SEPTEMBER 30, 2020

NET-ZERO ENERGY PROJECT DESIGN ASSISTANCE

FOR BRENT ELEMENTARY SCHOOL

FINAL REPORT

DGS
THE DEPARTMENT OF GENERAL SERVICES

DISTRICT OF COLUMBIA PUBLIC SCHOOLS

MOYA DESIGN PARTNERS

hord | coplan | macht

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FINAL REPORT

Project Team

General

Grant Award Information

- Project Title: Net-Zero Energy Project Design Assistance for Brent Elementary School
- DOEE ID #/Award Number: 2020-2008-USA-4
- Award Period: May 6, 2020 through September 30, 2020
- Specific Progress Reporting Period: Final Report
- Grantee Organization name: Moya Design Partners
- Grantee Organization primary contact person(s) – telephone and email: Paola Moya; paola@moyadesignpartners.com; +1.301.442.2045

Status Report

Briefly summarize the purpose and status of your project, including a statement as to whether or not the project is on time, on budget, and achieving the match.

DCPS is seeking to fully modernize the existing Brent Elementary School at North Carolina Ave and 3rd St SE. This project proposes to augment our sustainability design efforts with the goal of designing the school as a Net-Zero ready facility. The design work undertaken will reduce carbon emissions, as the energy saving strategies can be implemented into the design whether or not the project achieves Net Zero.

An initial budget of 55 million had been established for the school modernization. However, an estimate provided during concept phase ranged from 78-80 million. Even though the renovation of the school has been postponed until FY25, the project team considers the evaluation of NZE strategies highly relevant to this stage of design. The conclusions of this exercise will help inform future design decisions with valuable, quantifiable data.

The Net-Zero Energy Project Design Assistance for Brent Elementary School has been completed and has achieved the match. Due to COVID-19, the team was not able to pursue the 'Student Engagement' activity. Instead, the project team shifted the funds from 'Student Engagement' activity to the 'Detailed Energy Model' activity. This gave us the opportunity to run several options on our energy model and as a result helped us stream down our options to meet Brent's path for NZE performance.

Barriers to Implementation

Briefly summarize any barriers your project has faced, and if project implementation has been impeded as a result.

DCPS has notified the design team that this project will be implemented no sooner than during the FY 2025/26 timeframe, inclusive of any progress on the design beyond the concept design period. While DCPS still supports the work on the initiative, it does mean that certain detailed design elements will not be fully consolidated into the design. What this means for the Net Zero Initiative is that the design team will approach the design as an exercise in determining what values and systems considered as Energy Conservation Measures (ECMs) the project should have, considered as a function of the preliminary massing which has been developed during the concept design. The result will be a series of benchmark values and system selections that the design team can use as a series of guideposts once we are given a notice to proceed for the balance of the design.

Additionally, the COVID-19 pandemic impacted the likelihood that any meaningful student engagement exercise could be performed within the period required by this grant funding. The design team proposed to reallocate the funding targeted to the student engagement exercise to additional energy modeling iterations.

Activities/Outputs/Outcomes

List each specific activity conducted. These activities will correspond with Attachment 1 to the Grant Award Notice, "Activities Funded."

Refer to Work Plan (See Appendix) for activities conducted as of 7/27/2020.

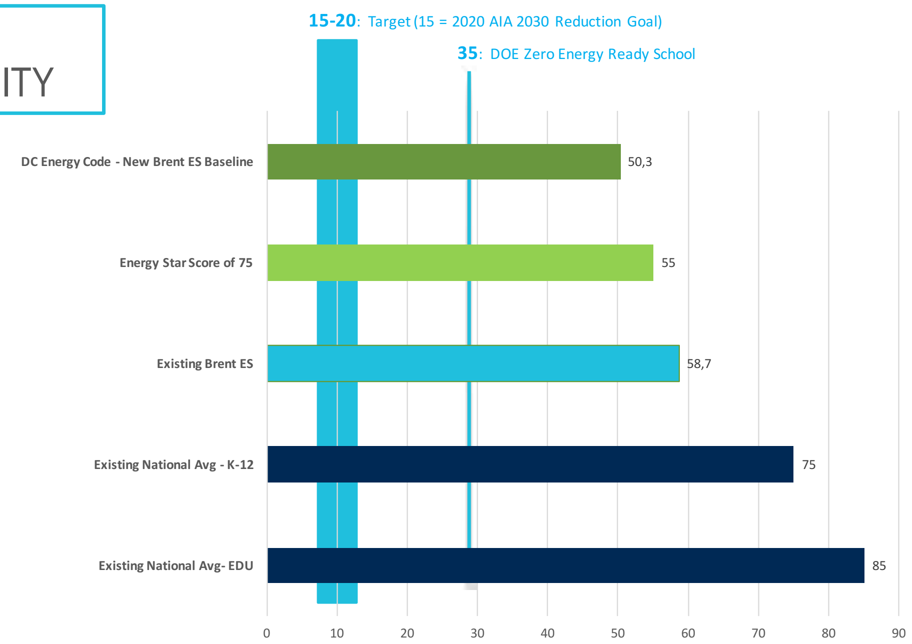
Integrated Design Charrette

Moya Design Partners, Hord Coplan Macht, Setty, and DCPS and DGS project management meet for an integrated design charette to review and evaluate sustainability and energy reduction strategies, determining the most feasible for this project and the best path to pursue zero energy.

See Appendix for the following:
- Presentation
- Meeting Minutes

The below chart illustrates the current energy consumption (in EUI) for Brent ES, and a comparison of that consumption to national averages for education facilities as well as the targets for achieving a zero-energy facility. The initial baseline configuration based on code requirements for the selected massing Option (see Early Energy Modelling for more info) is also shown. This is the baseline EUI that will be used for the Detailed Energy Modelling process.

EUI TARGET
ENERGY USE INTENSITY



Lessons Learned

DOEE introduced the design team to Flywheel, who also received in 2019 a NZE Design Assistance grant. Flywheel had some related experience with their project Stack 8, which has geothermal equipment in the public realm. Considering Brent Elementary School's site constraints, the design team had thought of exploring the adjacent park (Providence Park) as a host for their geothermal wells. On September 10th of 2020, the design team met with Jessica Pitts (Flywheel) to discuss. Refer to meeting minutes on the appendix for highlights of the conversation.

On the project Stack 8, Flywheel only had to go through DDOT to get approval for having geothermal equipment in public space. However, it seems the process to get approvals for having geothermal equipment on Providence Park could be much more complex and challenging. DOEE contacted Nick Kushner, planner at DPR, who confirmed that Providence Park is not under DPR's jurisdiction.

This means that the park likely falls under the jurisdiction of the Architect of the Capitol, which strongly implies that the land will be unavailable to host geothermal wells.

As a further lesson learned from the detailed energy modeling, the energy required to circulate water through a geothermal well field located at such a distance form the school resulted in a more energy intensive strategy than other options.

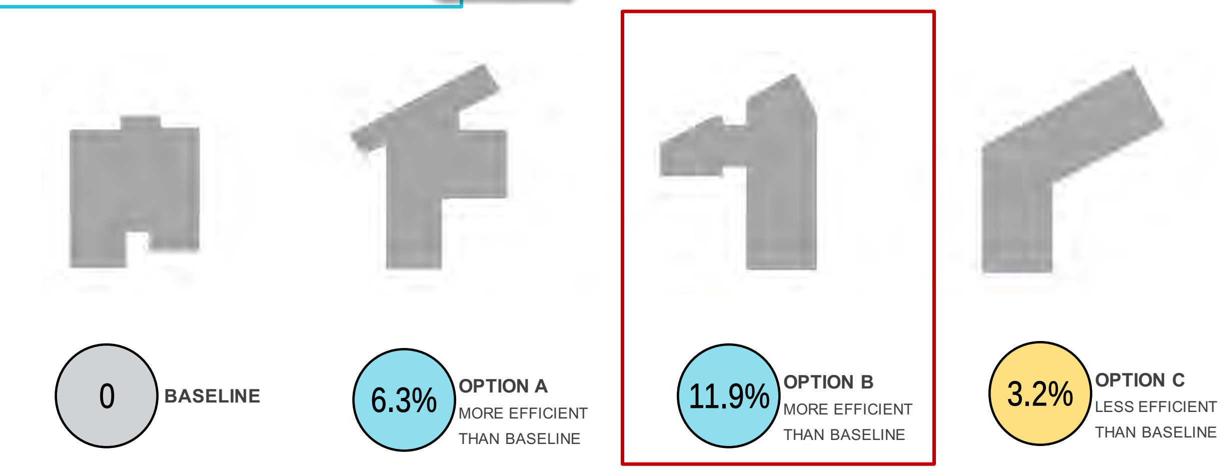
Early Energy Modeling

An initial round of energy modelling was performed to evaluate the building massing and orientation options considered at the conclusion of concept design for possible reductions in energy usage and aiding in the selection of a concept for advancement into more detailed energy modelling and eventual later stages of design. This round of energy modelling considered as its baseline the existing building configuration. This means that if no other variables are changed, the impact to the building's energy usage can be estimated.

Below our findings:

EARLY
ENERGY ANALYSIS

ORIENTATION



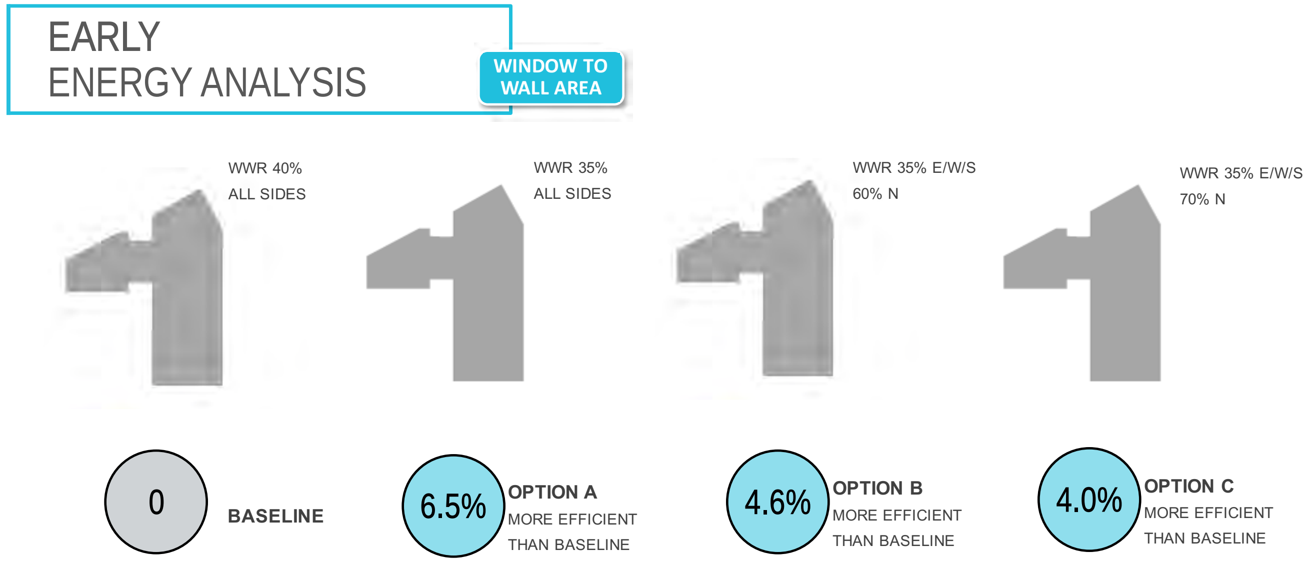
Note: Analysis is not intended to predict actual annual energy consumption of project – but is used as a comparative tool to help the team make informed decisions about design options.

The configuration for Option B resulted in the highest energy savings over baseline. Option A resulted in a smaller improvement in performance, while Option C resulted in a modest increase in energy consumption over baseline.

For the purposes of the Net Zero Initiative, Option B will be the anticipated design configuration for the building for all future analyses.

The next step in the early energy modelling process is to identify opportunities to strategically allocate fenestrated area to balance the desire for views and daylighting against the impact to the energy consumption of the building. The baseline for this iteration is the 40% Window to Wall Ratio (WWR) as defined by building codes. Since the optimum views for the site are to the North and West, the design team believes that the North Carolina Ave. façade of the building (the Northwest façade) is the preferred place to increase glazing area while decreasing glazing areas elsewhere.

Below are the results of that analysis:



Note: Analysis is not intended to predict actual annual energy consumption of project – but is used as a comparative tool to help the team make informed decisions about design options.

In the floor plan, the Library spaces, building entry lobby, and dining spaces all front along North Carolina Ave., making them ideal candidates for increased glazing areas. The bulk of the classrooms are located in the N/S oriented wing, so a corresponding reduction in glazing (but by no means an elimination) from the baseline can be accommodated, while still providing for an overall reduction in energy consumption.

