Improved Life Cycle Performance for Construction of Big Box Retail

Amanda Pidgeon
IIT Masters Project
Spring 2012
The U.S. building industry was responsible for 8% of the world’s primary energy consumption in 2008. We consume more energy than any other country, but we are not even in the top five in terms of population size. Within the United States, the building industry accounted for 40% of the primary energy consumption, making the building sector a larger consumer than any other sector.

Many people would be surprised to learn that the transportation sector is actually not the largest producer of CO₂ emissions. At 40%, the building sector is responsible for more CO₂ emissions than any other sector in the United States. The U.S. is the second largest producer of emissions in the world, and our building industry alone accounts for 7.5% of the global total.

There already exist many movements and standards which strive to achieve lower levels of energy consumption and CO₂ emissions in the construction and operation of buildings. However, there seems to be less concern about what happens to buildings at the end of their life cycle. Annual construction and demolition debris currently accounts for roughly 24% of the municipal solid waste stream. Demolition accounts for 85% of that compared to 15% for construction. As much as 95% of building related construction waste is recyclable.

1 American house uses approximately 41,000 MJ annually

1 passenger car emits approximately 7.5 tonnes of CO₂ annually

1 passenger car emits approximately 7.5 tonnes of CO₂ annually

1 adult male elephant weighs 6.8 tonnes
**Life Cycle Analysis**

The Life Cycle Analysis of a building is the process of accounting for the impacts of the building resulting from the materials and processes associated with the production, use, and recycle/reuse/disposal of the building at the end of its life. This includes harvesting raw materials, manufacturing of products, transportation of materials and products, assembly into a structure, maintenance and operations during use, and disposal at the end of its useful life.

LCA is a way of quantifying and analyzing many different factors which affect the human environment, one of which is embodied energy. Embodied Energy of a building is defined as the total energy input consumed during the life cycle of the materials and products of the building. A life cycle analysis could also include factors like CO2 emissions, ozone depletion, and/or human respiratory effects to name a few. Currently, there are a number of sources which are producing life cycle data. Unfortunately, there is no standard by which these values are weighted so conflicting data exists.

**Athena Sustainable Materials Institute**

The Athena Sustainable Materials Institute (www.athenamsi.ca) is a Canadian not-for-profit whose objective is “to foster sustainability of the built environment, by meeting the building community’s need for better information and tools that allow environmental considerations to be factored into the design process.”

Athena has created two software tools, both of which analyze construction assemblies for 8 different impact measurements. They reference data that the Athena Institute has compiled as well as the National Renewable Energy Laboratory’s (NREL) research and data.

The EcoCalculator software, used in this project, was created by the Athena Institute as a free spreadsheet available by download on their website. The second software created by Athena is the Building Impact Estimator software. This software may be downloaded from their website for a cost and is much more customizable.

I have chosen to use this the EcoCalculator because it offers easily comparable data. There are many sources and softwares where similar data can be found. Unfortunately, there is a lot of debate about how these different factors should be weighted. Therefore, much of the data from different sources is conflicting.

This project will compare multiple construction materials and assemblies in order to find options which will improve the life cycle performance of retail big box structures, using Walmart Supercenters as a specific case study. It will utilize the Athena EcoCalculator to accomplish this task.
**Athena EcoCalculator**

The Athena Sustainable Materials Institute (www.athenamsi.ca) is a Canadian not-for-profit whose objective is “to foster sustainability of the built environment, by meeting the building community’s need for better information and tools that allow environmental considerations to be factored into the design process.”

The EcoCalculator Software, used in this project, was created by the Athena Institute as a free spreadsheet software available by download on their website. The software analyzes 7 assembly categories for 8 different impact measurements (see right). It references data that the Athena institute has completed as well as the National Renewable Energy Laboratory’s (NREL) research and data. For each category, the user inputs the area or volume associated with that assembly. The software summarizes the results with graphs for each impact measurement.

