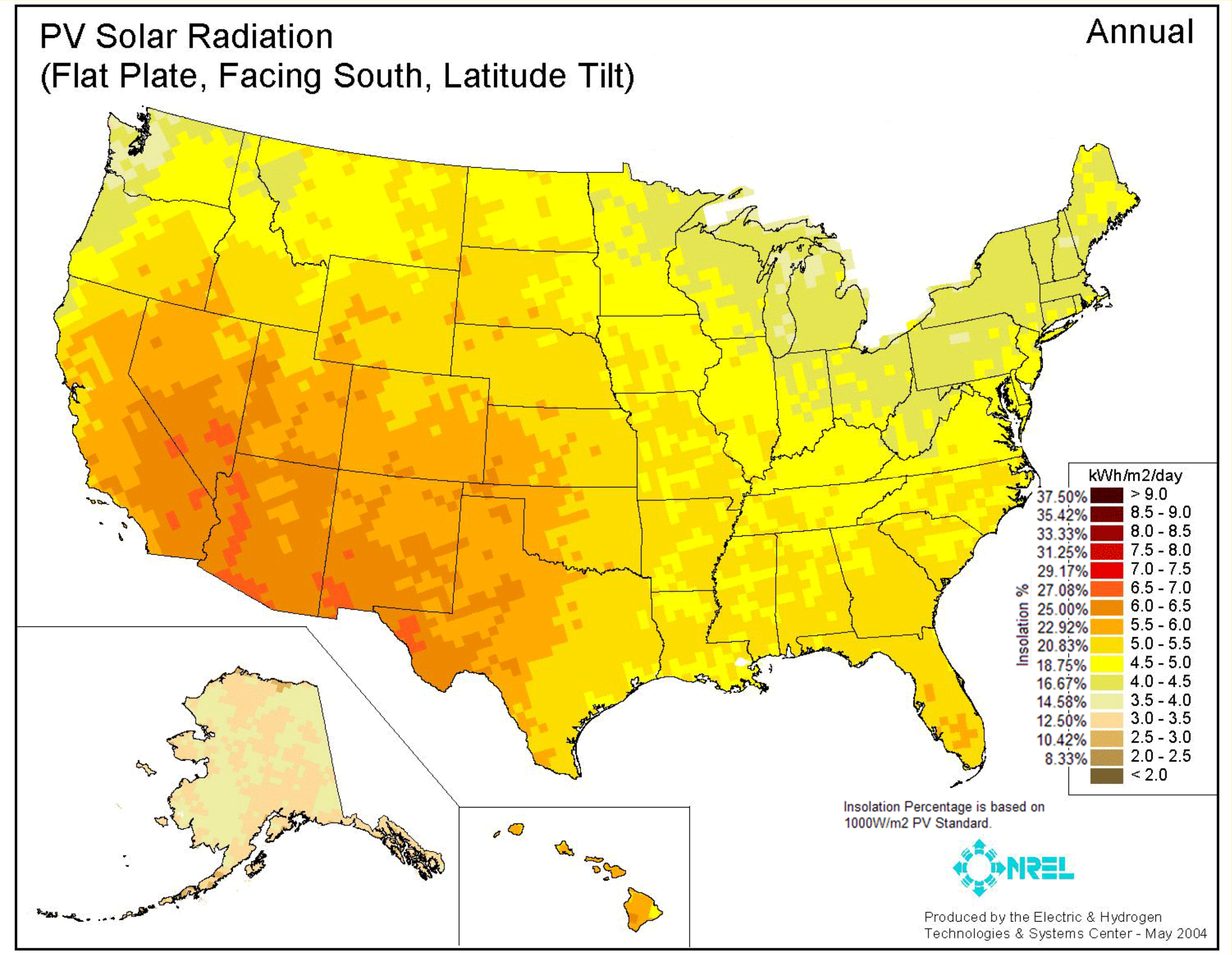


- 97% of all homes in the United States used fossil fuels directly or electricity created from fossil fuels for space heating.



