Better Buildings
U.S. DEPARTMENT OF ENERGY

Getting to Zero: The How (and Why) of Net Zero Energy Buildings

Carolyn Sarno
Mason Cavell
Tom Hootman
Theresa Spurling-Wood
Agenda

- Presentations
  - Mason Cavell, Community Housing Partners
  - Tom Hootman, RNL
  - Theresa Spurling-Wood, Alachua County Public Schools

- Additional Resources
- Discussion
Mason Cavell
Community Housing Partners
Affordable Net Zero Housing
Mason Cavell, Community Housing Partners
Sustainable Approach

Social

Economic

Environmental

Social
Single-family Residential
Multi-family Residential
Vertical Integration

Develop

Design

Build

Commission

Maintain and Monitor
Collaborative Process
Grissom Lane

8-unit property in Blacksburg, VA

Universal design, exclusively for seniors

First affordable net-zero housing in Virginia
For DOE and EarthCraft Net Zero Standards, we must achieve...

- **HERS index of <50 (pre-solar)**
  - Target: HERS 35 pre-solar
- **Infiltration <1.5 ACH50**
- **Lighting:** minimum 75% CFL/LED
- **Appliances:** Energy STAR / WaterSense
- **Windows:** U-Value < 0.30
- **Ventilation:** ASHRAE 62.2 2010
- **Code:** IECC 2012 or better
Elements of Net Zero

**Envelope**
- Thermal and pressure boundaries
- Windows and doors

**Systems**
- HVAC
- Appliances
- Water heating
- Lighting

**Renewable Energy**
- Solar PV
<table>
<thead>
<tr>
<th>Envelope</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Insulation</strong></td>
<td>• R-60 attic (blown cellulose)</td>
</tr>
<tr>
<td></td>
<td>• R-24.5 walls (dense-pack cellulose)</td>
</tr>
<tr>
<td><strong>Air Barrier</strong></td>
<td>• Continuous air barrier</td>
</tr>
<tr>
<td></td>
<td>• 1.5 ACH @ CFM50</td>
</tr>
<tr>
<td><strong>Windows</strong></td>
<td>• Ply-Gem 3-pane, vinyl trim</td>
</tr>
<tr>
<td></td>
<td>• U-0.21</td>
</tr>
<tr>
<td><strong>Construction</strong></td>
<td>• 2x4 cellulose plus Structural Insulated Sheathing</td>
</tr>
</tbody>
</table>
AN INSULATED ATTIC HATCH SHALL BE BUILT TO OPEN TO THE ATTIC AND FORM AN AIRTIGHT SEAL WHEN CLOSED. THE ATTIC HATCH MUST ACCOMMODATE THE "HIDEAWAY STAIRS" AND BE INSULATED TO AT LEAST R-5. ADDITIONAL POINTS MAY BE EARNED IF THE ATTIC HATCH IS INSULATED TO R-19.
<table>
<thead>
<tr>
<th>Systems</th>
<th>Details</th>
</tr>
</thead>
</table>
| HVAC (all electric) | • 21 SEER Mini-Split Heat Pump  
|                  | • Continuous 15cfm ventilation  
|                  | • Ducts inside building envelope                                      |
| Appliances       | • Energy STAR refrigerators, front-load W/D                             
|                  | • EPA WaterSense toilets and plumbing fixtures                          |
| Water Heating    | • Heat pump hybrid water heater (1 per 2 units)                         |
| Lighting         | • LED bulbs in incandescent fixtures                                   |
Renewable Energy

36 kW Solar PV
(approximately 18x larger than pictured above)
Measurement and Verification
Major Challenges

Tenant Behavior (X-factor)

• Education and feedback

Cost

• Long payback, low cash flows

Utility Cooperation

• Solar net-metering uncertainty
• Dependent on state-by-state policies
Thanks!

Mason Cavell
Director, Energy Programs
Community Housing Partners
RESEARCH SUPPORT FACILITY

Federal Office Building
222,000 SF
822 Occupants

$64M Firm Fixed Price
$57.4M Construction
Complete June 2010
NREL – RESEARCH SUPPORT FACILITY II

BUCKLEY ANNEX NET ZERO ENERGY COMMUNITY

SMUD – EAST CAMPUS OPERATIONS CENTER

SINGAPORE – NET ZERO PROTOTYPE
OWNER BEST PRACTICES

01 Put it in writing.
02 Integrated delivery for cost control.
03 Invest in architecture.
04 LEED energy modeling is not enough.
05 Follow through.
01 Put it in writing.