**Impact Measurements**
- Energy Consumption
- Material Resource Use
- Global Warming Potential
- Acidification Potential
- Human Health Respiratory Effect Potential
- Aquatic Eutrophication Potential
- Ozone Depletion Potential

**Assembly Types**
- Foundations and Footings
- Columns and Beams
- Intermediate Floors
- Exterior Walls
- Windows
- Interior Walls
- Roofs
- Smog Potential

**Software Assumptions**

The software does have some limitations. It is limited in the types of materials and construction assemblies to choose from. Any material that is relatively new or unique is not included. You can not edit/add assemblies to the spreadsheet; you may only use what they provide. For example, column heights are set to 10 ft with bays of 30’ x 30’.

**Global Assumptions:**
- 60 year useful life
- All concrete (except floor topping) is 4000 psi
- Cast-in-place concrete contains 25% fly ash
- Concrete masonry contains 0% fly ash
- Precast concrete contains 10% silica fume

**Column and Beam Assumptions:**
- Bay sizes are set at 30’ x 30’
- Column heights are set at 10’
- Glulam beams are 24’ grade
- HSS steel columns are 5” x 5” x 1/4” steel tube
- Softwood columns are 6” x 6” built up

**Roof Assumptions:**
- Live load for roofs are set at 45 psf
- Spacing of structural members are set based on system

---

**F. INTERIOR WALLS**

In the yellow cells below, enter the amount of square footage that each assembly uses in Y.

<table>
<thead>
<tr>
<th>ASSEMBLY TYPE</th>
<th>Square footage</th>
<th>Percentage of total</th>
<th>Feas:Fuel Consumption (Mg)</th>
<th>Weighted Resource Use (tonnes)</th>
<th>GWF (tCO2eq/TOT)</th>
<th>Acidification Potential (tHg/TOT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average across interior walls</td>
<td>73.07</td>
<td>9.11</td>
<td>4.90</td>
<td>1.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 24’ Wood stud wall 2” x 6”</td>
<td>0.0</td>
<td>31.41</td>
<td>5.8309</td>
<td>1.45</td>
<td>0.64</td>
<td></td>
</tr>
<tr>
<td>2 8’2” x 6” Gypsum board</td>
<td>2 coats Latex paint</td>
<td>0.0</td>
<td>30.94</td>
<td>5.3725</td>
<td>1.89</td>
<td>0.63</td>
</tr>
<tr>
<td>3 24” Wood stud wall 2” x 6”</td>
<td>0.0</td>
<td>44.48</td>
<td>7.9299</td>
<td>2.30</td>
<td>1.06</td>
<td></td>
</tr>
<tr>
<td>4 6” x 6” x 3-3/8” Steel stud 14 gauge</td>
<td>0.0</td>
<td>27.47</td>
<td>4.5814</td>
<td>1.94</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td>5 1-5/8” x 3-3/8” Steel stud 24 gauge</td>
<td>0.0</td>
<td>35.40</td>
<td>4.3000</td>
<td>1.78</td>
<td>0.71</td>
<td></td>
</tr>
</tbody>
</table>

Columns and beams can be confusing. You need only enter the supported floor and/or roof areas in the yellow column. (In yellow in this diagram)

Note: This models a 10 ft. floor-to-floor height, therefore the columns are included.

To hide or view this pop-up, select View > Comments, or click the Show/Hide comments box above.
Walmart is by far the largest retailer both in terms of sales and physical store space. In sales, Walmart makes nearly four times in sales compared to the next largest retail company. Walmart has more stores nationwide than any other retailer, which together cover more area than the island of Manhattan.

The average size of a Walmart Supercenter is 185,000 square feet. In 2012 they plan to build approximately 110 new supercenters in the US which works out to just over 20 million square feet.

Walmart's Sustainability Plan

Launched in 2005
1. Be supplied 100 percent by renewable energy.
2. Create zero waste. Sell products that sustain people and the environment.

Walmart has a huge amount of influence in the commercial sector and claim to be a leader for sustainability practices. However, when you look closely at the numbers, things don't quite add up.