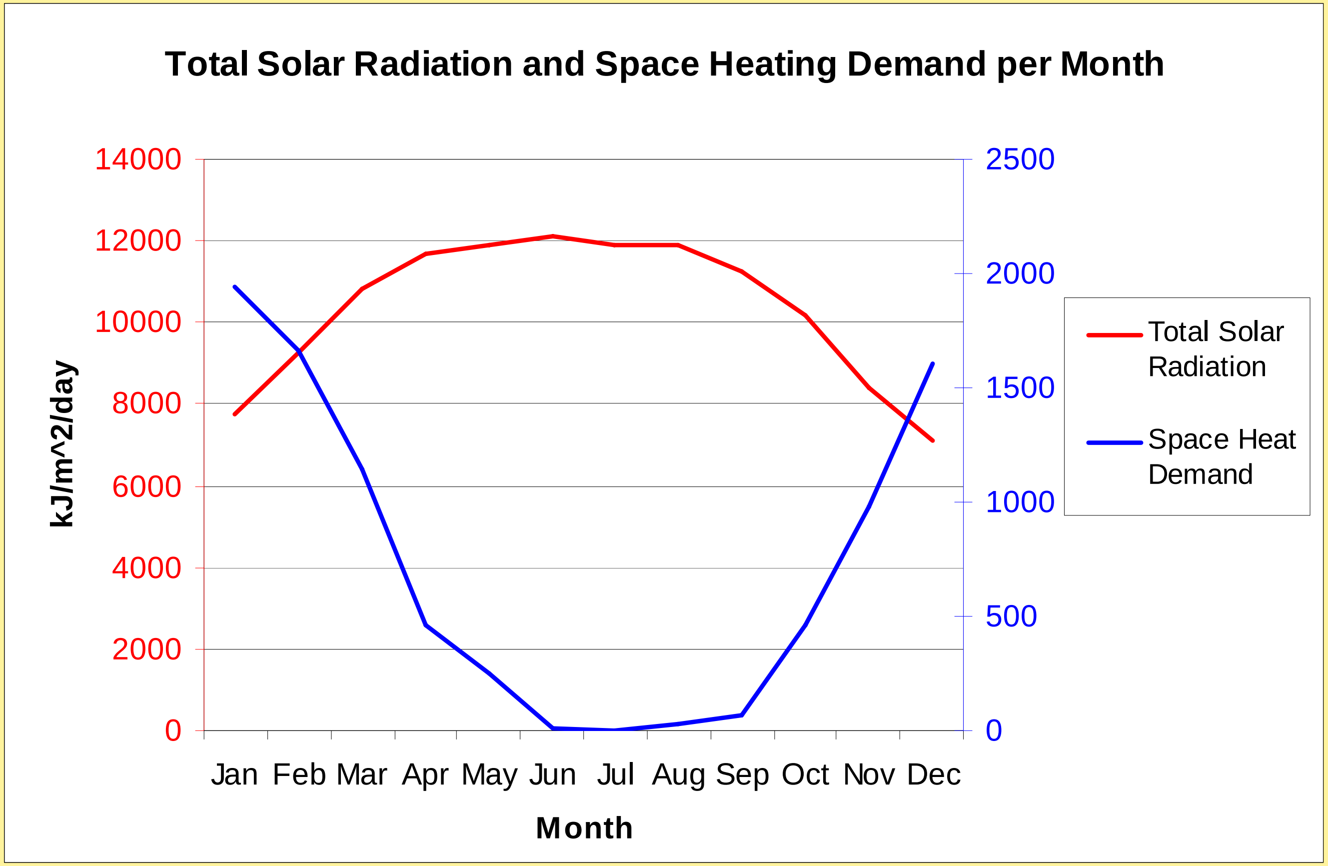
502 million metric tons of CO_2 per year