OBJECTIVES

1. Mission Critical
   - Safety
   - LEED Platinum
   - Energy Star

2. Highly Desirable
   - 800 staff Capacity
   - 25kBTU/ft²/year
   - Substantial Completion by 2010

3. If Possible
   - Net zero design approach
   - Visual displays of current energy efficiency
   - National and global recognition and awards
Integrated delivery for cost control.
$259/SF
35 kBtu/SF
FAST TRACK
03 Invest in architecture.

- **System Intensive Building (High Tech)**
- **Envelope Intensive Building (Low Tech)**

Cost vs. Energy Savings graph:
- As energy savings increase, cost decreases for Envelope Intensive Building but increases for System Intensive Building.

![Graph](image-url)
COST TRANSFER
SOLAR WALL

60’ WIDE

SUPER WINDOW
Improved Daylight

Solar Control

Triple-Pane Low-e Glazing

Natural Ventilation
04 LEED energy modeling is not enough.

Figure ES- 4: Measured versus Design EUIs
All EUIs in kBtu/sf
PREDICTIVE MODELING

1. CONCEPT
2. DESIGN
3. CONSTRUCTION
4. OPERATIONS

CHARRETTE MODEL
AS-DESIGNED MODEL
LEED MODEL + BASELINE
AS-BUILT MODEL
OPERATIONS MODEL

ZERO
35 kBtu/ft²/Year

- Space Heating: 24.4%
- Space Cooling: 2.4%
- Pumps: 1.3%
- Ventilation Fans: 5.3%
- Domestic Hot Water: 2.6%
- Exterior Lights: 0.3%
- Lights: 5.9%
- Office Plug Loads: 22.4%
- Task Lights: 0.3%
- Data Center: 34.4%
- Data Center Cooling: 0.1%
- Data Center Fans: 0.6%
Follow through.

Data Center
Mechanical Systems
Plug Loads
Lighting
Heating
Cooling
Model Annual EUI
RSF Annual EUI

Note: The annual EUI values are demand side values and do not include the

MODELED VS. MEASURED

35 kBtu/ft² (110 kWh/m²)
<table>
<thead>
<tr>
<th>Device</th>
<th>Power (Watts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOIP Phones</td>
<td>2</td>
</tr>
<tr>
<td>VOIP Phones</td>
<td>15</td>
</tr>
<tr>
<td>LED Task Light</td>
<td>6</td>
</tr>
<tr>
<td>Fluorescent Task Light</td>
<td>35</td>
</tr>
<tr>
<td>24” LCD Monitor</td>
<td>18</td>
</tr>
<tr>
<td>24” LCD Monitor</td>
<td>50</td>
</tr>
<tr>
<td>Laptop Computer</td>
<td>30</td>
</tr>
<tr>
<td>Desktop Computer</td>
<td>300</td>
</tr>
<tr>
<td>Shared Printers</td>
<td>100</td>
</tr>
<tr>
<td>Personal Printer</td>
<td>460</td>
</tr>
<tr>
<td>Load Sensing Power Strip</td>
<td>1500</td>
</tr>
<tr>
<td>Personal Space Heater</td>
<td>460</td>
</tr>
</tbody>
</table>

**PLUG LOAD**

![Image of a computer setup with a keyboard and monitor]
01 Put it in writing.
02 Integrated delivery for cost control.
03 Invest in architecture.
04 LEED energy modeling is not enough.
05 Follow through.
Theresa Spurling-Wood
Alachua County Public Schools
Getting to Zero:
The How (and Why) of Net Zero Energy For K-12 Schools

Better Buildings Summit 2014
Theresa Spurling-Wood CIE, GGP, LEED AP
The EISA of 2007 set a goal of net-zero energy use for commercial buildings by 2030. EISA 2007 further specified a net-zero energy target of 50% of U.S. commercial buildings by 2040 and a net-zero standard for 100% of new and existing commercial buildings by 2050. When does it apply to schools?