Detailed Energy Modeling

Several initial iterations of the Detailed Energy Modelling were performed by the project's engineer, Setty and Associates. This is a detailed iterative modeling process that evaluates the buildings envelope, HVAC systems, lighting, controls—all the main energy consumers of the building. Energy conservation measures (ECM) will be identified to help make informed decisions evaluating energy life cycle costs versus first construction cost.

Refer to the following exhibits:
- Energy Conservation Measures spreadsheet

The total square footage of the roof area for Concept B is 23,383. We are considering 55% of the roof area to be available for PVs. Based on this, the PV panel system we can install will generate about 400 KW.

Additional Concept B details:

	Existing	Concept B
Gross Square Footage:	46,000 SF	89,330 SF
Total Outdoor Area at Grade:	25,668 SF	35,386 SF
Roof Area for Solar/SWM:	N/A	23,383 SF
Parking Spots:	10	10

Energy modeling at this stage of design first requires the creation of a baseline, code minimum building. The building's overall dimensions, orientation, and climate zone was input into eQuest modeling software. All other inputs such as envelope types and values, window to wall ratios, glazing types and values, lighting power density, and HVAC system was determined by ASHRAE 90.1-2010 Appendix G listed values as code minimum for the proposed building size, number of floors, and building usage.

Brent Elementary School Code Minimum values – ASHRAE 90.1-2010, Climate Zone 4A:

Opaque Elements	Non - Residential	
	Assembly Maximum U-value	**Insulation Min. R-value**
Roofs Insulation Entirely above Deck	0.048	R-20.0 c.i.
Walls, Above-Grade Steel-Framed	0.064	R-13.0 + R-7.5 c.i
Floors Steel-joist	0.038	R-30
Slab-On-Grade Floors Unheated	F-0.730	Not Required
Opaque Doors Swinging	0.700	-
Fenestration	**Assembly Maximum U-value**	**Assembly Maximum SHGC**
Vertical Glazing Metal framing	0.55	0.40

Other values considered into the baseline code minimum building are as follows:

- Window-to-wall ratio is 40%.
- Interior Lighting Power Density of 0.99 W/sf for school/university type as per Table 9.5.1 using building area method as per ASHRAE 90.1-2010.
- Exterior lighting estimated at 0.15 W/sf.
- Elevator load estimated 40 HP.
- HVAC System 5 – Packaged VAV with Reheat as per Table G3.1.1.A following Appendix G ASHRAE 90.1-2010.
- Domestic hot water heating of gas storage tank type with 8-% efficiency 180F design hot water temperature and 50F loop delta following Appendix G ASHRAE 90.1-2010.

Once all of the building's code minimum values were determined and input into the software, the final output of the program into our baseline code minimum building for Brent Elementary School was 49.9 kBtu/sf-yr.

After the baseline code minimum building EUI was established, many iterations of the energy model could be run with varying one or more parameters. From varying HVAC system types, to modifying building envelope values, the energy model has many uses in determining the best direction for design efforts.

Please find below data on different iterations.

Case	kBtu/ft2-yr	MBtu/yr	$/yr
Iteration #1 – Baseline – 40% of window/ wall ratio for all sides of the building.	21.3	1852.2	60688
Iteration #2 – All sides of the building with a 35% window/wall ratio	20.9	1816.6	59404
Iteration #3 – E, W, and S walls have 35% ratio, N wall has 60% ratio	21.1	1833.1	59989
Iteration #4 - E, W, and S walls have 35% ratio, N wall has 70% ratio	21.1	1839.4	60211
Iteration #5 - Water cooled VRF	26.3	2253.6	74921

Energy modeling was completed by comparing two options, HVAC system and window/wall ratios to begin to understand where the most energy savings would come from. Historically, the first largest energy saving for a system would be through the HVAC system. The code baseline building, with packaged VAV with reheat per Appendix G in ASHRAE 90.1-2010, resulted in an EUI of 50.3.

From there, we explored HVAC system options with the following resultant EUI:

- **Option 1:** Full ground source heat pump using Providence Park – EUI 28.9
- **Option 2:** Hybrid ground source heat pump using site only plus air cooled VRF for additional capacity – 28.4. Note the water cooled VRF additional capacity is required due to the site being capable of producing enough capacity for the proposed building.
- **Option 3**: VRF with DOAS – EUI 27.9
- **Option 4:** Full ground source heat pump with water cooled VRF – EUI 26.3

We were then asked to run an energy model on the building with proposed envelope values (all above items were run with baseline envelope values, and only varying the HVAC systems). This option 5, with the proposed envelope values, used the common DC area school HVAC system of VRF with DOAS and gave us the EUI of 21.3. A second round of energy modeling was asked to compare window/wall ratio since this is historically the second most energy savings in a project. Using our Option 5 number, the window/wall ratio was compared the following ways and with the resultant EUIs:

- **Option 5** has baseline 40% window/wall ratio on all building sides – EUI 21.3.
- **Option 6** was reducing window/wall ration to 35% on all building sides. – EUI 20.9
- **Option 7** was WWR of 35% on E, W, & S, 60% WWR on N – EUI 21.1.
- **Option 8** was WWR of 35% on E, W, & S, 70% WWR on N – EUI 21.1.

FOR OUTPUTS OF THE ENERGY MODELING, PLEASE REFER TO APPENDIX.

SUMMARY OF FINDINGS

The design team undertook the Brent Net Zero initiative with the understanding that the end result would be a series of design criteria that could be followed once the design project resumed sometime around FY2025. While the design team is limited in how specific we can be in terms of the design and performance of the facility at this time, the grant activities have provided a few specific data points that will be worthwhile to the final design effort.

- System Selection – Ground Sourced Heat Pump vs. Hybridized Water Cooled VRF vs. Conventional VRF: As a result of the detailed energy modelling performed by Setty, it does not appear that GSHP will be a viable system for achieving NZE at this facility. Due to the restricted site size, geotechnical characteristics of the site, and distance required to circulate the water to a suitably sized well field, the GSHP system the best performer in terms of energy reduction. When coupled with the administrative and procedural hurdles in securing access to a suitable well field area, this option becomes even less attractive for consideration. One option which did arise from the charette was to create a hybridized system where a ground source water loop could be coupled to the condensing side of the VRF loop (rather than air in the typical VRF system). The detailed energy modelling indicated that this option would not be the most energy efficient either, due largely to the same issues with the GSHP system. Taken together, the design team's analysis indicates that the conventional VRF system, which is already commonly employed among recent DCPS modernization projects, is the most energy efficient option.
- Solar Orientation: The early energy modelling performed by HCM was able to confirm that the massing scheme selected during Concept Design would result in the most energy savings relative to the existing building.
- Window to Wall Ratio: A combination of early and detailed energy modelling was able to determine that a distribution of glazing that favored Northern exposures and reduced glazing on others could improve energy efficiency over the baseline thresholds (40% overall) while preserving access to views and transparency to the neighborhood.
- Envelope Design: Detailed energy modelling was able to confirm that an envelope assembly of moderate, but by no means extreme, energy consciousness could deliver energy savings that can get the project close to NZE.

While the design team was restricted to a more abstract "sandbox" during this exercise, there are numerous other energy saving strategies that can be explored once the project resumes design and more detail can be considered in the energy modelling. Daylighting strategies, reduction in plug loads, facility use and scheduling, and double walled and/or screened fenestration systems are all potential strategies that can be explored at that time and can help push the energy consumption of the building to below 20 EUI.

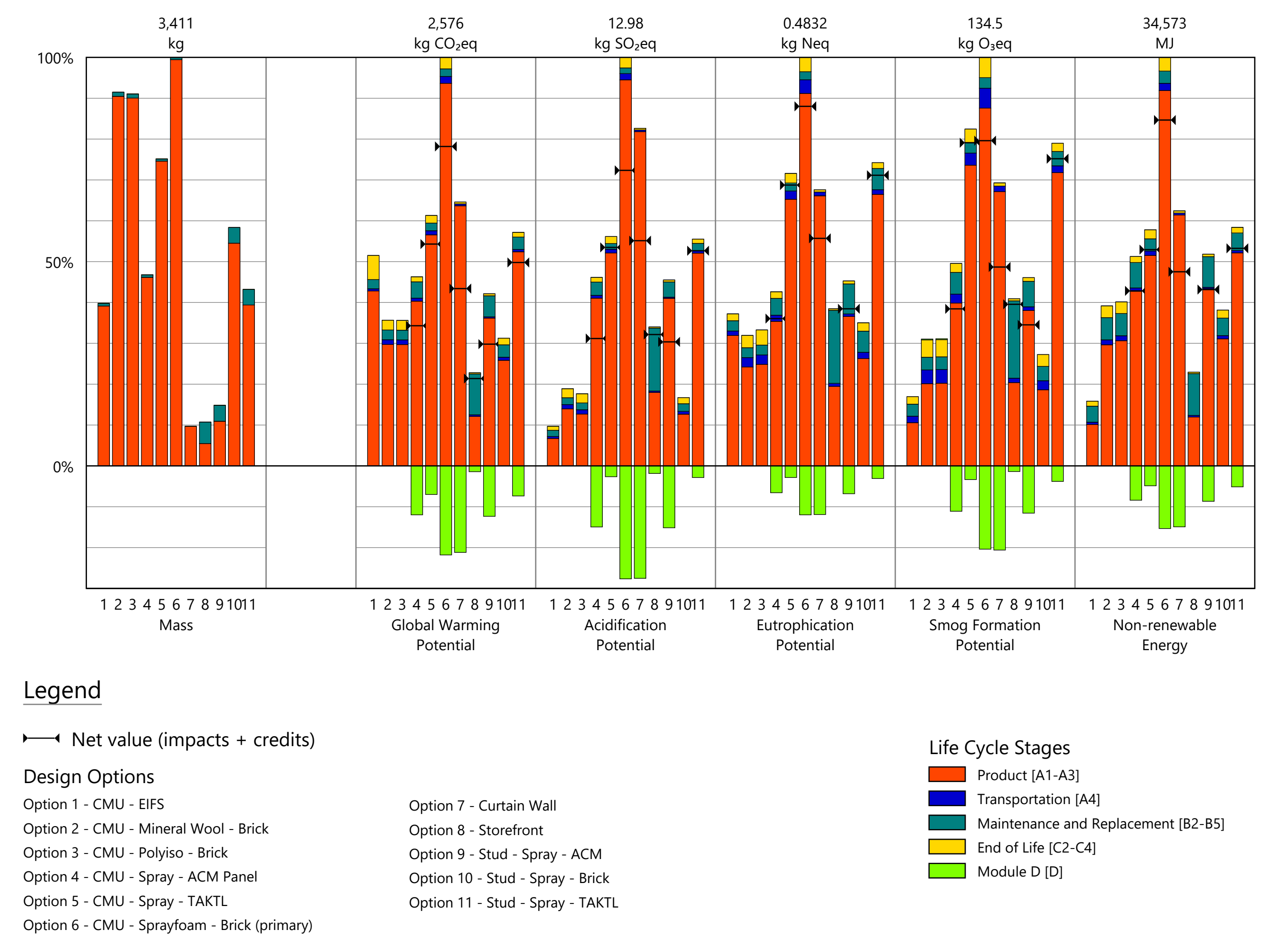
NZE STRATEGIES SUMMARY OF ESTIMATES

Summary of Estimates Item Description	**Cost Differential Over Baseline**
Estimate - Interation #1 Baseline - 40% Window/Wall ratio	$5,548,978
Estimate - Interation #2 35% Window/Wall ratio in lieu of Baseline	($37,493)
Estimate - Interation #3 35% Window/Wall ratio; North 60% in lieu of Baseline	$0
Estimate - Interation #4 35% Window/Wall ratio; North 70% in lieu of Baseline	$14,997
Estimate - Interation #5 HVAC - Watercooled VRF System in lieu of Baseline VAV System	$5,865,695

For more data per iteration, please refer to index.

After running some iterations of the energy model, we learned that the envelope and HVAC systems are the top two main factors that could bring the EUI closer to net-zero. Iteration #2 proposes having all sides of the building with a 35% window/wall ratio, allowing us to get to an EUI of 20.9 - the closest we are getting to our target of 20 EUI. Compared to the concept estimate project baseline, pursuing this iteration provide a total reduction of $37,493. Not only iteration #2 allow us getting closer to our net-zero target, but it also achieves project cost savings.

Results per Life Cycle Stage



ANALYSIS OF EMBODIED CARBON

Annually, the embodied carbon of building structure, substructure, and enclosures are responsible for 11% of global GHG emissions and 28% of global building sector emissions. Eliminating these emissions is key to addressing climate change and meeting Paris Climate Agreement targets. While not originally part of the scope of the Brent Net Zero Energy Initiative, we felt it would be informative to explore the broader context of carbon emissions related to the life cycle of the materials that make up the building, from their initial manufacture, through transportation and installation and eventual disposal or recycling. As the ultimate goal of pursuing a NZE facility is to reduce energy consumption and thus reduce GHG Emissions, reducing the embodied carbon of the facility is a parallel and complementary objective that supports the same end result.

Performing a more comprehensive analysis of embodied carbon in the ultimate design project will contribute towards LEED credits and the ultimate project goal of LEED Gold Certification.