Motivation – Richmond's solar radiation 4.5-5 kWh/m2/day



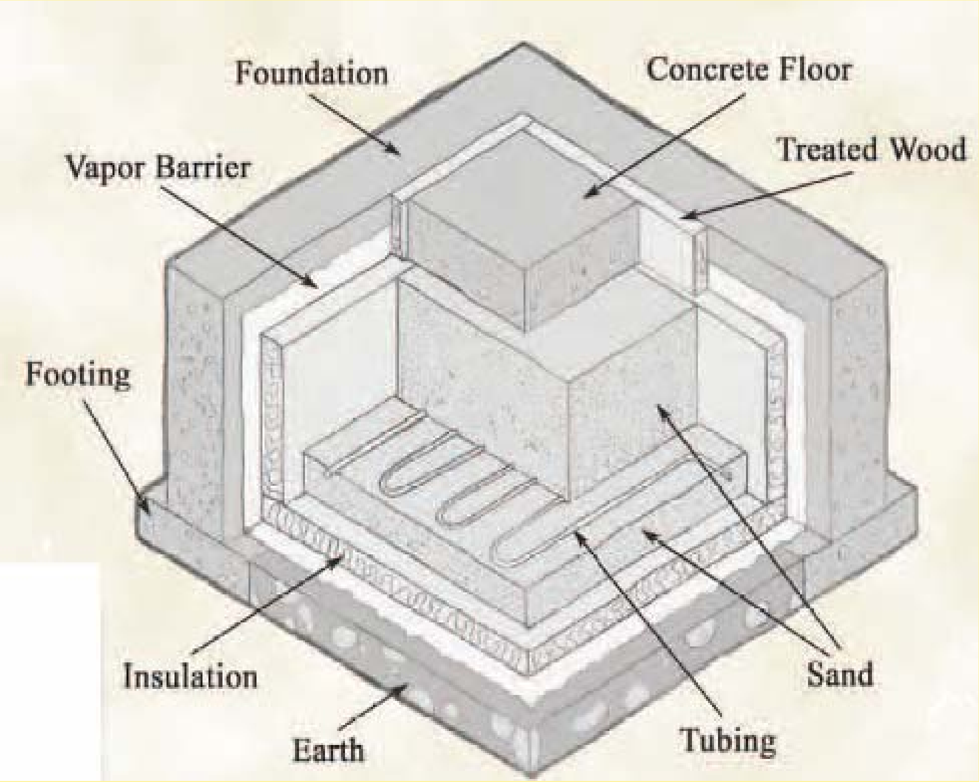
Motivation

It's a storage problem

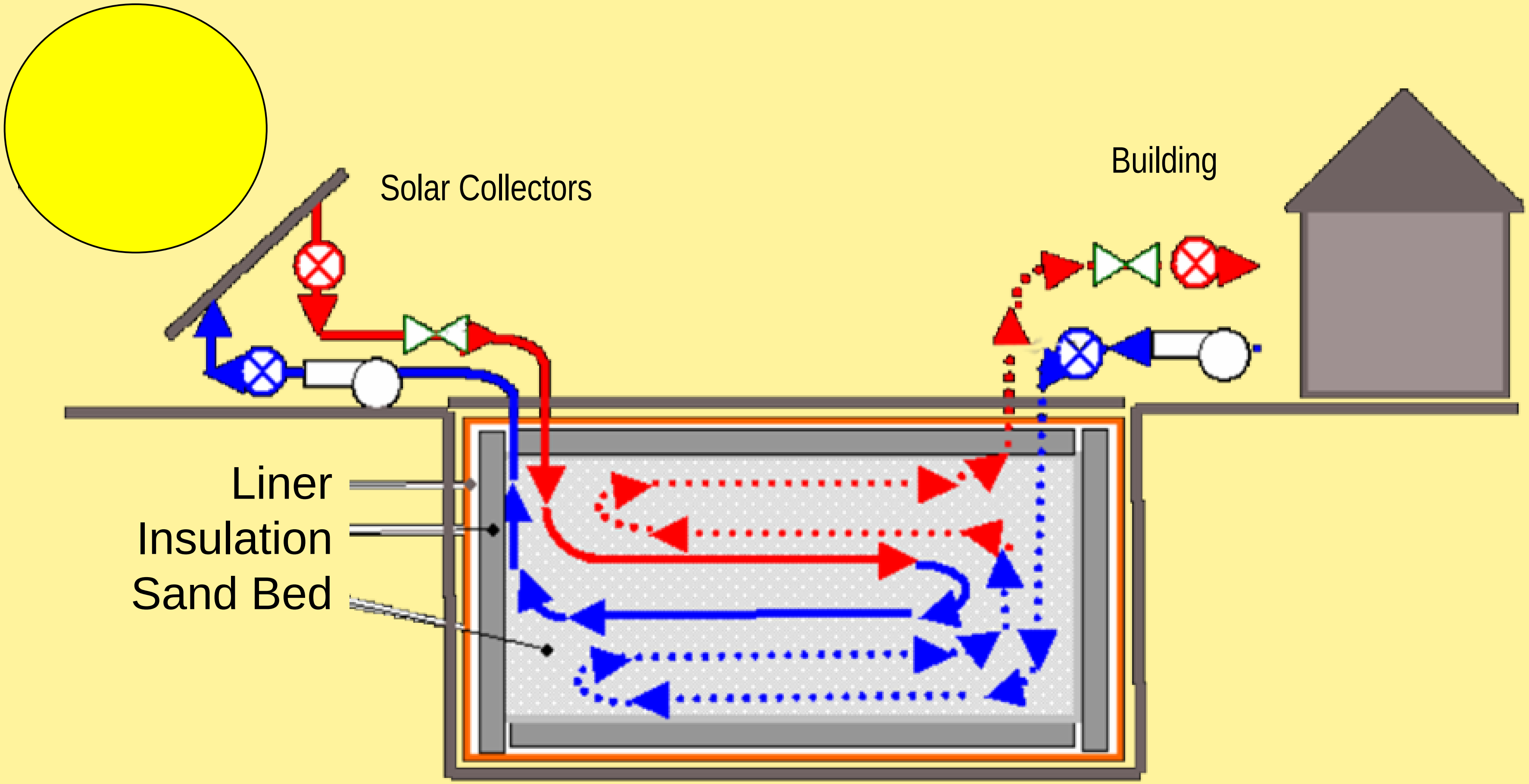


High Mass Storage in Wisconsin

(with permission of Bob Ramlow)