2% of Walmart's U.S. electricity consumption that currently comes from its solar projects and specially purchased wind energy

3.7 million metric tons of CO₂ emitted annually by stores built since 2006

1.5 million metric tons of CO₂ saved annually by energy efficiency improvements to stores built before 2006

Some of what Walmart is doing:
- daylight harvesting system
- daylight sensors which dim sales floor lighting
- solar arrays on roofs
- T-8 fluorescent lamps and electronic ballasts
- centralized energy management system
- LED lighting in exterior building signage
- LED lighting and occupancy sensors in refrigerated/freezer cases
- no more open air refrigerated cases
- occupancy sensors in non-sales areas
- “super” high efficiency HVAC units (6% more efficient than required by California Title 24
- dehumidification allows more efficient cooling
- radiant floors in some stores
- white membrane roofs (no PVC)
- 70% of water heated by reclaiming waste heat from refrigeration equipment
- low-flow plumbing fixtures

Walmart by the numbers

2011 Sales in the U.S.:

$307.7 billion  Walmart
$78.3 billion  The Kroger Co.
$65.8 billion  Target

Walmart's Sustainability Plan

Launched in 2005
1. Be supplied 100 percent by renewable energy.
2. Create zero waste. Sell products that sustain people and the environment.

Walmart has a huge amount of influence in the commercial sector and claim to be a leader for sustainability practices. However, when you look closely at the numbers, things don't quite add up.

2% of Walmart's U.S. electricity consumption that currently comes from its solar projects and specially purchased wind energy

3.7 million metric tons of CO₂ emitted annually by stores built since 2006

1.5 million metric tons of CO₂ saved annually by energy efficiency improvements to stores built before 2006

Some of what Walmart is doing:
- daylight harvesting system
- daylight sensors which dim sales floor lighting
- solar arrays on roofs
- T-8 fluorescent lamps and electronic ballasts
- centralized energy management system
- LED lighting in exterior building signage
- LED lighting and occupancy sensors in refrigerated/freezer cases
- no more open air refrigerated cases
- occupancy sensors in non-sales areas
- “super” high efficiency HVAC units (6% more efficient than required by California Title 24
- dehumidification allows more efficient cooling
- radiant floors in some stores
- white membrane roofs (no PVC)
- 70% of water heated by reclaiming waste heat from refrigeration equipment
- low-flow plumbing fixtures

Walmart by the numbers

2011 Sales in the U.S.:

$307.7 billion  Walmart
$78.3 billion  The Kroger Co.
$65.8 billion  Target

Walmart is by far the largest retailer both in terms of sales and physical store space. In sales, Walmart makes nearly four times in sales compared to the next largest retail company.

Walmart has more stores nationwide than any other retailer, which together cover more area than the island of Manhattan.

The average size of a Walmart Supercenter is 185,000 square feet. In 2012 they plan to build approximately 110 new supercenters in the US which works out to just over 20 million square feet.
Current Supercenter Construction
(Baseline)

Roof Construction
188,019 sf
EPDM Membrane
R-20 cont. rigid insulation (4") + polyethylene membrane
Open-web steel joist w/ steel decking

Exterior Wall Construction
205,318 sf
4" Face brick
Air Space
2" cont. rigid insulation
8" CMU

Interior Columns
10" square HSS

Interior Wall Construction
6,540 sf
6" CMU
2 coats latex paint

Floor Slab
188,019 sf
4" poured concrete slab

Foundations and Footings:
205,318 sf / 3,230 cf
CIP concrete
R-7.5 XPS insulation (1.5")

This is an example of the current design of a typical Walmart Supercenter. These values will be used to establish a baseline comparison using the Athena EcoCalculator software.

Foundation Wall Surface Area: 8,464 sf
Footing Volume: 3,230 cf
Floor/Roof Area: 188,019 sf
Exterior Wall Surface Area: 205,318 sf
Interior Wall Surface Area: 6,540 sf

Floor Plan

This is an example of the current design of a typical Walmart Supercenter. These values will be used to establish a baseline comparison using the Athena EcoCalculator software.
Baseline Analysis

After entering the construction assembly information into the Athena EcoCalculator software, it generates a summary of the information first by assembly type and then by impact measurement. Here I have shown the three impact values that are significant to this project: energy, emissions and waste. As you can see, the roof, exterior walls, and the foundations are the biggest contributors in all three categories.