For this round of analysis, we modeled a representative assembly of 100 sf assuming typical assembly types that we have used in school construction, both for DC and other clients. For each assembly, a continuous insulation value of R-13 was assumed. The model data was then filtered through Tally's database and the resulting graphs depict the varying levels of embodied carbon as a percentage of the most carbon intensive assembly.

The results of the analysis indicate that the use of CMU as an exterior wall backup material is a significant driver of embodied carbon, while on the exterior, curtain wall is significantly more carbon intensive than storefront. This information is useful as the overall wall materials have not been selected for this project, and there is a lot to be gained by selecting materials with a lower embodied carbon. The design team will have a reasonable amount of control over the extent and arrangement of the window area, and thus control over which components will require storefront versus curtain wall type framing, while also being in charge of generating the first round of material selection for the exterior palette. The use of steel stud as backup (and for interior partitions) is in keeping with DCPS's recent track record of projects. Ultimately, DCPS and the Commission of Fine Arts will have much to say about the materials used inside and outside of the building respectively, but this information will be useful once those conversations take place.

Once the project moves into Design Development, a more thorough analysis of the embodied carbon profile and alternative options can be performed, but this initial foray into the process has been illuminating as it provides a general impression of the carbon intensities of materials in a more general application.

NEP/LEP

For this progress reporting period, report the total number of ongoing program or special event participants, and the number of these participants with Low English Proficiency or No English Proficiency (NEP/LEP). Attach the LEP/NEP Data Collection Sheet if the LEP/NEP count is greater than zero.

Not Applicable.

Single Audit Requirement

Report the end date of your organization's current fiscal year: Dec 31, 2020

In the progress reporting time period following the date of the close of the Grantee fiscal year, report to DOEE whether the Grantee is required to perform a single audit: Not required.

If your organization was required by the federal government to complete a single audit, submit that report to DOEE, as an attachment to this report, within nine months after this fiscal year-end date. Not Applicable.

If your organization is not required by the federal government to complete a single audit, then submit to DOEE the Sub-grantee Single Audit Exemption Certification, which is Attachment 7b to your grant award. Pending.

Budget Reporting

For the current reporting period (until Sept 15), update the status of the project budget against the amount awarded, per line item. See sample below.

Net-Zero Energy Project Design Assistance for Brent Elementary School

Budget Category	Amounts Awarded	Amount Matched	Amount Awarded Spent	Current Balance Awarded	Notes
Personnel					
Project Architect	$ 950	$ 950	$ 950	$ 0	5 hrs (PA)x $190
Project Manager	$ 3,227.17	$ 3,255.83	$ 3,227.17	$ 0	20 hrs (PM)x $180
Graphic Designer	$ 750	$ 750	$ 750	$ 0	5 hrs (GD)x $150
Admin/Editorial Content	$ 600	$ 600	$ 600	$ 0	6 hrs (ADM) x $100
Subtotal Personnel					
Indirect Costs (__ %)					
Total Personnel					
Direct					
Contractor or sub-grantee fees					
HCM	$ 5,527.17	$ 5,555.83	$ 5,527.17	$ 0	
SETTY	$ 6,370.67	$ 6,387.33	$ 6,370.67	$ 0	
HANSCOMB	$ 2,575.00	$ 2,576.00	$ 2,575.00	$ 0	
Travel and Training	N/A	N/A			
Supplies	N/A	N/A			
Equipment	N/A	N/A			
Rentals	N/A	N/A			
Other costs (one item per line)	N/A	N/A			
Total Direct					
Grand Total	$ 20,000.00	$ 20,075.00			

02

APPENDIX

Work Plan

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Work Plan Template
Attachment 2

Please refer to your Grant Award Notice, Activities Funded:

Chart out your *Activities* in a Work Plan table similar to the one below. You may modify this chart's format if necessary. A Work Plan takes the ideas presented in a grant application and turns those ideas into a series of actionable steps that move a project from a concept toward an *outcome*. The Work Plan should break the long term goal (or *outcome*) into activities that create a series of discreet short term steps. Those activities can then be turned into quantifiable results (or *outputs*).

The following should be included in a Work Plan: an up-to-date budget, phasing, a timeline, a list of private and public partners, a breakdown of outcomes, outputs and activities with associated timelines and responsible parties.

The Work Plan is a document that will not only help the Grantee to strategize implementation, but will also facilitate communication between the Grantee and the DOEE. The Work Plan should lay out important milestones like the dates Progress Reports and Final Reports are due and the dates for the completion of activities specified in the grant. The Work Plan is not meant to be a rigid document, but rather a framework that provides organization. The Work Plan is based on the scope of activities in the Grant, but the Grantee should communicate with their Grant Manager frequently, especially if the Work Plan schedule needs to be adjusted. Please contact the Grant Administrator to see examples of work plans, should you need them.

Service #:					
Activity	**Task(s)**	**Output**	**Outcome**	**Person(s) Responsible**	**Completion Date**
#0 – Submit Work Plan to DOEE [COMPLETED]	a) MOYA/HCM to submit edits/remarks to the specific service requirements expected on the grant.	MOYA/HCM to review activities listed on grant application and establish which ones are applicable to Brent ES considering that the project is on Concept Phase.	DOEE to review edits and approve Work Plan.	MOYA (leads) HCM	6/12/2020
#1 – Conduct an integrated	a) Conduct an integrated design charrette with key personnel from MOYA HCM,	1) Design Team to schedule a conference call with design team and DCPS/DGS.	Gather feedback provided during design charrette, implement	MOYA HCM	7/10/2020

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design charrette [COMPLETED]	Setty, DCPS and DGS project Management b) Review and evaluate sustainability and energy reduction strategies, determining the most feasible for this project and the best path to pursue for NZE.	2) Design Team to meet prior design charrette to brainstorm ideas and prepare material to be discussed during design charrette 3) Based on the design charrette's discussion, Design Team to start a draft of the Report to be submitted to DOEE and include a summary of findings and energy reduction strategies applicable to the project.	it, and use it to establish the best path to pursue for NZE.		
#2 – Early energy modeling [COMPLETED]	a) Conduct early energy modeling to assess building orientation and massing to evaluate energy saving potential relative to a baseline. [COMPLETED] b) Look at the WWR, window to wall area ratios. [COMPLETED] c) Establish a preliminary understanding of the building's annual energy consumption and NZE targets using the design strategies identified in the charrette. [COMPLETED]	1) MOYA/HCM to share Concept B with Setty. [COMPLETED] 2) Setty to develop Energy Model [COMPLETED] 3) MOYA/HCM to provide feedback to Setty, as needed. [COMPLETED] 4) Setty to revise energy model as needed. [COMPLETED] 5) MOYA/HCM to submit final model with Hanscomb (cost estimator). [COMPLETED] 6) Hanscomb to submit a cost estimate of design strategies proposed for NZE. [COMPLETED]	Conducting an early energy modeling will guide the path for achieving NZE, and will identify the building needs and requirements.	HCM MOYA Setty (leads) Hanscomb	1st Week of August

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#3 – Detailed energy modeling [COMPLETED]	a) Conduct detailed, iterative energy modeling to evaluate all of the main energy consuming systems in the building, including the building envelope, HVAC systems, lighting, and controls; and b) Identify energy conservation measures to help make informed decisions evaluating life cycle costs versus first construction costs.	1) Setty to perform a detailed energy modeling by analyzing Energy Conservation Measures. See form attached. 2) MOYA/HCM/Cost Estimator to review.	Conducting a detailed energy modeling will help make informed decisions evaluating life cycle costs versus first construction costs.	HCM MOYA Setty (leads) Hanscomb	1st Week of August
#4 – Student engagement [NOT APPLICABLE – FUNDS SHIFTED TO DETAILED ENERGY MODELING]	a) Members of the design team will adapt existing curriculum to the specifics of the Brent Modernization project. b) The team will present the information and guide the students through hands-on a. activities to reinforce the concepts presented.	1) DCPS to schedule a virtual design charrette with Brent ES students. 2) MOYA/HCM to coordinate the content of the presentation. 3) MOYA/HCM to prepare the slides. 4) MOYA/HCM to share the slides with DOEE/DCPS/DGS. 5) DOEE/DCPS/DGS to provide feedback. 6) MOYA/HCM to revise the presentation accordingly. 7) MOYA/HCM to prepare a report/meeting minutes of the meeting.	Gather feedback, thoughts and ideas from the student community and find ways to implement those in Brent ES modernization.	HCM (content of presentation) MOYA (presentation graphics, meeting minutes)	August/ September 2020
#5 – Report on work performed and results [COMPLETED]	a) Meet with DOEE staff monthly to discuss project progress. [COMPLETED] b) Provide a Progress Report for the preceding quarter in accordance with the standardized progress-reporting template (Attachment 3) by July 27. [COMPLETED]	1) MOYA/HCM to give DOEE suggested date and time for a recurring monthly check-in call. [COMPLETED] 2) DOEE to set up cohort meeting with MOYA/HCM and other awardees. [COMPLETED] 3) MOYA/HCM to continue working on Progress Report		HCM (content of presentation) MOYA (presentation graphics, meeting minutes)	1) 6/12/2020 2) Week of June 15 3) 7/27/2020 4) 9/16/2020 5) 9/30/2020 6) 10/14/2020

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	a. The Grantee shall attach to the Progress Report a revised Work Plan if requested. [COMPLETED] c) Provide DOEE a draft Final Report in Microsoft Word format, (Attachment 4) two weeks before the end of the grant period a. The following information should be included: i. A clear listing of the activities conducted and an evaluation of their effectiveness in supporting the project's pursuit of NZE performance. ii. Documentation confirming that the activities have been completed prior to the end of the grant period. iii. Details on the activities conducted to support a case study. iv. A basic proforma project budget, if completed as part of this analysis. v. A copy of the energy model outputs, if completed as part of this analysis; and vi. Status of the development project and anticipated completion date.	and submit to DOEE 1st draft. [COMPLETED] DOEE to provide feedback and MOYA/HCM to implement as needed. 4) MOYA/HCM to work on final report and submit to DOEE. 5) DOEE to review and provide feedback. 6) MOYA/HCM to submit Final Report.			