Overall Idea
Virginia Heatstore

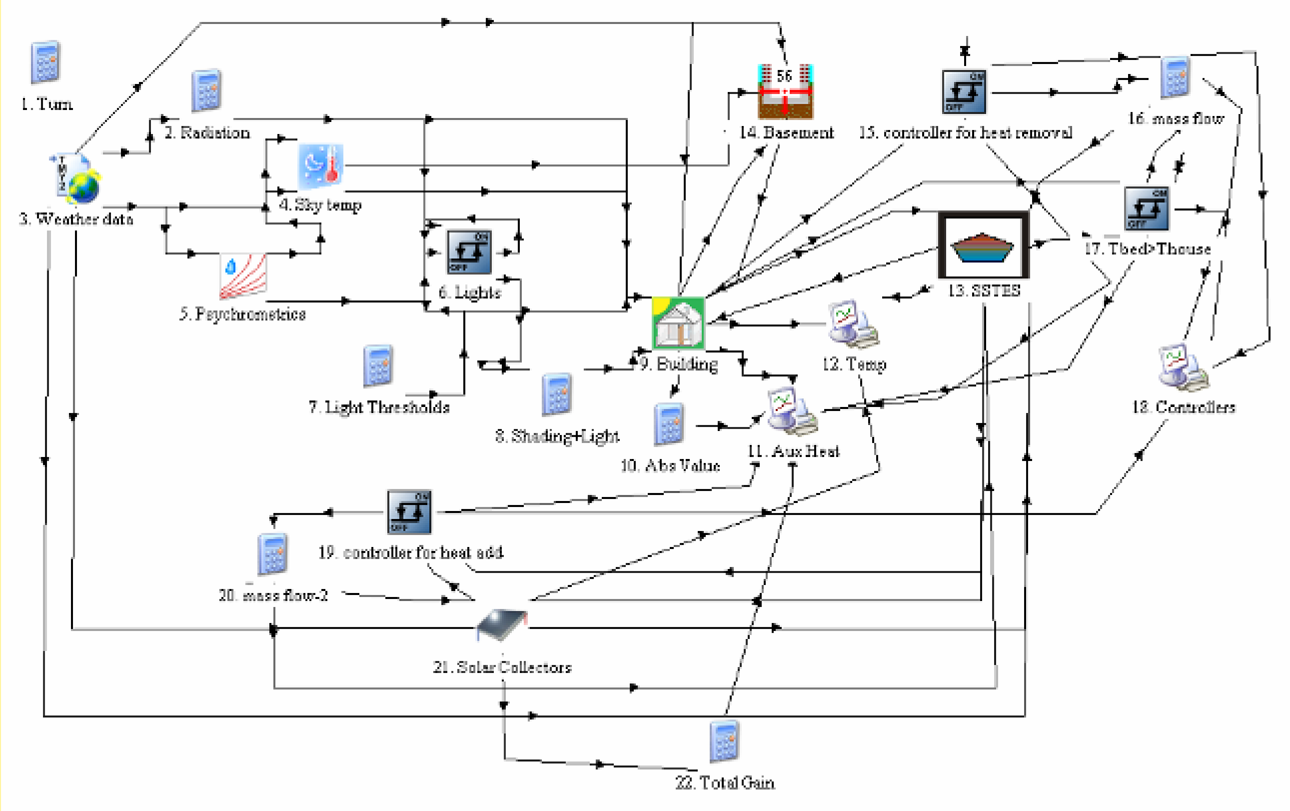


Objectives

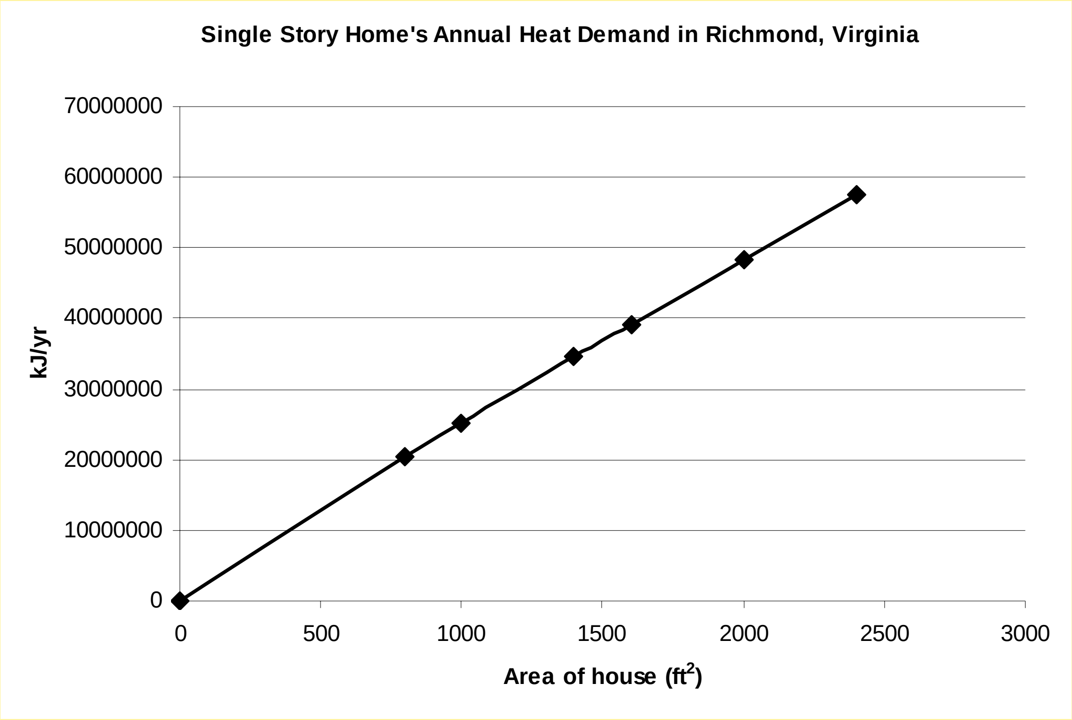
1. Model Thermal Load of Residential Homes in Richmond, VA
2. Model a Seasonal Solar Thermal Energy Storage (Virginia Heatstore) scheme and apply it to the 1st objective

Methods/TRNSYS

- Energy Simulation Software developed at the University of Wisconsin – Madison
- Flexible tool designed to simulate the transient performance of thermal energy systems
- *Calculations Are Complex, Many Variables