From here I decided the best method to evaluate the multiple combinations of assemblies would be to analyze each assembly individually.
NOTES: Insulation data based on CIP foundation.

Fossil Fuel Consumption (MJ/sf)

<table>
<thead>
<tr>
<th>Structure</th>
<th>Insulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIP</td>
<td>78.93</td>
</tr>
<tr>
<td>CMU</td>
<td>199.08</td>
</tr>
<tr>
<td>XPS</td>
<td>78.93</td>
</tr>
<tr>
<td>EPS</td>
<td>75.36</td>
</tr>
</tbody>
</table>

Global Warming Potential (kg CO2 eq /sf)

<table>
<thead>
<tr>
<th>Structure</th>
<th>Insulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIP</td>
<td>9.52</td>
</tr>
<tr>
<td>CMU</td>
<td>15.01</td>
</tr>
<tr>
<td>XPS</td>
<td>9.52</td>
</tr>
<tr>
<td>EPS</td>
<td>9.33</td>
</tr>
</tbody>
</table>

Weighted Resource Use (kg/sf)

<table>
<thead>
<tr>
<th>Structure</th>
<th>Insulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIP</td>
<td>61.65</td>
</tr>
<tr>
<td>CMU</td>
<td>13.25</td>
</tr>
<tr>
<td>XPS</td>
<td>61.65</td>
</tr>
<tr>
<td>EPS</td>
<td>61.57</td>
</tr>
</tbody>
</table>

CIP Concrete
- 4" poured concrete slab
- Cast-in-place concrete foundation
- R-7.5 continuous insulation
- Poured concrete footing

CMU
- 4" poured concrete slab
- Concrete block foundation
- R-7.5 continuous insulation
- Poured concrete footing
### Columns

<table>
<thead>
<tr>
<th>Material</th>
<th>Fossil Fuel Consumption (MJ/sf)</th>
<th>Global Warming Potential (kg CO2 eq /sf)</th>
<th>Weighted Resource Use (kg/sf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Concrete</td>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
<td><img src="image3" alt="Graph" /></td>
</tr>
<tr>
<td>2 - Glulam</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 - LVL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 - Hollow Structural Section</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 - Wide Flange</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTES:**
Data based on load bearing exterior wall values.
Interior Wall Assemblies

NOTES:
*Gyp. Bd. + Paint on interior
**studs 16” o.c.
Exterior Wall Assemblies - Cladding

NOTES:
Comparison based on metal stud values

Brick
- Brick Cladding
- Continuous Insulation
- Steel Stud w/ Cavity Insulation
- Gyp. Bd. + Paint

Steel
- Steel Cladding
- Continuous Insulation
- Steel Stud w/ Cavity Insulation
- Gyp. Bd. + Paint

Stucco
- Stucco Cladding
- Continuous Insulation
- Steel Stud w/ Cavity Insulation
- Gyp. Bd. + Paint

Vinyl Cladding
- Vinyl Cladding
- Continuous Insulation
- Steel Stud w/ Cavity Insulation
- Gyp. Bd. + Paint

Wood Cladding
- Wood Cladding
- Continuous Insulation
- Steel Stud w/ Cavity Insulation
- Gyp. Bd. + Paint

EIFS
- EIFS
- Continuous Insulation
- Steel Stud w/ Cavity Insulation
- Gyp. Bd. + Paint

Precast Concrete
- Precast Concrete Cladding
- Continuous Insulation
- Steel Stud w/ Cavity Insulation
- Gyp. Bd. + Paint

Fossil Fuel Consumption (MJ/sf)

147.74 (Brick)
90.17 (Steel)
95.1 (Stucco)
66.44 (Vinyl)
326.72 (Wood)
146.1 (EIFS)
24.43 (Precast)

Global Warming Potential (kg CO2 eq /sf)

9.34 (Brick)
5.96 (Steel)
5.12 (Stucco)
4.1 (Vinyl)
13.54 (Wood)
13.74 (EIFS)
27.29 (Precast)

Weighted Resource Use (kg)

24.43 (Brick)
23.76 (Steel)
14.87 (Stucco)
7.3 (Vinyl)
11.35 (Wood)
27.29 (EIFS)
65.1 (Precast)
1 - Precast Hollow Core Concrete
EPDM over Continuous Insulation
Precast Hollow Core Concrete
Latex Paint