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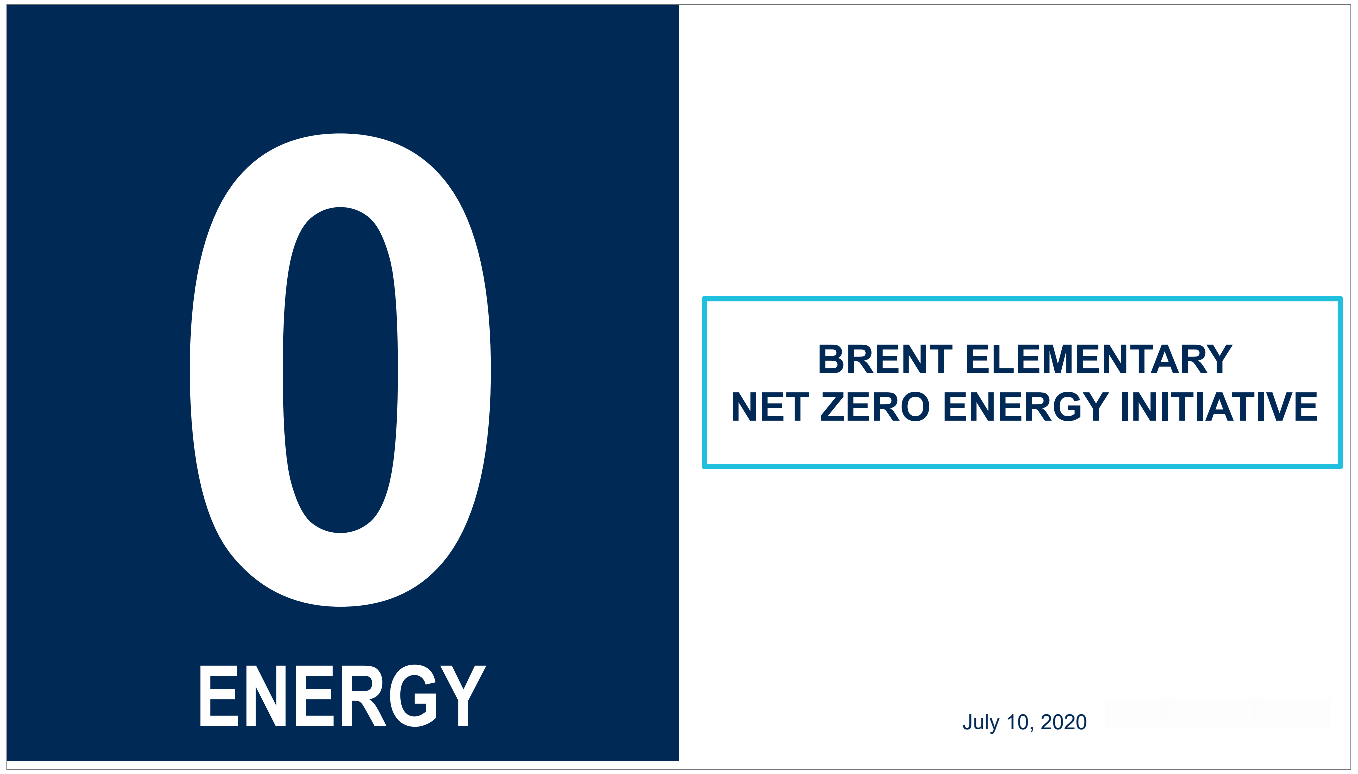
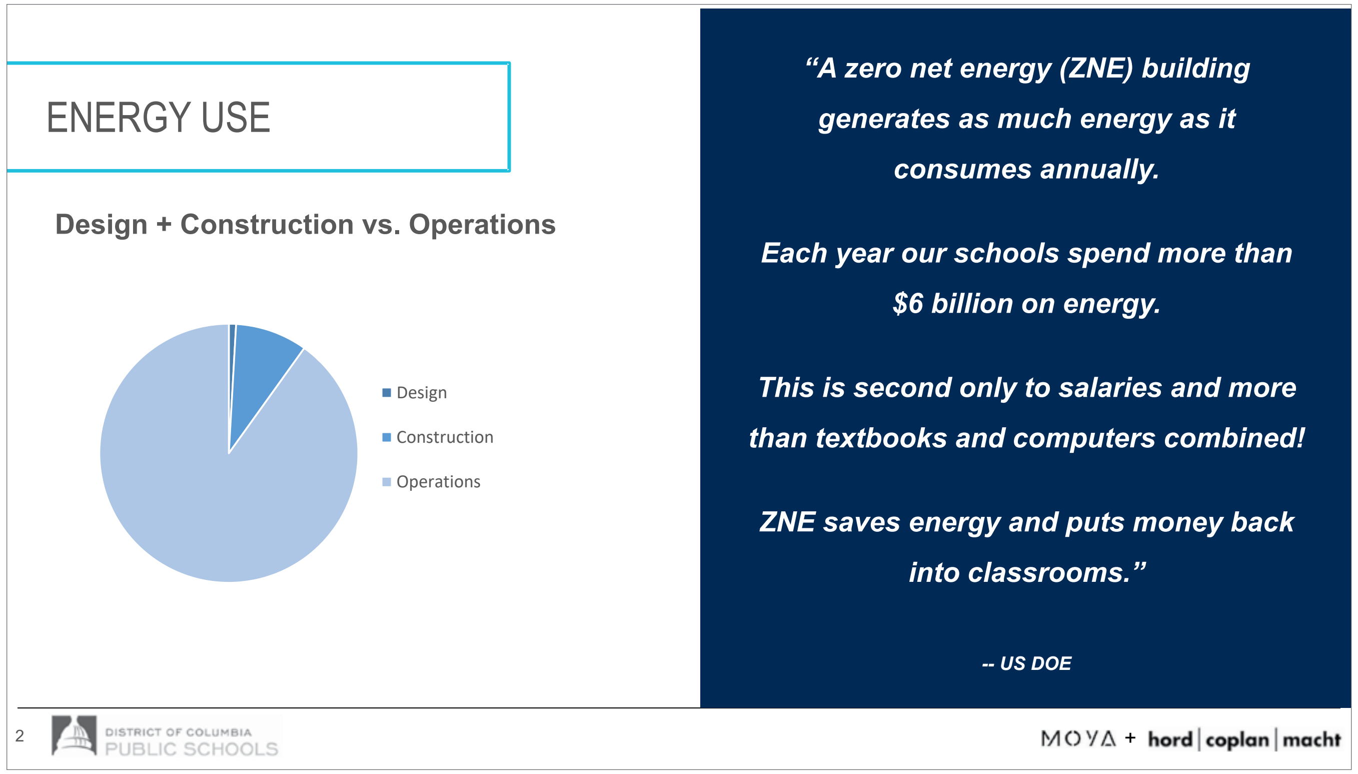
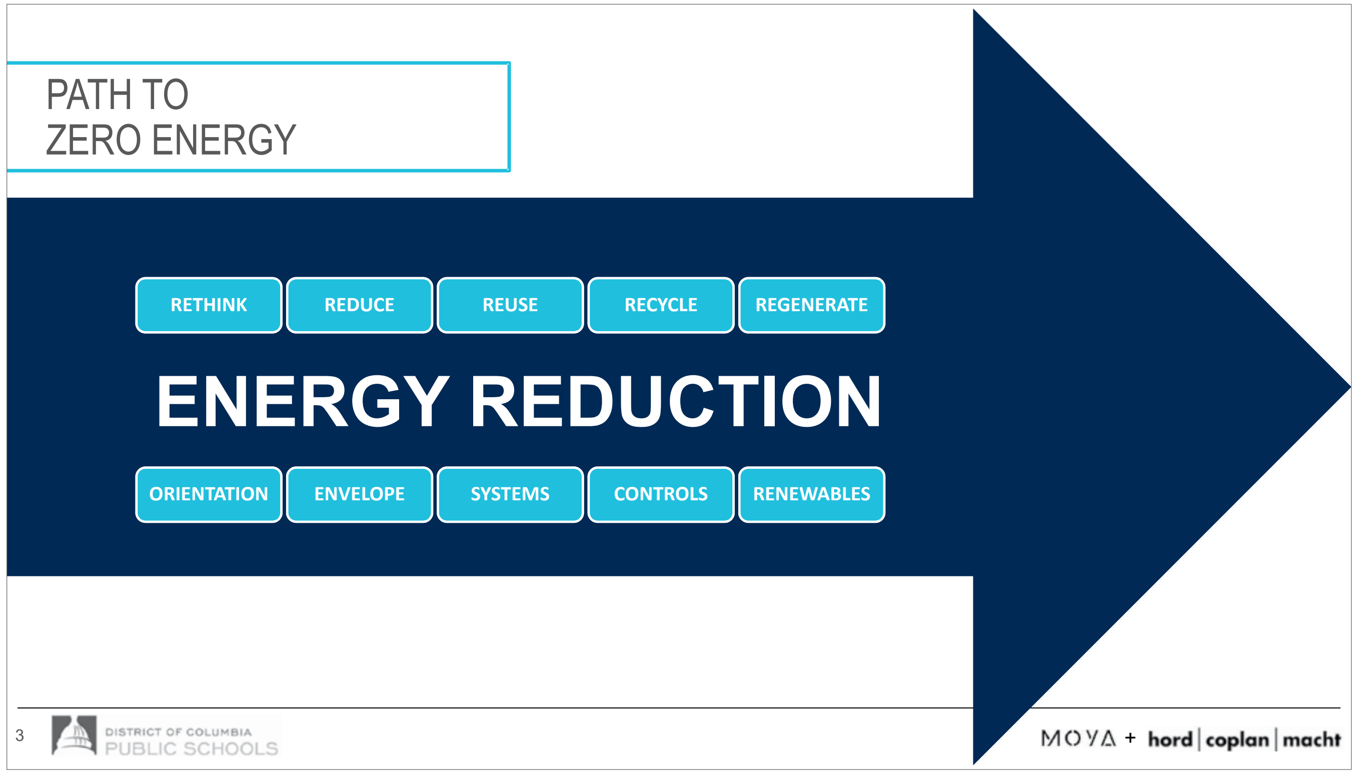
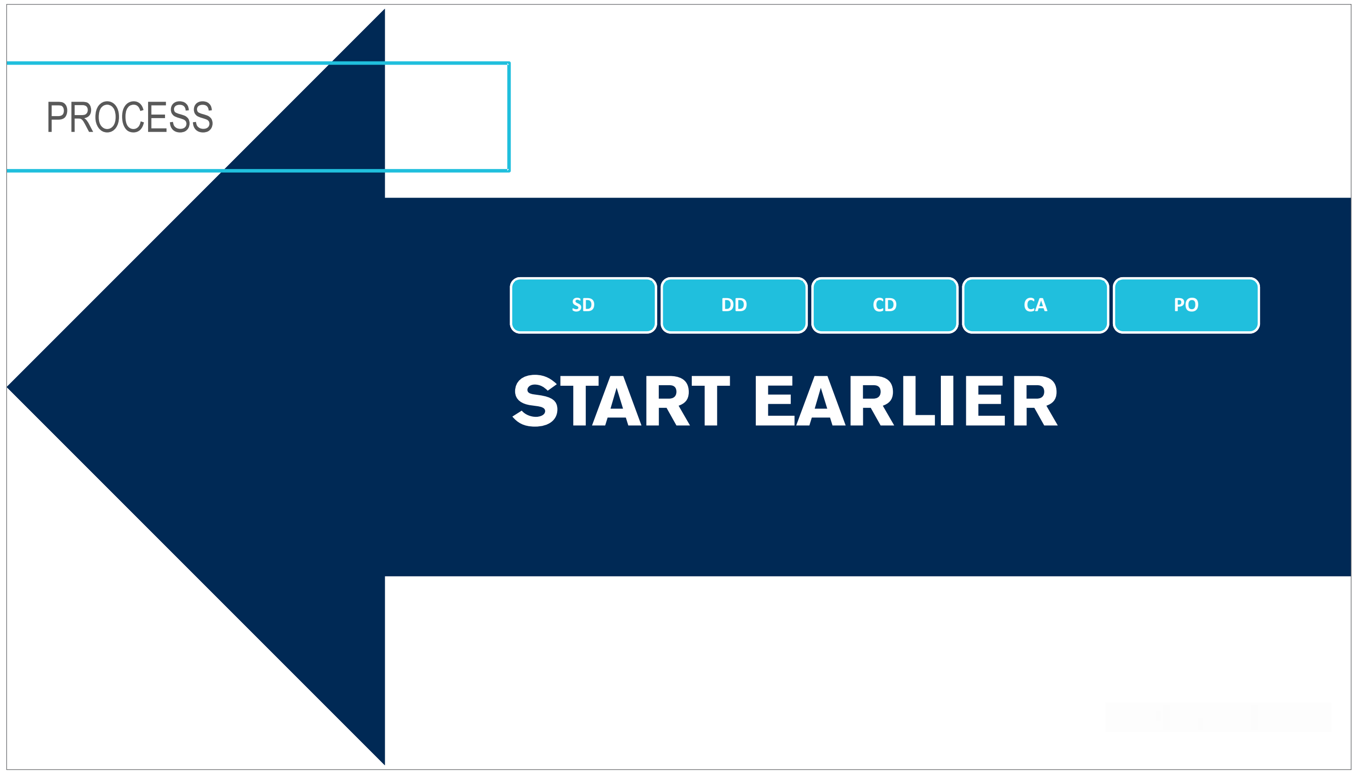
	b. Receive and review DOEE's comments and redraft accordingly c. Submit the Final Report within two weeks after the expiration of the grant period.				