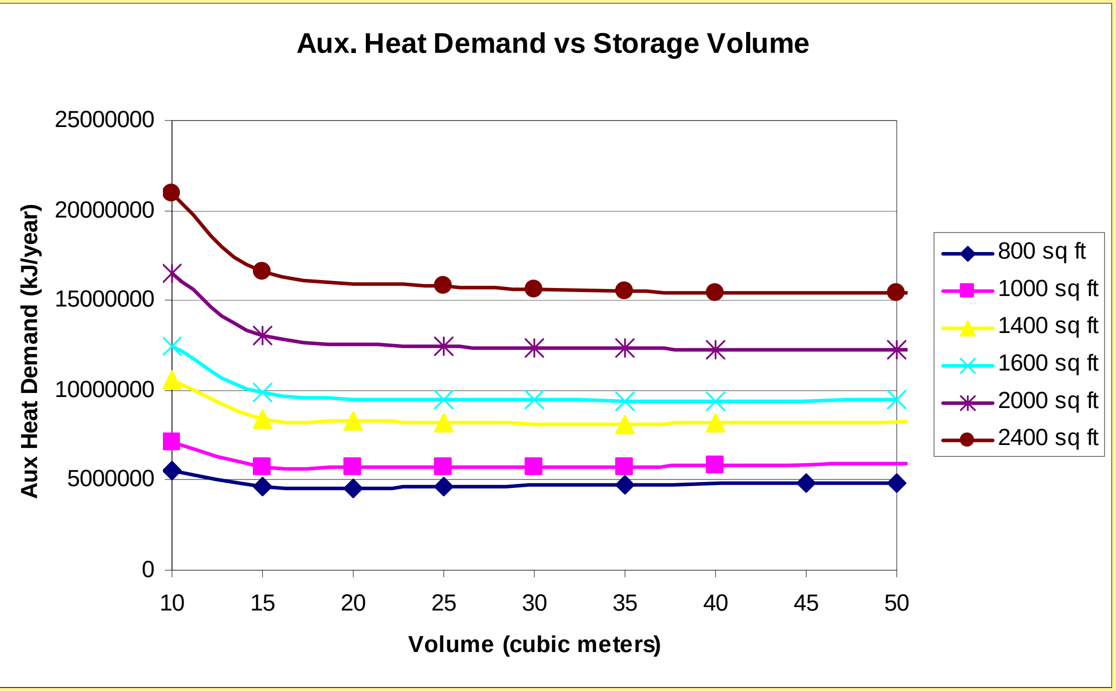
House Load



- House model is based off a typical ranch style home
- Materials and Specs are based off USGBC LEED standards for residential homes

- Homes face North
- Dimensions of different sized homes are all proportional
- Demand only includes energy for space heating to 68 °F/ 20 °C