2 - Precast Concrete Double-T
EPDM over Continuous Insulation
Precast Concrete Double T
Latex Paint

3 - Suspended Concrete Slab
EPDM over Continuous Insulation
Suspended Concrete Slab
Latex Paint

4 - Open Web Stl Joist w/ Stl Deck
EPDM over Continuous Insulation
Open Web Stl Joist w/ Stl Deck

5 - Open Web Stl Joist w/ Wd Deck
EPDM over Continuous Insulation
Open Web Stl Joist w/ Wd Deck

6 - Glulam Joist w/ Plank Deck
EPDM over Continuous Insulation
Glulam Joist w/ Plank Deck

7 - Wood I-Joist w/ Wood Deck
EPDM over Continuous Insulation
Wood I-Joist w/ Wood Deck

8 - Solid Wood Joist w/ Wood Deck
EPDM over Continuous Insulation
Solid Wood Joist w/ Wood Deck

9 - Flat Wood Truss w/ Wood Deck
EPDM over Continuous Insulation
Flat Wood Truss w/ Wood Deck

### Roof Assemblies - Structure

**Fossil Fuel Consumption (MJ/sf)**

- 1: 173.40
- 2: 158.96
- 3: 241.91
- 4: 174.28
- 5: 159.81
- 6: 148.43
- 7: 153.33
- 8: 138.86
- 9: 144.30

### Global Warming Potential (kg CO2 eq /sf)

- 1: 10.02
- 2: 8.15
- 3: 17.81
- 4: 6.28
- 5: 4.00
- 6: 4.53
- 7: 4.81
- 8: 4.17
- 9: 4.32

### Weighted Resource Use (kg/sf)

- 1: 45.47
- 2: 31.27
- 3: 99.36
- 4: 10.32
- 5: 8.54
- 6: 7.55
- 7: 18.94
- 8: 12.41
- 9: 13.90

*NOTES:
Comparison based on values for EPDM membrane over continuous rigid insulation
*Gyp. Bd. + Paint on interior
Comparison based on values for rigid insulation on metal decking. Only flat roof options are considered.


**Lowest EcoCalculator Values Condition**  
**All Wood Construction**

This construction is what results from choosing the assemblies with the lowest values (particularly for fossil fuel consumption and global warming potential. It is mostly wood, including wood cladding on the exterior. It reduces these two categories by more than half.

What impact would Walmart have if they switched to this construction?  
They would be able to...

*based on 110 supercenters per annum  
**each icon equals 5,000 units

- ...power 195,800 houses  
  (8 million MJ annually)

- ...remove 70,290 cars from the road  
  (527,100 tonnes CO2 eq annually)

- ...reduce waste by the weight of 39,600 elephants  
  (269,600 tonnes of waste annually)
This construction is a combination the previous assembly with a brick facade. This construction would allow Walmart to keep the exterior aesthetic of their stores relatively similar to the current look. This still results in a major reduction in fossil fuel and global warming potential. However, this system shows an increase in raw resources use according to the EcoCalculator.

What impact would Walmart have if they switched to this construction?

They would be able to...

*based on 110 supercenters per annum
**each icon equals 5,000 units

...power **168,219 houses**

(6.8 million MJ annually)

...remove **61,820 cars** from the road

(463,650 tonnes CO2 eq annually)

...increase waste by the weight of **1,650 elephants**

(+11,220 tonnes of waste annually)
This construction is a variation on the original construction. The only change is cast-in-place walls instead of concrete block. As expected from the graphs on the exterior wall structure page earlier in this document, this results in a decent reduction in energy and emissions. Unfortunately, it is a significant increase in resource consumption.

What impact would Walmart have if they switched to this construction?

They would be able to...

*based on 110 supercenters per annum
**each icon equals 5,000 units

...power 119,802 houses
(4.9 million MJ annually)

...remove 35,200 cars from the road
(264,000 tonnes CO2 eq annually)

...increase waste by the weight of 99,615 elephants
(+677,400 tonnes of waste annually)