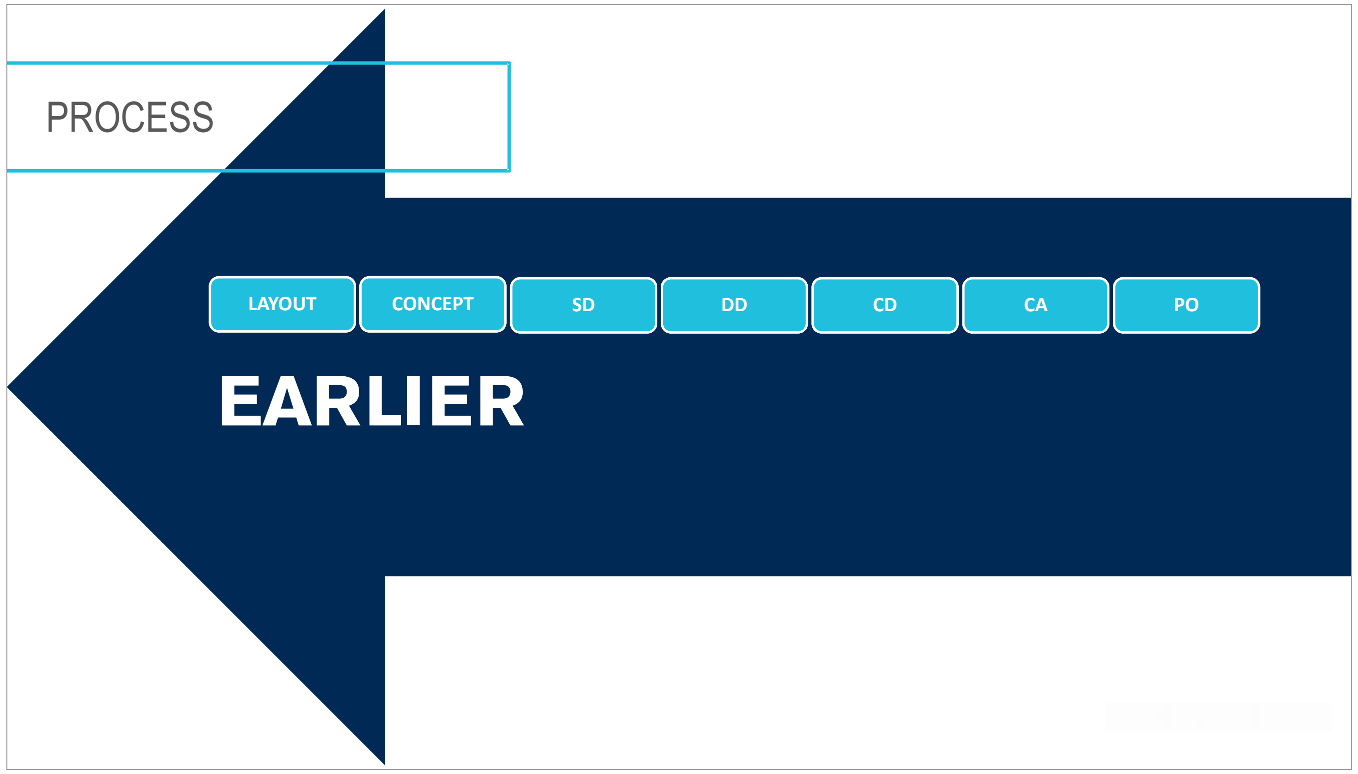
Design Charette Presentation

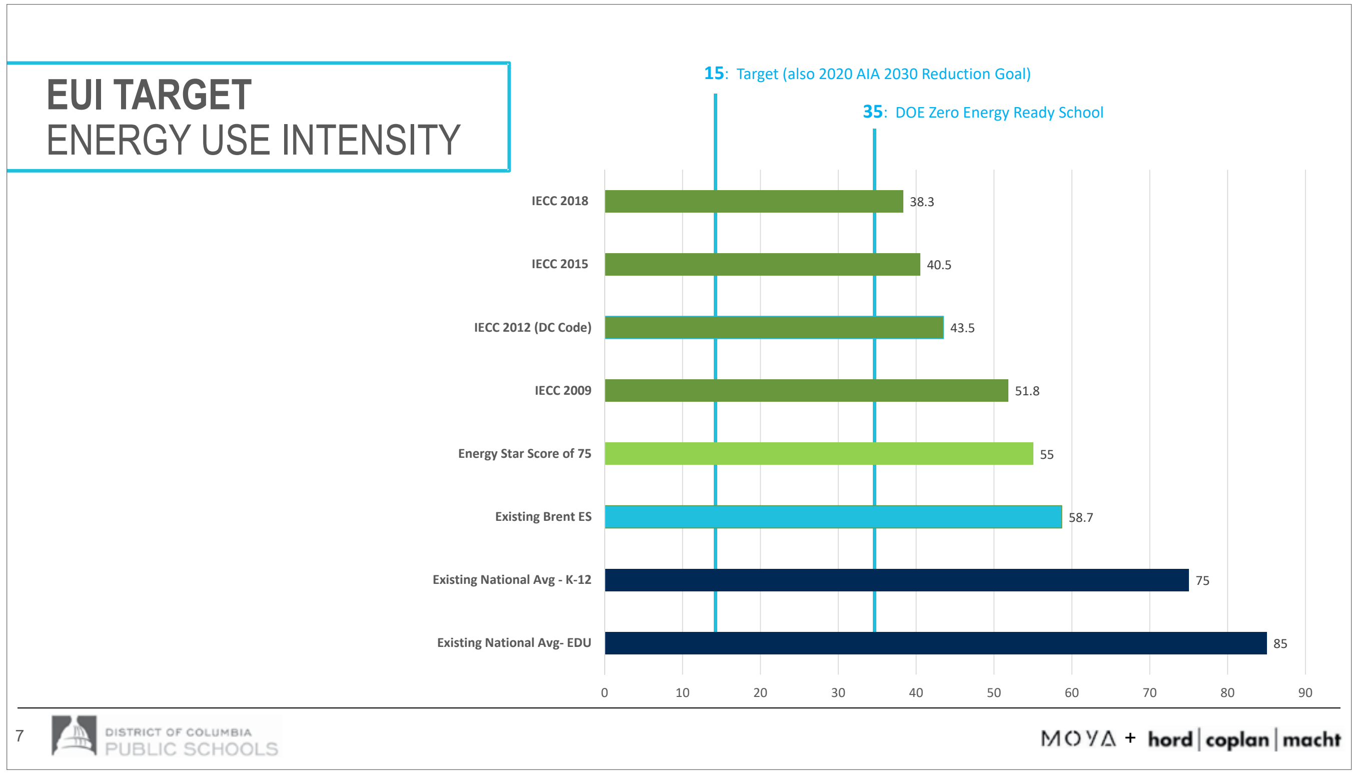









PROCESS
LAYOUT
CONCEPT
SD
DD
CD
CA
PO
EARLIER


EUI TARGET
ENERGY USE INTENSITY
15: Target (also 2020 AIA 2030 Reduction Goal)
35: DOE Zero Energy Ready School
IECC 2018 38.3
IECC 2015 40.5
IECC 2012 (DC Code) 43.5
IECC 2009 51.8
Energy Star Score of 75 55
Existing Brent ES 58.7
Existing National Avg - K-12 75
Existing National Avg- EDU 85
0 10 20 30 40 50 60 70 80 90
7
DISTRICT OF COLUMBIA PUBLIC SCHOOLS
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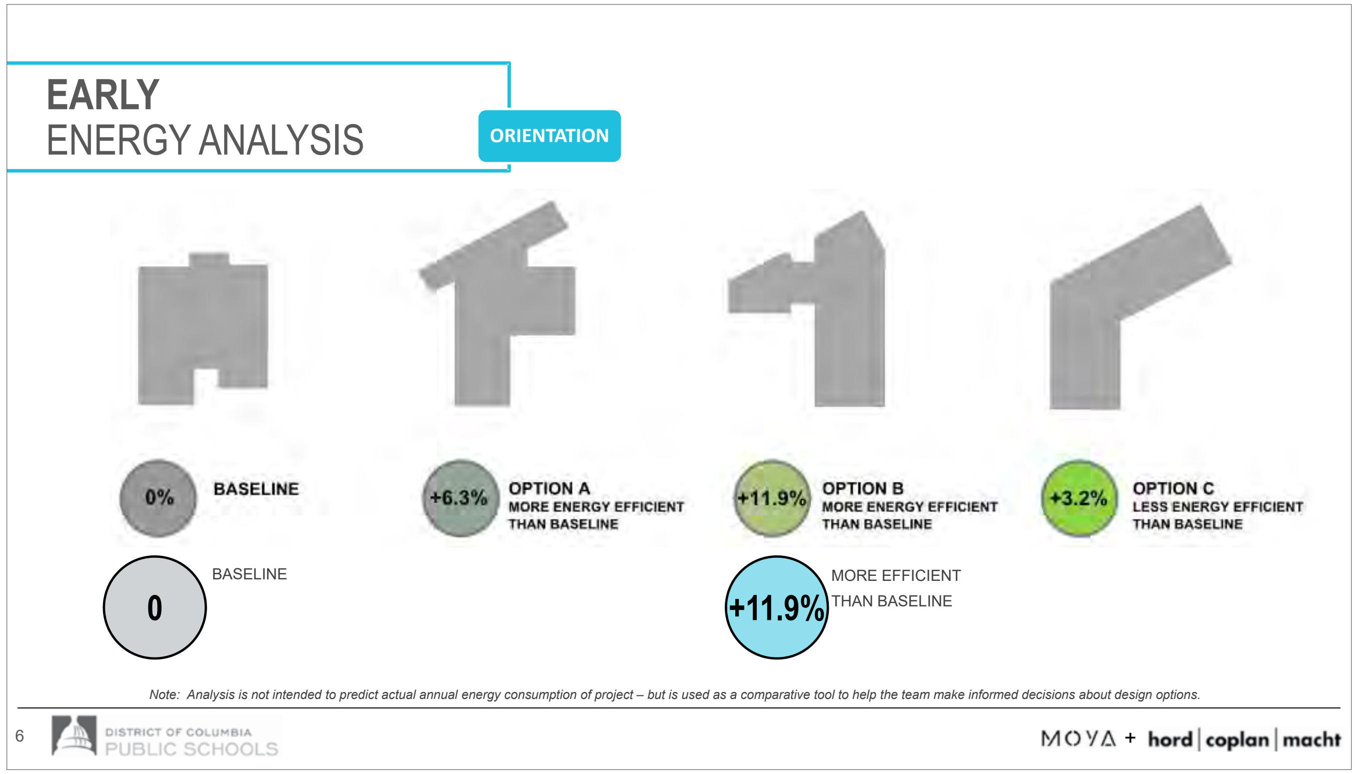
EARLY
ENERGY ANALYSIS
ORIENTATION
0% BASELINE
+6.3% OPTION A MORE ENERGY EFFICIENT THAN BASELINE
+11.9% OPTION B MORE ENERGY EFFICIENT THAN BASELINE
+3.2% OPTION C LESS ENERGY EFFICIENT THAN BASELINE
0 BASELINE
+11.9% MORE EFFICIENT THAN BASELINE
Note: Analysis is not intended to predict actual annual energy consumption of project – but is used as a comparative tool to help the team make informed decisions about design options.
6
DISTRICT OF COLUMBIA PUBLIC SCHOOLS
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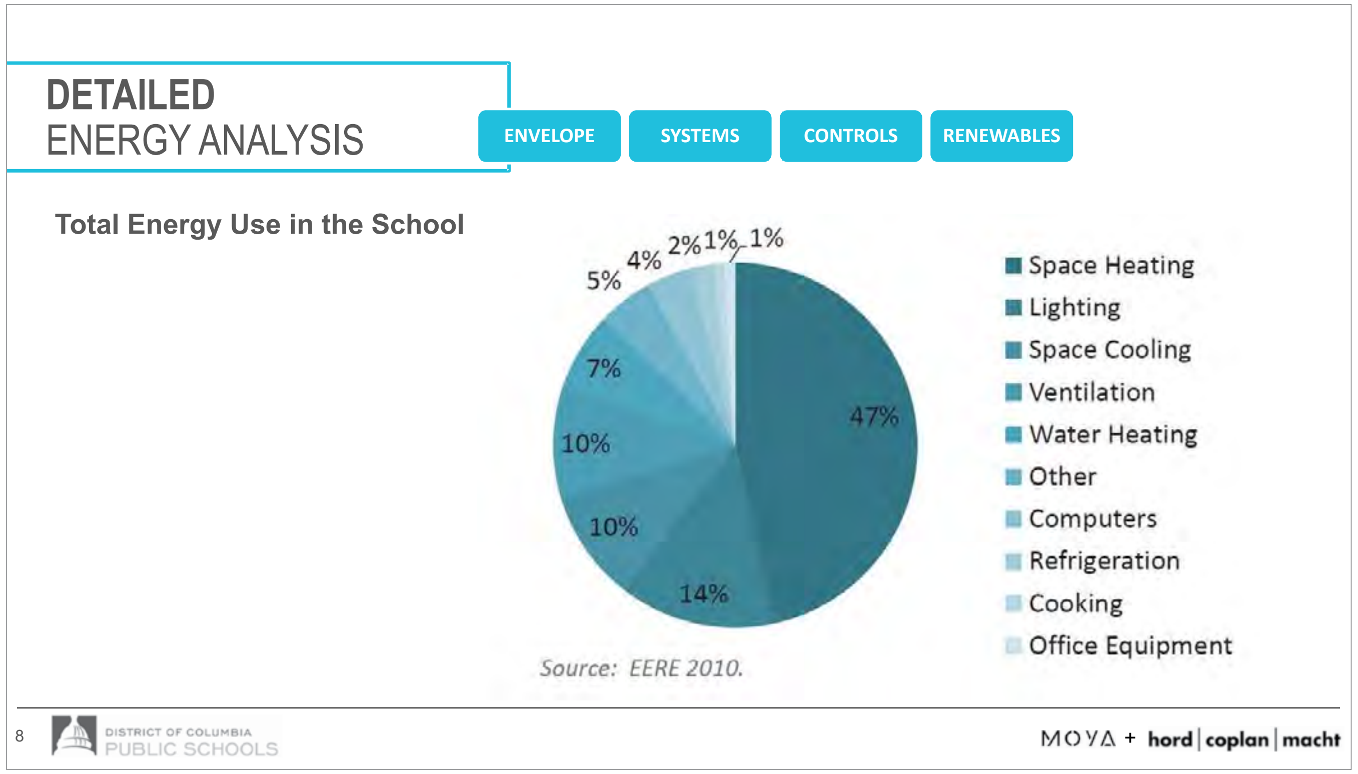
DETAILED
ENERGY ANALYSIS
ENVELOPE
SYSTEMS
CONTROLS
RENEWABLES
Total Energy Use in the School
47%
14%
10%
10%
7%
5%
4%
2%
1%
1%
Space Heating
Lighting
Space Cooling
Ventilation
Water Heating
Other
Computers
Refrigeration
Cooking
Office Equipment
Source: EERE 2010.
8
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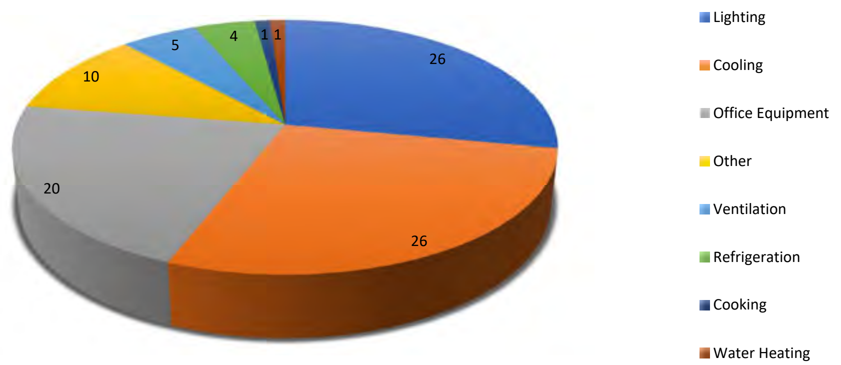
DETAILED ENERGY ANALYSIS