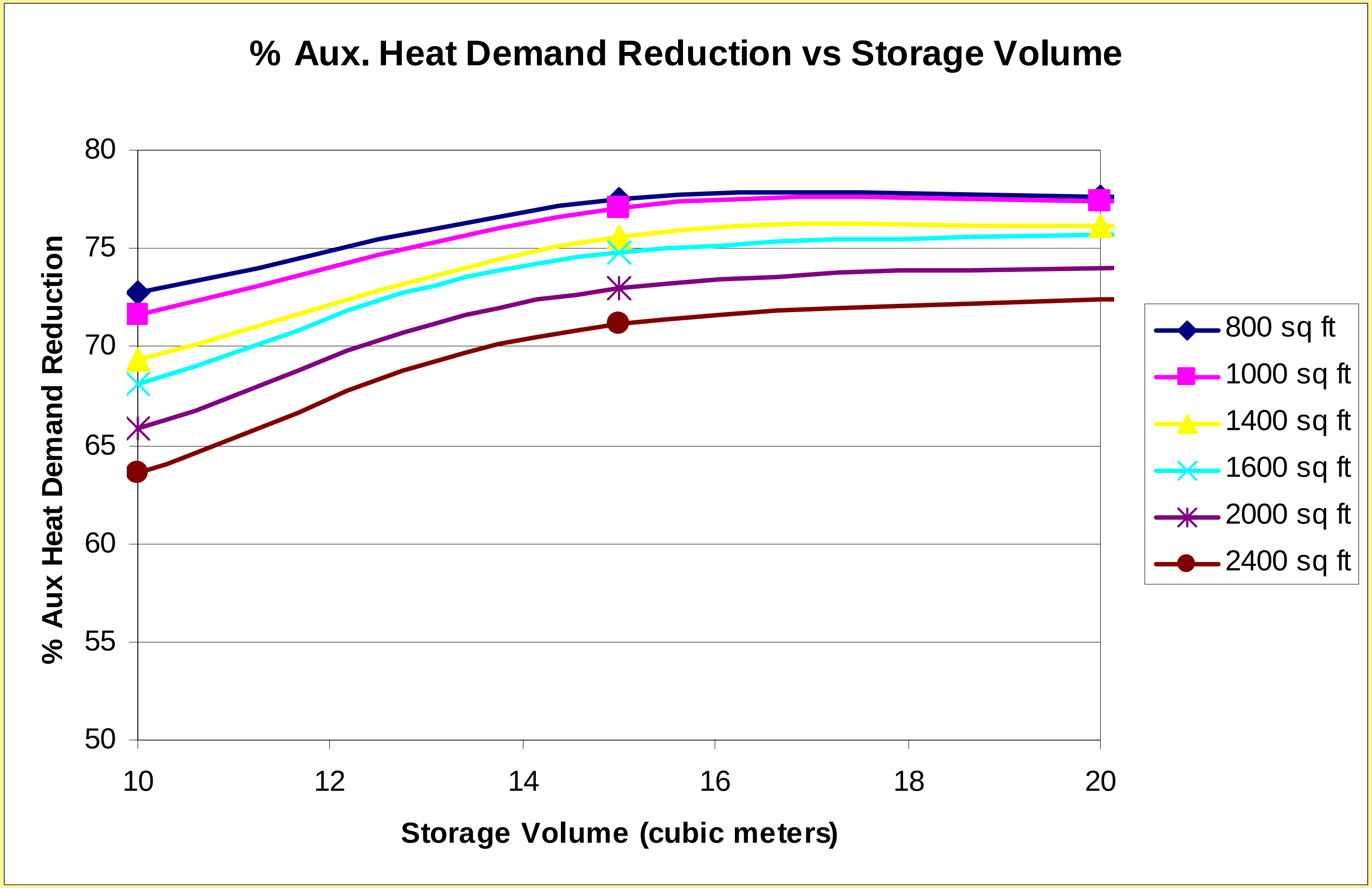
Seasonal Solar Thermal Energy Storage



- 3 m Deep Cylinder
- Length = Width
- Filled with Sand
  - Density 1201 kg/m^3
  - Heat Capacity 996.8 kJ/m^3 K
  - Conductivity 3.24 kJ / (hr m K)
- Initial Temperature 55.4°F
- 5th year projections

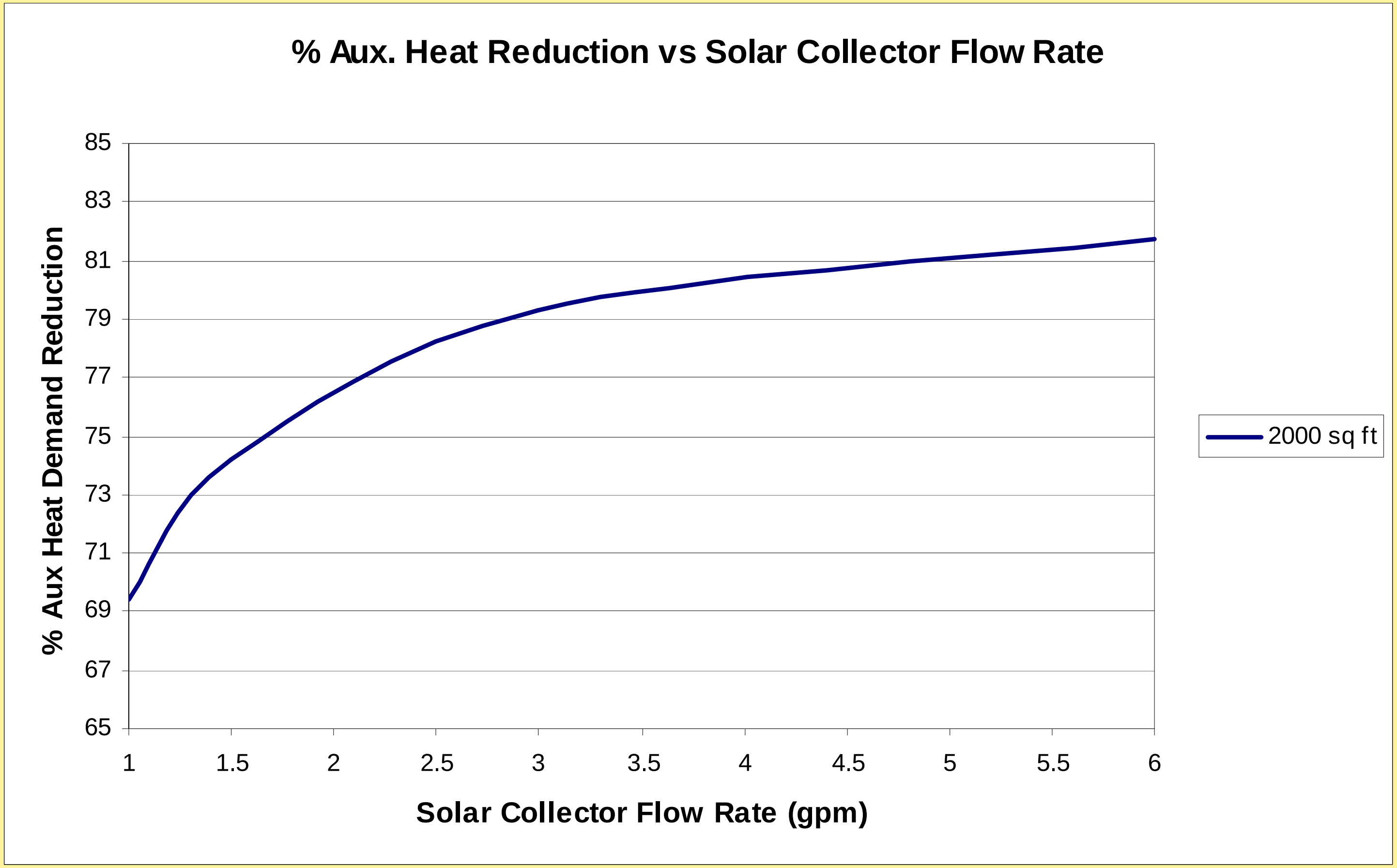
•*Solar Collector Area Used for Each Simulation Corresponds to 80% of Available South Facing Roof Area