According to US DOE, nationally K-12 schools spend more than $6 billion each year on energy, more than on books and computers.
PV totaling 2.03 Megawatts on 21 sites

<table>
<thead>
<tr>
<th>School</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
<th>Total kW Installed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buchholz High School</td>
<td>156</td>
<td>52</td>
<td>104</td>
<td>313</td>
</tr>
<tr>
<td>Duval</td>
<td></td>
<td></td>
<td></td>
<td>54</td>
</tr>
<tr>
<td>Eastside High School</td>
<td></td>
<td></td>
<td>26</td>
<td>78</td>
</tr>
<tr>
<td>Ft. Clarke Middle School</td>
<td>156</td>
<td></td>
<td>52</td>
<td>208</td>
</tr>
<tr>
<td>GlenSprings Elementary School</td>
<td></td>
<td>79</td>
<td></td>
<td>79</td>
</tr>
<tr>
<td>Howard Bishop</td>
<td></td>
<td></td>
<td>31</td>
<td>31</td>
</tr>
<tr>
<td>Kanapaha Middle School</td>
<td>52</td>
<td>157</td>
<td></td>
<td>209</td>
</tr>
<tr>
<td>Lincoln Middle School</td>
<td>52</td>
<td>53</td>
<td></td>
<td>105</td>
</tr>
<tr>
<td>Littlewood Elementary School</td>
<td></td>
<td></td>
<td>57</td>
<td>57</td>
</tr>
<tr>
<td>Loften High School</td>
<td>105</td>
<td></td>
<td></td>
<td>105</td>
</tr>
<tr>
<td>Meadowbrook Elementary School</td>
<td></td>
<td>183</td>
<td></td>
<td>183</td>
</tr>
<tr>
<td>Sidney Lanier Center</td>
<td>52</td>
<td></td>
<td></td>
<td>52</td>
</tr>
<tr>
<td>Terwilliger Elementary School</td>
<td></td>
<td></td>
<td>103</td>
<td>103</td>
</tr>
<tr>
<td>Westwood Middle School</td>
<td>126</td>
<td></td>
<td></td>
<td>126</td>
</tr>
<tr>
<td>Wiles Elementary School</td>
<td></td>
<td>52</td>
<td></td>
<td>52</td>
</tr>
<tr>
<td>Williams Elementary School</td>
<td>50</td>
<td>104</td>
<td></td>
<td>155</td>
</tr>
<tr>
<td>Gainesville High School</td>
<td></td>
<td></td>
<td>52</td>
<td>52</td>
</tr>
<tr>
<td>Lake Forest Elementary School</td>
<td></td>
<td>26</td>
<td></td>
<td>26</td>
</tr>
<tr>
<td>Hawthorne HS</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>High Springs Community</td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Waldo Community</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>750</strong></td>
<td><strong>528</strong></td>
<td><strong>736</strong></td>
<td><strong>2,034</strong></td>
</tr>
</tbody>
</table>
WHEREAS, both the City of Gainesville and the SBAC believe that a solar awareness program at schools is an important first step to increasing the use of solar energy in the community and that schools are an excellent showcase for the benefits of solar energy.

2003

The path to getting there started with a partnership project between the City of Gainesville and School Board of Alachua County which included installation of two 1.8 kW PV arrays at two middle school locations.
Typical Hot & Humid School
2002 Energy Consumption Profile

- HVAC: 53%
- Lighting: 30%
- Miscellaneous: 10%
- Hot Water: 7%
2008 - 2009

- Started a district wide energy reduction program due to increasing utility costs

- FY 07/08 annual usage was 57,563,967 kWh*

*These numbers are for the schools involved in the annual conservation incentive program and only uses kWh reduction for rewards data.
2009 - 2011

- FY 08/09  51,956,668 kWh
- FY 09/10  53,578,536 kWh
- FY 10/11  53,175,367 kWh

- Consumption trending upward
- School Board requested more energy savings
- Going backward on “Path to Net Zero” possibilities
2011
Alachua County Public Schools begins PV Feed In Tariff Program

• No installation or maintenance cost to School Board
• Provides roof rental income to the District for 20 years
• 750kW of FIT PV installed on schools, program sponsored by Gainesville Regional Utilities
• Roof leases will expire in 20 years and PV system ownership including revenue or net metering deductions will be turned over to ACPS
• To ensure current roof warranties not voided, some manufacturers required additional protection from PV array installations
2012
Lessons learned and energy consumption decreases

- FY 11/12  48,966,737  kWh
- 528kW of FIT PV added to school roofs
- While selecting sites to mount PV arrays, always check the condition of every site roof because sometimes locations will need to be shifted
- Inspect all building electrical tie-ins and it should be noted permitting process needs to be streamlined for renewables
- Ownership of a school building does not change and is appealing to investors
- It is a long term relationship with installation contractor and investors
2013

- FY 12/13  46,183,508 kWh
- New school usage 815,121 kWh*
- Reducing load everywhere involves everyone
- 736 kW of FIT PV on school sites includes *Meadowbrook ES
- 10 Percent district wide total energy reduction
Analysis of Meadowbrook Elementary School Performance:  
**Towards Net Zero Energy**

*Presented by*

Hamed Hakim  
Ruthwik Pasunuru  
Arati Sakhalkar
Why Net Zero schools?