ENVELOPE | SYSTEMS | CONTROLS | RENEWABLES

Electrical Energy Use in the School



ENERGY CONSERVATION MEASURES, (ECM)

ENVELOPE | SYSTEMS | CONTROLS | RENEWABLES

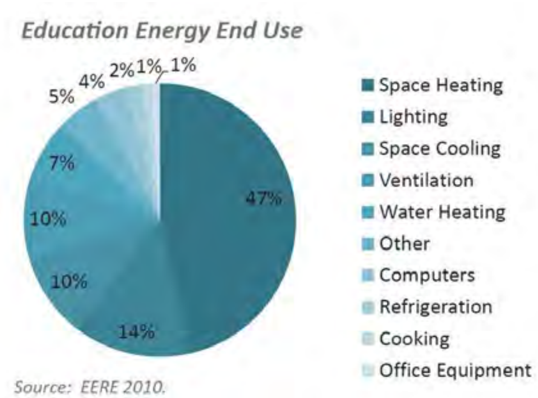
ENVELOPE
- A WWR, Window Wall Area Ratio
- B Glazing - U-value and SHGC
- C Wall - Insulation
- D Roof - Insulation

SYSTEMS
- E HVAC
- F Lighting - Interior
- G Lighting - Exterior
- H Hot Water

CONTROLS
- I Controls

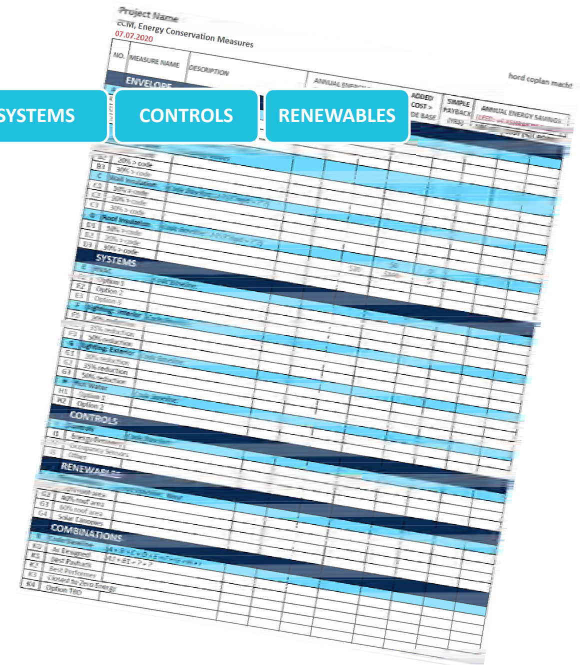
RENEWABLES
- J Renewable Energy

COMBINATIONS / TOTAL ENERGY REDUCTION
With Solar PV
Without Solar PV



ENERGY CONSERVATION MEASURES, (ECM)

ENVELOPE | SYSTEMS | CONTROLS | RENEWABLES



ENERGY CONSERVATION MEASURES, (ECM)

ENVELOPE | SYSTEMS | CONTROLS | RENEWABLES

NO.	MEASURE NAME	DESCRIPTION	ANNUAL ENERGY SAVINGS (ENERGY CODE: IECC 20--)			ADDED COST > CODE BASE	SIMPLE PAYBACK (YRS)	ANNUAL ENERGY SAVINGS (LEED: v4 ASHRAE 90.1-2010)		
			USE (%)	COST (%)	COST ($)			USE (%)	COST (%)	POINTS
	ENVELOPE									
A	**Window Wall Ratio**	*Code Baseline: 40%*								
A1	50%									
A2	30%									
A3	20% + 60%									
B	**Glazing Values**	*Code Baseline: U-?, SHGC-? *Assembly Values*								
B1	10% > code									
B2	20% > code									
B3	30% > code									
C	**Wall Insulation**	*Code Baseline: U-? (?"rigid + ?"?)*								
C1	10% > code									
C2	20% > code									
C3	30% > code									
D	**Roof Insulation**	*Code Baseline: U-? (?"rigid + ?"?)*				$0	0			
D1	10% > code				$20	$100	5			
D2	20% > code									
D3	30% > code									

ENERGY CONSERVATION MEASURES, (ECM)

ENVELOPE | SYSTEMS | CONTROLS | RENEWABLES

NO.	MEASURE NAME	DESCRIPTION	ANNUAL ENERGY SAVINGS (ENERGY CODE: IECC 20--)			ADDED COST > CODE BASE	SIMPLE PAYBACK (YRS)	ANNUAL ENERGY SAVINGS (LEED: v4 ASHRAE 90.1-2010)		
			USE (%)	COST (%)	COST ($)			USE (%)	COST (%)	POINTS
	RENEWABLES									
J	Photovoltaics	Code Baseline: None								
J1	20% roof area									
J2	40% roof area									
J3	60% roof area									
J4	Solar Canopies									
	COMBINATIONS									
K	Code Baseline	A + B + C + D + E + F + G + H + I								
KO	As Designed	A1 + B1 + ? + ?								
K1	Best Payback									
K2	Best Performer									
K3	Closest to Zero Energy									
K4	Option TBD									

ECM REPORTING

K	CODE BASELINE	K0	AS DESIGNED	K3	CLOSEST TO ZERO ENERGY
A		A		A	
B		B		B	
C		C		C	
D		D		D	
E		E		E	
F		F		F	
G		G		G	
H		H		H	
I		I		I	
J		J		J	
0%	% Annual Energy Use Savings	20%?	% Annual Energy Use Savings	75%?	% Annual Energy Use Savings
$0	Annual Energy Cost Savings	$?	Annual Energy Cost Savings	$?	Annual Energy Cost Savings
$0	Additional First Cost	$0	Additional First Cost	$?	Additional First Cost
0	Year(s), Simple Payback	0	Year(s), Simple Payback	?	Year(s), Simple Payback
?	EUI	?	EUI	15?	EUI
?	LEED Points	?	LEED Points	?	LEED Points

ENERGY CONSERVATION MEASURES, (ECM)

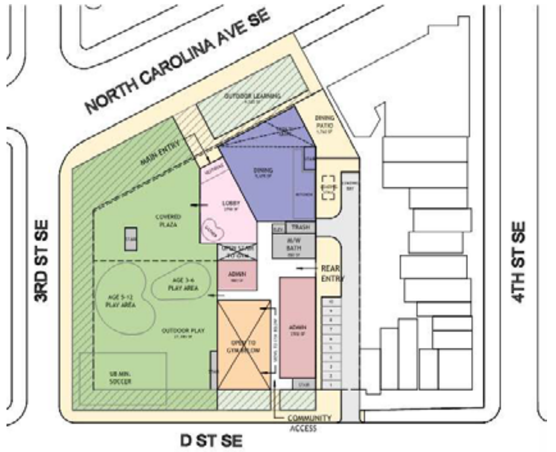
ENVELOPE | SYSTEMS | CONTROLS | RENEWABLES

Solar Roof Potential

ENERGY CONSERVATION MEASURES, (ECM)

ENVELOPE | SYSTEMS | CONTROLS | RENEWABLES

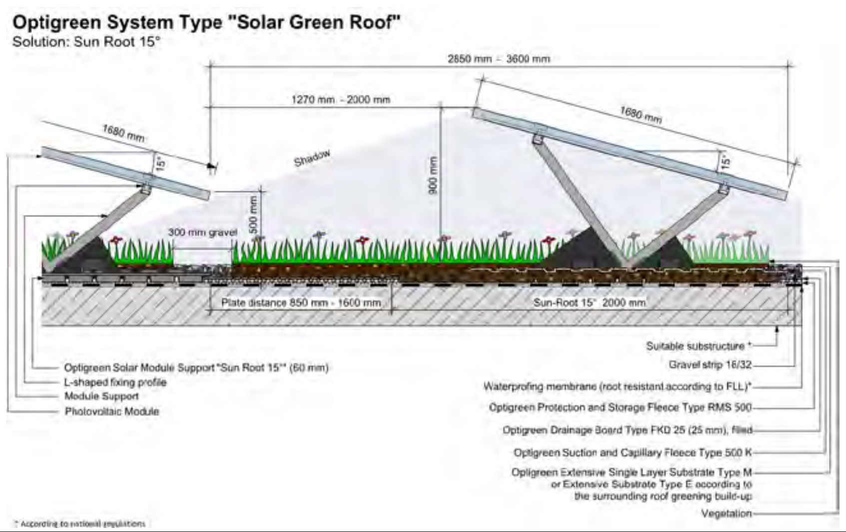
Solar Site Potential



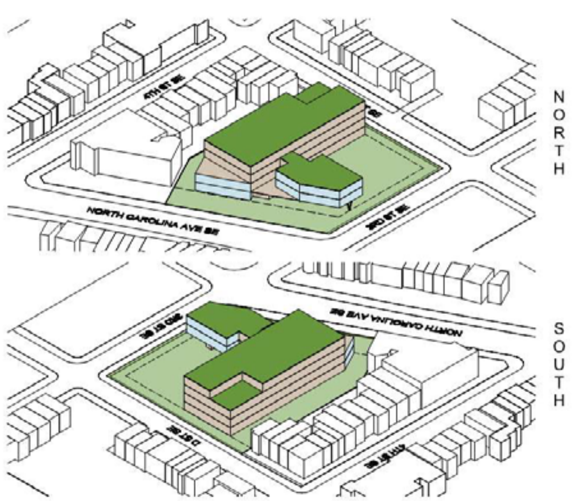
ENERGY CONSERVATION MEASURES, (ECM)