Seasonal Solar Thermal Energy Storage



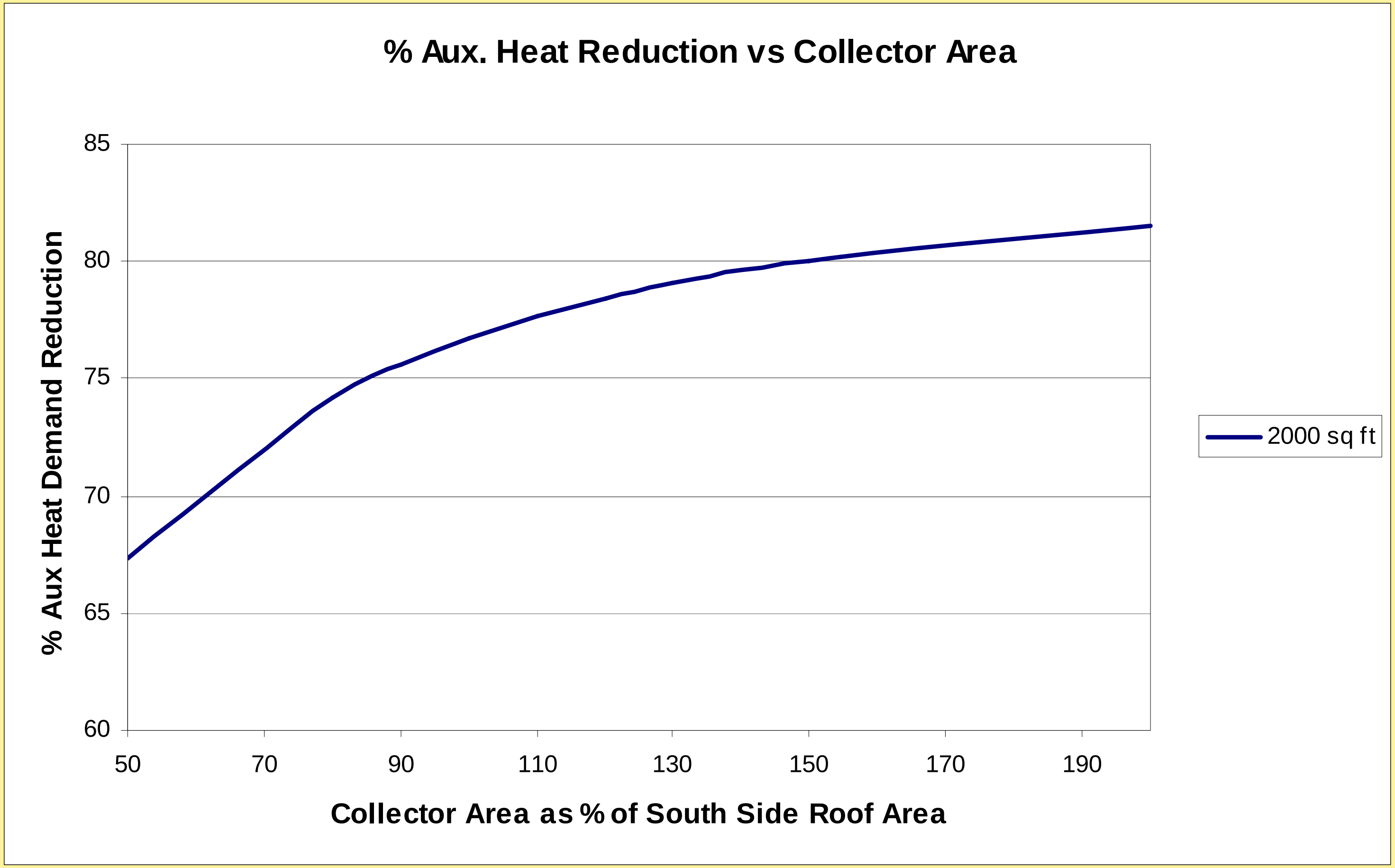
70%-77% Aux. heat Demand Reduction for all sized homes with a *15 cubic meter Heatstore.
*May Be Related to Geographic Location.

Optimizing SSTES



Traditional installations have used 1.5-2 gpm. We see that by *Increasing the Flow rate to 5 gpm, the Total Aux Heat Reduction Increases 6%.

Optimizing SSTES



The greater the collector area, the greater the useful solar thermal energy gain, increased reductions in aux heating demand. *Optimal size is about 150% of south facing roof or 75% of total roof.