- Schools consume 17% of non-residential energy in US
- According to U.S.DOE (2006), $2 billion can be saved by improving energy strategies in schools
- Easy to make Net Zero since
  - Less operation hours
  - Seasonal Occupation
  - Long holiday break periods
  - Large site and roof areas
- 15 Net Zero schools in US
  - none in Florida
- Based on studies
  - average EUI of existing NZE school: 21.1 kBtu/sf/yr

Net Zero School Projects’ EUI (kBtu/sf-yr),
Source: Hutton; Doo Consulting Firm
ASHRAE Advanced Energy Design Guide for K-12 School Buildings

• Developed by collaboration of ASHRAE, American Institute of Architects (AIA), Illuminating Engineering Society of North America (IESNA), US Green Building Council with support from Department of Energy (DOE)

• Guidelines to achieving 50% energy savings for a building complying with ASHRAE/IESNA 90.1-2004 standard

• Recommendations for 8 primary climate zones in USA and highlights various steps involved to design a NetZero Energy School

• Outlines requirements for design criteria for Envelope, Daylighting, Electric Lighting, HVAC, Plug loads, Quality Assurance, Kitchen Equipment, Commissioning
# Meadowbrook Elementary School Data

<table>
<thead>
<tr>
<th>SCHOOL AT GLANCE</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Owner</td>
<td>Alachua County Public Schools</td>
</tr>
<tr>
<td>Designer</td>
<td>Schenkel Shultz Architectural Firm</td>
</tr>
<tr>
<td>Contractor</td>
<td>Parrish-McCall Constructors</td>
</tr>
<tr>
<td>Principal Use</td>
<td>Elementary K-12 school</td>
</tr>
<tr>
<td>Occupants</td>
<td>Approximately 600 students, 50 employees</td>
</tr>
<tr>
<td>Gross Area</td>
<td>95,620 SF</td>
</tr>
<tr>
<td>Conditioned Area</td>
<td>Approximately 85,000 SF</td>
</tr>
<tr>
<td>Distinctions/Awards</td>
<td>4-Globes</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$16.5 M</td>
</tr>
<tr>
<td>Completion</td>
<td>July 2012</td>
</tr>
</tbody>
</table>
Meadowbrook Elementary School Design Data

- Integrated design approach used
- East/West axis building orientation optimum for daylight harvesting
- Good lighting design and with local light controls
- Two 150 ton chillers outfitted with Bipolar Ionization modules
- Low-emission and non-toxic paints, sealers, coatings, and adhesives used in construction phase
- Green Globes certified (4 Green Globes)
- Can be considered as Net Zero ready school
Meadowbrook Elementary School

Actual modeling consumption

- Software used for modelling: Trane Trace 700
- End Energy Use breakdown:
  - Heating: 5%
  - Primary cooling: 19%
  - Auxiliary: 34%
  - Lighting: 15%
  - Receptacle: 27%
- EUI: 27.68 kBtu/sf/yr
## Results

Energy Use Intensity (EUI) in kBtu/sf/yr

<table>
<thead>
<tr>
<th>Actual Model</th>
<th>ASHRAE 90.1, 2007</th>
<th>ASHRAE AEDG 50% Savings</th>
<th>Proposed Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>27.68</td>
<td>35.83</td>
<td>25.7</td>
<td>22.71</td>
</tr>
</tbody>
</table>

Close to average EUI of Net Zero Schools in US ie 21.1 kBtu/sf/yr
Calibration of simulated model

Calibration Standards & Techniques used -
- IPMVP (2002)
- FEMP (2008)
- ASHRAE (2002)

Coefficient of Variance –

\[
RMSE_{MONTH} = \left[ \frac{(M_{Month} - S_{Month})^2}{N_{Month}} \right]^{1/2}
\]

\[
CV (RMSE_{MONTH})\% = \frac{RMSE_{MONTH}}{A_{MONTH}} \times 100
\]

Therefore, FEMP (±10%) & ASHRAE (±15%) compliant!
Energy Use Intensity

Path to NET ZERO energy

EUI (KBTU/sf-yr)