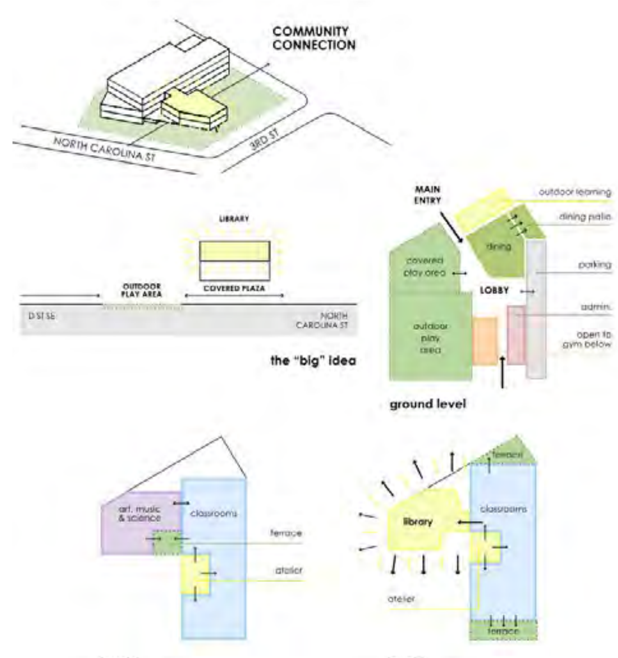
ENVELOPE SYSTEMS CONTROLS RENEWABLES

Solar Site Potential

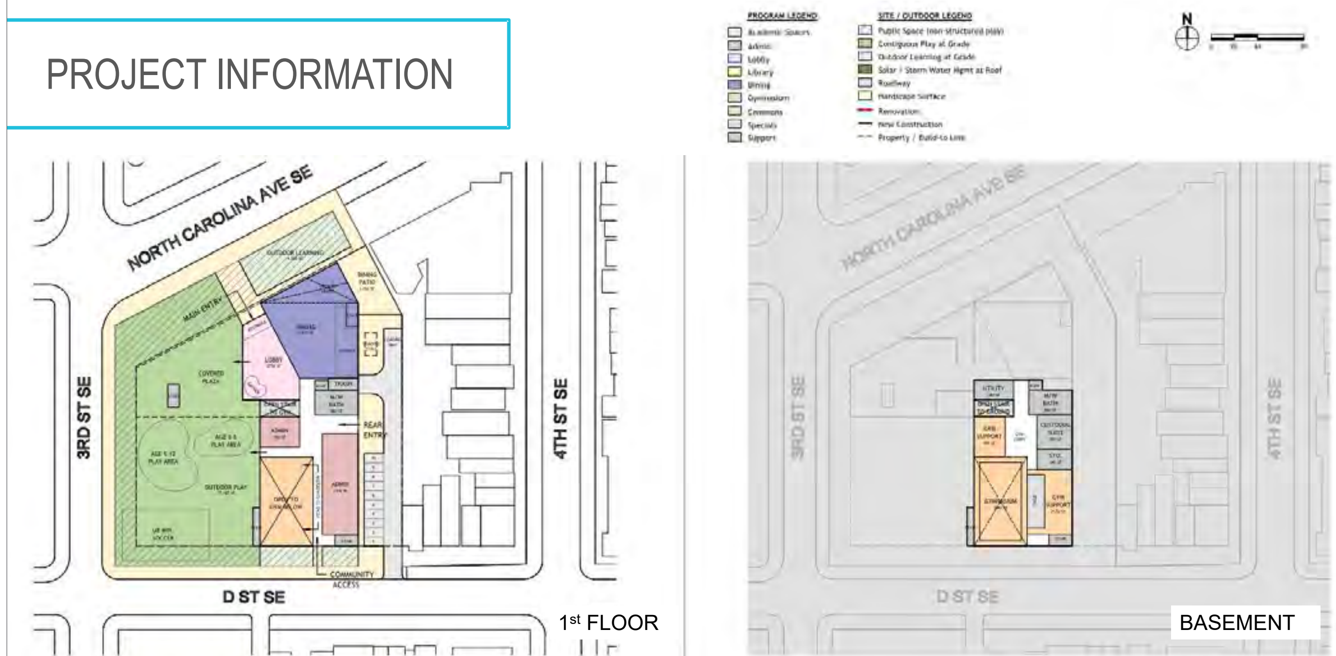


PROJECT INFORMATION

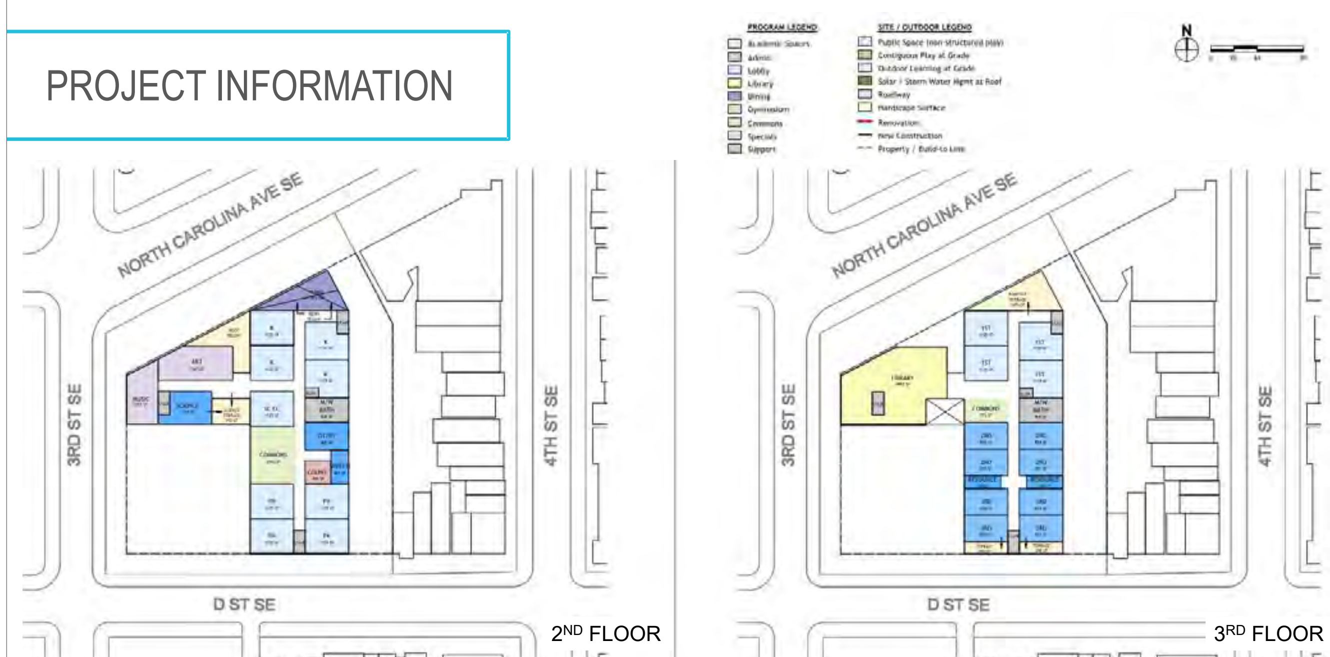




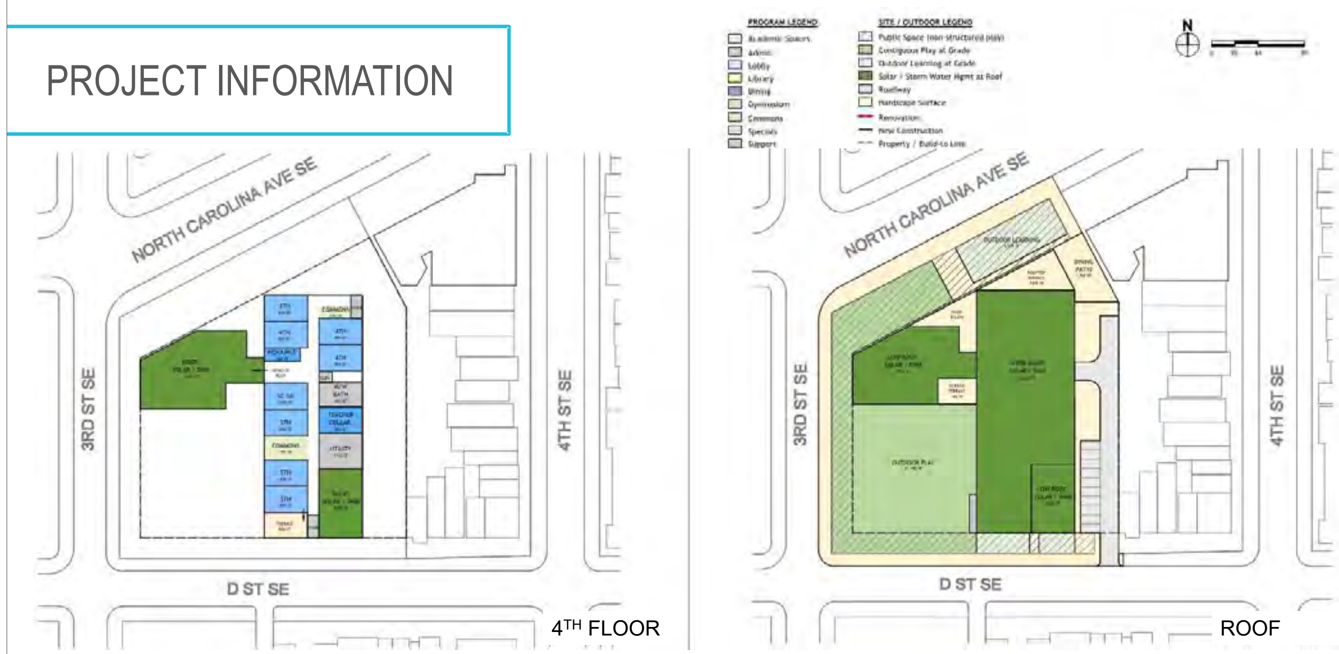
PROJECT INFORMATION



PROJECT INFORMATION



PROJECT INFORMATION



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DISCUSSION
NEXT STEPS

- Outline process for Modelling
- Investigate Incentives for NetZero Strategies

THANK YOU!

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Design Charette Meeting Minutes

MOYA DESIGN PARTNERS
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MEETING MINUTES

PROJECT NAME: Brent Elementary School-NetZero Award
PROJECT NO. : 13_2019

July 14, 2020

Eupert Braithwaite
Department of General Services
Amanda Ou
District of Columbia Public Schools

Sent Via Email to:
eupert.braithwaite@dc.gov
amanda.ou2@dc.gov

PROJECT NAME WEEKLY PROGRESS MEETING
MEETING MINUTES 001

Dear Eupert, Amanda and Casey,

On Friday, July 10th of 2020, the MOYA+HCM+SETTY met with DGS and DCPS for the first NetZero Design Charette and discussed the following:

NEW BUSINESS

ITEM	DESCRIPTION	STATUS	BALL-IN-COURT	RESPONSE TO ITEM
	Brent Elementary Net Zero Energy Initiative			
1.1	<u>Net Zero Energy Grant</u> • The goal of this grant is to understand what is required for a building to become net zero. • There is nothing that ties this project to be net zero but the aim is to gather data and advise future projects on the requirements needed for the implementation of this initiative. • The net zero initiative was not included in this projects RFP. MOYA+HCM saw it as a good opportunity to include it in the design. Once the grant opportunity came up, we thought it would be a good opportunity to include it in this project. • Starting early is key to make this initiative as successful as possible.	INFO	-	-
1.2	<u>Brent Elementary School</u> • Currently Brent's energy use intensity stands at 58.7, where the DOE zero energy ready schools	INFO	-	-

MEETING MINUTES 001

MOYA DESIGN PARTNERS

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	are at 35 and the 2020-2030 reduction goal is set to 15. We will be looking to set a target between 15-20. Once the project target is set a detailed energy analysis of the school will be completed. • The preferred layout of the school that is being further developed is known as “Library as a beacon” also knowns as scheme “B”. • The first story of the library building will be the art, music & science floor while the second story will be the library. • Below the building will be the covered plaza that will be connected to the outdoor play area. • If the project unfolds in phases there is a desire to get classrooms in first prior to the library, but we are analyzing the project at an end goal perspective. • The gym is located in the basement level. • The second floor of the building will be for the pre-k and kindergarten classes. • The third floor will be for 1st -3rd grade classes, where the first 1st grade classroom will be slightly larger. • Classroom layouts have been analyzed, we opted for double loaded corridors having classrooms on each side in this current theme. • The overall form and organization of the building was considered when designing the building with conservation of energy in mind. • There is currently no desire to keep the existing building at this moment, the initial phase would be to increase capacity whereas the second phase would be to bring the building to be fully modernized for DCPS.			
1.3	**Energy Consumption** • Currently the most energy in schools is spent on heating, lighting, and cooling which accounts for approximately 71% of energy use. • 72% of Electric consumption in school is used on lighting, cooling, and office equipment. • Once the target is set for the project and the energy use has been analyzed, we will then investigate potential for renewable energy. • Orientation and picking the right massing are one of the first steps during conceptual design to aid in the design for net zero initiatives. • The code building ratio to start with is a 40% window to wall ratio. We can then analyze the impact of slightly changing this ratio and seeing the energy improvements we can achieve by doing this. • If we were to have approximately 80% windows on the south wall of the library, we might look at having 30% on the other. By analyzing different scenarios, we could come up with an optimal solution for recommendation that balances design and esthetics of the building.	INFO	-	-
1.4	**Geothermal Systems** • Typical Geothermal wells are no more than 2 tons per well, if this building is approximately	INFO	-	-

MEETING MINUTES 001

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	4,000 tons we would need about 200 wells. Each well must be approximately 200 feet apart from each other, therefore the space required for this kind of systems would be about the size of a football field. • There are 2 parks located adjacent to the school, the one right across is a federal park and the one south of that is a district park. Developing a partnership with these parks would be something to be further look into. • Since space is somewhat limited at the site the adjacent park can be used to include the geothermal system. A potential partnership with the parks could be investigated to which would provide a large enough space for the installation of a complete geotechnical system for the building. A possible hybridized system approach of 1/3 of the wells will be on site and 2/3 off site could be possible. • The school currently uses the parks for some of their activities, if geothermal wells were to be installed upgrades to the park would be needed which would benefit the community as a whole. • If wells are to be located on the property they will not be allowed in the “right of way” area of the site. Anything that is permanently associated with the building will have to fall within the property line and not the right of way (storm water management, wells). • The current property area (excluding the right of way) would not be large enough to accommodate a complete geothermal system that will be able to meet the heating and cooling needs of the school. • The city might need to revisit their laws to allow for these possible upgrades to fall within the right of way when space is limited. • The system could also be installed under the gym floor, but further investigation would have to be done to assess viability. • A hybrid system to add a boiler or cooling tower to a geothermal system could also be viable to supplement the system to be able to meet the needs of the school. • Test wells should be done as soon as possible to see if the geothermal system is feasible for this project or not. • DGS to follow up with parks to start a discussion on the viability of installing wells on their property.			
1.5	**Solar Panel Systems & Green Roof** • We looked into how to integrate solar panels onto a green roof, as it is required for this project. We have come up with a method on how this can be accomplished having greenery in between the panels on supports at specified angles. • Solar panel system partnerships can be further investigated. Walmart has previously supplied selected businesses/school with a reduced electric fee from the energy produced from their solar panels on their nearby building. • We can investigate re-using the existing solar panels presently located on the roof of the	INFO	-	-

MEETING MINUTES 001

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	building. • We can also look into vertical solar skins for the building as well as solar canopy options and not only focus on the roof of the building for solar initiatives. • The green roof area ratio calculation uses a point system that includes many variables and alternative ways to achieve the ratio. Additional ways to improve the ratio would be to improve roof storm water management using plants if space is limited. • We would also like this roof area to be an educational one for the students to see the benefits of having these systems in place as it related to having a net zero building. • Past projects have been set up to be able to accommodate solar initiatives but have not progressed through with the installation of the systems. Since buildings are now going to be set up as net zero, incentives will be provided to follow through with the installation of these systems. • Most modernization projects going forward will be required to be net zero buildings.			
1.6	**Estimates** • An initial cost estimate for the project has been completed. • The cost estimator used code walls as a starting point, if we were to increase insulation of those walls by 10% we would then need to assess the additional cost of the insulation to be added to the base price already estimated. • If this project is to proceed to be net zero there is a buffer budget that can be used to follow through with these initiatives. • Once we select and analyze the energy saving improvements, we would then present a list of changes to the estimator. The base price estimated plus the extra costs for the energy improvements will be presented. • Models have been done with massing but not yet with actual building walls. Now would be a good time to build walls for the interior & exterior.	INFO	-	-
1.7	**Glazing & Solar Shading** • Exterior skin dimensions are what is required for the modeling software to build the code baseline model. • Roof & Walls insulation, once the code baseline model is created, we can then generate the curve that will provide us with the optimal point of improvement to be made to have significant effect. • Solar shading on the east/west walls are of greatest importance, MOYA to provide the design with the required dimensions.	ACTION	MOYA	7/15-MOYA provided dimensioned plans to SETTY.