Efficiency

1. Efficiency of the System based on “useful” solar gain:

$$\frac{\text{(Heat into Home)}}{\text{(Total } \underline{\text{Useful}} \text{ Gain of Collectors)}} = 50 – 70\%$$

2. Overall Efficiency based on total incident solar energy

$$\frac{\text{(Heat into Home)}}{\text{(Total Incident Solar Energy)}} = 6\% - 7\%$$

1st Virginia Heatstore



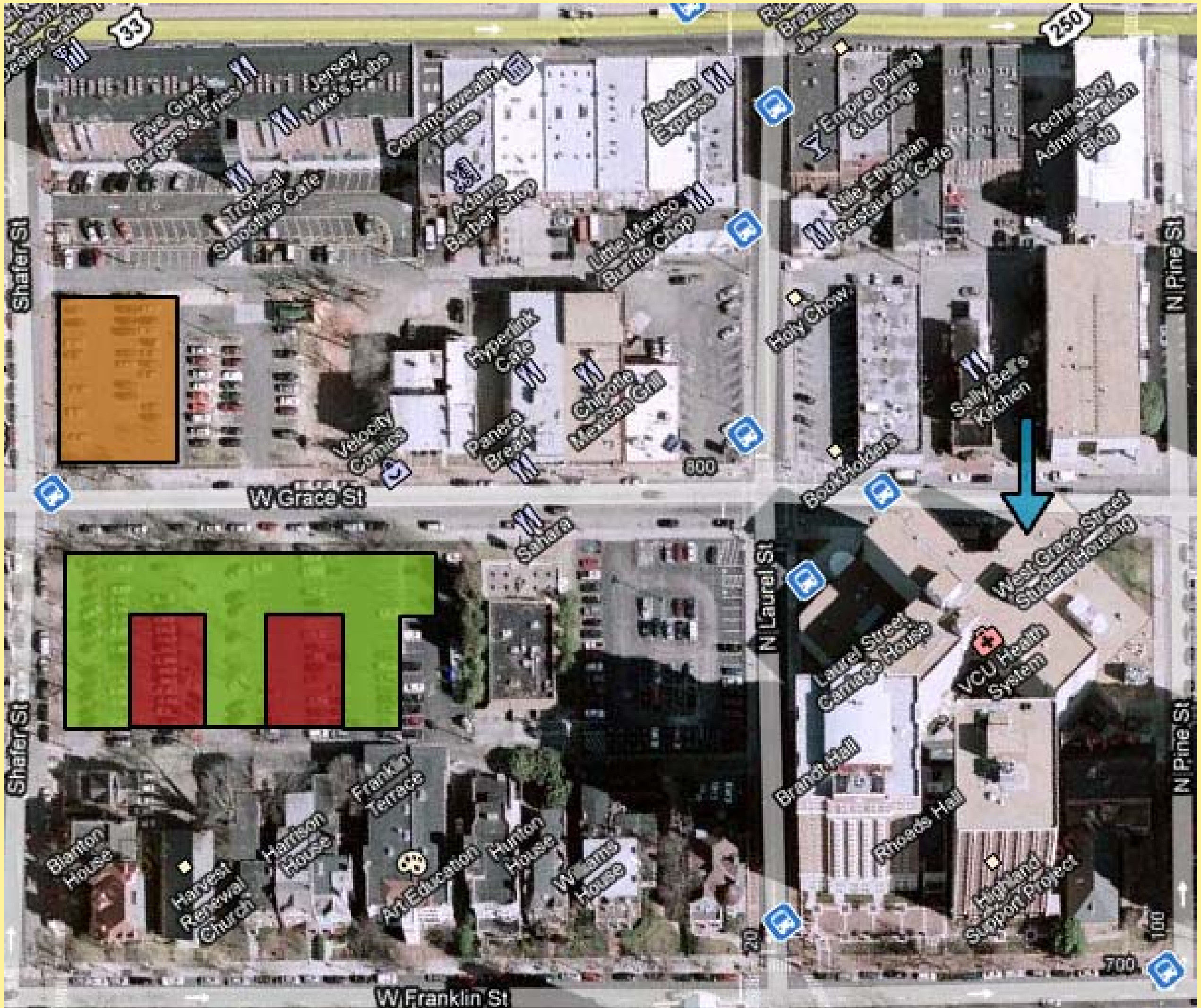



Heatstore Cost Analysis
2000 sq ft house / 80% roof coverage

• Dig and fill hole	$1,962
• *23 Solar Collectors	$19,045
• Panel Installation (roof)	$1,380
• Pipe, Fittings, Insulation	$1,050
• Solar Appliance	$1,000
• Vapor Liner	$95
• PEX Tubing	$1,260
• **TOTAL**	<u>$25,792</u>
• Approx. years to payback	25

* Need to Reduce Panel Cost

West Grace Student Housing


W Grace St
W Franklin St
Shafer St
N Laurel St
N Pine St
Five Guys Burgers & Fries
Jersey Mike's Subs
Commonwealth Times
Aladdin Express
Empire Dining & Lounge
Technology Administration Bldg
Tropical Smoothie Cafe
Adams Barber Shop
Little Mexico Burrito Chop
Nile Ethiopian Restaurant Cafe
Holy Chow
Hyperlink Cafe
Chipotle Mexican Grill
Sally Bell's Kitchen
Velocity Comics
Panera Bread
Bookholders
800
Sahara
West Grace Street Student Housing
Laurel Street Carriage House
VCU Health System
Branch Hall
Rhoads Hall
Highland Support Project
Franklin Terrace
Harrison House
Blanton House
Harvest Renewal Church
Art Education
Hunton House
Williams House
700

Thank You

James T. McLeskey, Jr.
Virginia Commonwealth University
Department of Mechanical Engineering
jtmcleskey@vcu.edu