- 68.00
- 35.83
- 27.68
- 25.7
- 21.10
- 22.71
Other recommendations based on AEDG

- HVAC: Strategies like Energy Recovery, Dedicated Outdoor Air Systems (DOAS), Demand Control Ventilation

- Plug Loads: 0.7 W/sf, Use of ENERGY STAR equipment, 2/3 laptops of total computers

- Lighting: Use of LEDs, additional 20% savings in lighting energy by daylighting strategies such as solar tubes, sky lights, roof monitors

- Using VFD demand based exhaust, highly efficient refrigeration systems for kitchens

- Regular auditing, operation & maintenance, educating occupants
Scope of PV panels to offset energy consumption

- EUI of Proposed Model: 22.71 kBtu/sf/yr

- NREL’s PV Watts Calculator: 500 kW array required to completely offset Energy Consumption

- Current PV System: 183 kW, 609 Hanwha Panels, 14 – 15% efficient

- Additional array required to achieve net zero status: 317 kW (approx.)
Potential areas for PV installation

- Area available on roof -

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4400</td>
<td>SF</td>
</tr>
<tr>
<td>B</td>
<td>11700</td>
<td>SF</td>
</tr>
<tr>
<td>C</td>
<td>7000</td>
<td>SF</td>
</tr>
<tr>
<td>D</td>
<td>3100</td>
<td>SF</td>
</tr>
<tr>
<td>E</td>
<td>4500</td>
<td>SF</td>
</tr>
<tr>
<td>F</td>
<td>2300</td>
<td>SF</td>
</tr>
<tr>
<td>Total:</td>
<td>33000</td>
<td>SF</td>
</tr>
</tbody>
</table>

PV Panel Area = (85%)(33000) = 28050 SF

- Current PV occupies 18,000 sf.

- Therefore, area available 10,050 sf.

- Cannot achieve Net Zero status on footprint, if existing panels used.
Potential areas for PV installation

Solar carport system for parking lot

- PV system support
- Shade for parking
- Minimize radiant heat transfer

- 53,000 sf of roof area is available if flat roof is considered.
- Flat roof increases the PV installation area by 50%
Limitations

- Economics of energy efficiency designs is not discussed in this work.
- All the results are based on estimated inputs.
- We recommend more detailed research on integrating energy and economic policies for schools in Florida which can motivate them to achieve net zero energy status.

Summary & Conclusions

- NetZero Concept is moving towards next “normal” in the Construction Industry.
- Net Zero Schools are serving as test platforms for adopting technical and financial aspects of NetZero.
- If designed and implemented all NetZero strategies well, Florida is not far away in getting its First Net Zero School.
- Most importantly, making students stewards of NetZero Energy concept is the biggest achievement.
Moving forward

- The cost of existing system was $525K
- An additional 100kW could be added on the roof of Meadowbrook for additional $300K
- Contractor stated almost no issues with the existing building design for installing the solar modules, racking, DC wiring, and inverters since all of the conduits ran on the exterior of the building and
- Based on current marginal cost of electricity of $0.132/kWh, would be approximately a 15-year payback for district which is longer than usual because there are no tax benefits for a school district and assuming 4% electricity inflation.
Meadowbrook Elementary
Installation completed
Total Net Zero

• Would require a total of system total of 500 kW

• Would require an additional ground mounted system of 217 kW to reach Net Zero using existing PV panel arrays

• Ground options could be a covered parking area or the existing roof of the covered play court.

• Additional electrical infrastructure would be needed.
Could District go to NET ZERO?

How many kW would you need to provide 45,000,000 kWh of electrical energy from a PV system? What would be the payback?

Current annual electricity total $7 million
http://www.earthday.org/footprint-calculator

Special Thanks goes to
Charles J. Kibert, Ph.D., P.E.
Holland Professor
Powell Center for Construction & Environment
University of Florida
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Gainesville, Florida 32611-5703  USA
t: +1 352 273 1189

ACPS Link to all solar projects:
http://www.sbac.edu/pages/ACPS/Departments_Programs/DepartmentsAF/D_thru_F/FacilitiesMainConstr/Energy_Conservation/Solar_Projects

Questions and comments:
Theresa Spurling-Wood, LEED AP, CIE
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352-955-7400 ext 1430
NZE Resources

Commercial Building Consortium
http://www.zeroenergyCBC.org/

SEE Action
http://www1.eere.energy.gov/seeaction/

NEEP ZNE Roadmap

New Buildings Institute
http://newbuildings.org/zero-energy
Discussion