ATTENDEES:

MEETING MINUTES 001

MOYA DESIGN PARTNERS
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Amanda Ou (DCPS)
Eupert Braithwaite (DGS)
Marilaura Guerrero (MOYA)
Greg Miller (MOYA)
Lisa Ferretto (HCM)
Shayne Pintur (HCM)
Jenine Kotob (HCM)
Paul Lund (HCM)
Ashley Staples (SETTY)
Gowtham SL (SETTY)

MEETING MINUTES 001

Lessons Learned Meeting with Flywheel

MOYA DESIGN PARTNERS
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MEETING MINUTES

PROJECT NAME: Brent Elementary School-NetZero Award
PROJECT NO. : 13_2019

September 10, 2020

Eupert Braithwaite
Department of General Services
Amanda Ou
District of Columbia Public Schools

Sent Via Email to:
eupert.braithwaite@dc.gov
amanda.ou2@dc.gov

PROJECT NAME WEEKLY PROGRESS MEETING
MEETING MINUTES 003

Dear Eupert, Amanda and Casey,

On Friday, September 10th of 2020, MOYA met with Flywheel and discussed the following on the NetZero Design Initiative:

NEW BUSINESS

ITEM	DESCRIPTION	STATUS	BALL-IN-COURT	RESPONSE TO ITEM
	Brent Elementary Net Zero Energy Initiative			
3.1	Lessons Learned w/Flywheel: Geothermal Wells in Public Space • The approach Flywheel had in installing a geothermal system for one of their buildings was to install the wells in the "public parking" area which was the setback between the sidewalk and the build-to line. They ended up having 16 feet of public space in this area. They went to the Pubic Space committee to request the installation of these wells and they were well received and approved. • They describe the wells as a "utility" that is a deep vertical well that would not interfere with the existing utilities. • They are building a courtyard style community located on a corner with most of all their utilities to be located in the center court area of the building. If the wells were to be placed there it would most likely interfere with the utilities and also make it difficult to service the wells in the future. • They only had to coordinate with TOPS and DDOT. • Geothermal wells have also been installed at Canal park, they are located under the sidewalk/street, they were given permission to install the wells under the public space. • The rough estimate of the number of wells required for Brent elementary school is approximately 200 based on the estimated weight of the building at 4,000 tons. • Brent Elementary school is exploring the possibility of the wells to be located in the park across the street from the school (Providence Park), we would need to further consult with DPR. • Casey has sent an email to the DPR to get the conversation started and to understand what the possibilities are for this project.	OPEN	DOEE	Casey reached out to DPR and confirmed the following: DPR said that Providence Park is not DPR's jurisdiction. Seems like it is AOC's jurisdiction which involves multiple layers of bureaucracy. Here is an article on Providence's park history: *https://ghostsofdc.org/2013/04/02/lost-history-providence-hospital-on-capitol-hill/* Considering that it is technically under the Architect of the Capitol's jurisdiction now, it might require a taller order to get approval.

ATTENDEES:
Marilaura Guerrero (MOYA)
Greg Miller (MOYA)
Jessica (Flywheel)

MEETING MINUTES 003

Energy Conservation Measures Spreadsheet

Project Name

ECM, Energy Conservation Measures

09.22.2020

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NO.	MEASURE NAME	DESCRIPTION	ANNUAL ENERGY SAVINGS (ENERGY CODE: IECC 2013)			ADDED COST > CODE BASE	SIMPLE PAYBACK (YRS)
			USE (%)	COST (%)	COST ($)		
	ENVELOPE						
A	Window Wall Ratio	Code Baseline: 40%					
A1	35%	35% all building directions					
A2	35%/60%	35% E, W, & S/ 60% N					
A3	35%/70%	35% E, W, & S/ 70% N					
A4	Proposed Building	40%					
B	Glazing Values	Code Baseline: U-0.55, SHGC-0.40 *Assembly Values					
B1	10% > code						
B2	20% > code						
B3	30% > code						
B4	Proposed Building	U-0.47, SHGC-0.40					
C	Wall Insulation	Code Baseline: U-0.064 (R-13 + R-7.5 ci)					
C1	10% > code						
C2	20% > code						
C3	30% > code						
C4	Proposed Building	U-0.048					
D	Roof Insulation	Code Baseline: U-0.048 (R-20 ci)				$0	0
D1	10% > code				$20	$100	5
D2	20% > code						
D3	30% > code						
D4	Proposed Building	U-0.027					
	SYSTEMS						
E	HVAC	Code Baseline: Packaged VAV with Reheat per Appendix G ASHRAE 90.1-2010					
E1	Option 1	Full GSHP using Providence Park					
E2	Option 2	Hybrid GSHP Site Only					

BEHIND THE SCENES DATA

ANNUAL ENERGY SAVINGS (LEED: v4 ASHRAE 90.1-2010)			NO.	EUI	ANNUAL USE (10^6 Btu/yr)	ANNUAL COST ($/year)	FIRST COST	NOTES
USE (%)	COST (%)	POINTS						
			-1	21,3	1852,2	$60.688		Using proposed building values and VRF with DOAS HVAC
			-1	20,9	1816,6	$59.404		Using proposed building values and VRF with DOAS HVAC
			-1	21,1	1833,1	$59.989		Using proposed building values and VRF with DOAS HVAC
			A3	21,1	1839,4	$60.211		Using proposed building values and VRF with DOAS HVAC
			-1					
			-1					
			-1					
			-1					
			B3					
			-1					
			-1					
			-1					
			-1					
			C3					
			-1					
			-1				$1.000.000	
			-1				$1.000.100	
			-1					
			D3					
			-1					
			-1	50,3	4373,9	$104.335		
			-1	28,9	2515	$84.203		
			-1	28,4	2468,7	$82.183		

Project Name

ECM, Energy Conservation Measures

09.22.2020

NO.	MEASURE NAME	DESCRIPTION	ANNUAL ENERGY SAVINGS (ENERGY CODE: IECC 2013)			ADDED COST > CODE BASE	SIMPLE PAYBACK (YRS)
			USE (%)	COST (%)	COST ($)		
E3	Option 3	VRF with DOAS					
E4	Option 4	Full GSHP plus water cooled VRF					
E5	Proposed Building	VRF with DOAS					
F	Lighting: Interior	Code Baseline: 0.99 w/sf					
F1	20% reduction						
F2	35% reduction						
F3	50% reduction						
F4	Proposed Building	0.53 w/sf					
G	Lighting: Exterior	Code Baseline: 0.15 w/sf					
G1	20% reduction						
G2	35% reduction						
G3	50% reduction						
G4	Proposed Building	3.8 KW					
H	Hot Water	Code Baseline: Gas Storage Type with 80% eff 180F- 50F loop					
H1	Option 1						
H2	Option 2						
	CONTROLS						
I	Controls	Code Baseline: n/a					
I1	Energy Recovery						
I2	Occupancy Sensors						
I3	Other						
	RENEWABLES						
J	Photovoltaics	Code Baseline: None					
J1	20% roof area						
J2	40% roof area						
J3	60% roof area						
J4	Solar Canopies						
	COMBINATIONS						
K	Code Baseline	A + B + C + D + E + F + G + H + I					
KO	As Designed	A1 + B1 + ? + ?					
K1	Best Payback						
K2	Best Performer						
K3	Closest to Zero Energy						
K4	Option TBD						

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BEHIND THE SCENES DATA

ANNUAL ENERGY SAVINGS (LEED: v4 ASHRAE 90.1-2010)			NO.	EUI	ANNUAL USE (10^6 Btu/yr)	ANNUAL COST ($/year)	FIRST COST	NOTES
USE (%)	COST (%)	POINTS						
			E3	27,9	2430,1	$81.186		
			E4	26,3	2253,6	$60.211		
			E5	21,3	1852,2	$60.668		
			-1					
			-1					
			-1					
			F3					
			-1					
			-1					
			-1					
			-1					
			G3					
			-1					
			-1					
			-1					
			-1					
			-1					
			-1					
			-1					
			-1					
			-1					
			-1					
			-1					
			-1					
			-1					
			KO					
			K1					
			K2					
			K3					
			K4					

LCA Analysis

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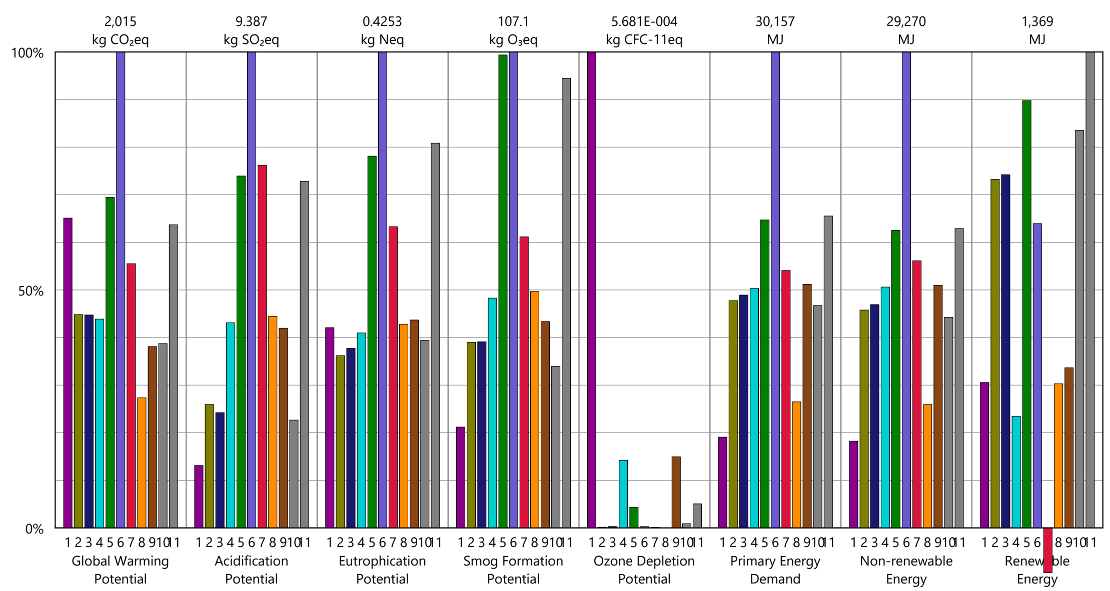
Report Summary

Created with Tally
Commercial Version 2020.01.15.01

Goal and Scope of Assessment
Exterior Wall Comparison

Author	amacdona
Company	HCM
Date	9/18/2020
Project	BRENT ES
Location	301 North Carolina Ave SE, Washington, DC 20003
Gross Area	60000 ft²
Building Life	50
Boundaries	Cradle to grave, inclusive of biogenic carbon; see appendix for a full list of materials and processes



Legend

Design Options

- CMU - EIFS
- CMU - Mineral Wool - Brick
- CMU - Polyiso - Brick
- CMU - Spray - ACM Panel
- CMU - Spray - TAKTL
- CMU - Sprayfoam - Brick (primary)
- Curtain Wall
- Storefront
- Stud - Spray - ACM
- Stud - Spray - Brick
- Stud - Spray - TAKTL

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Design option comparison

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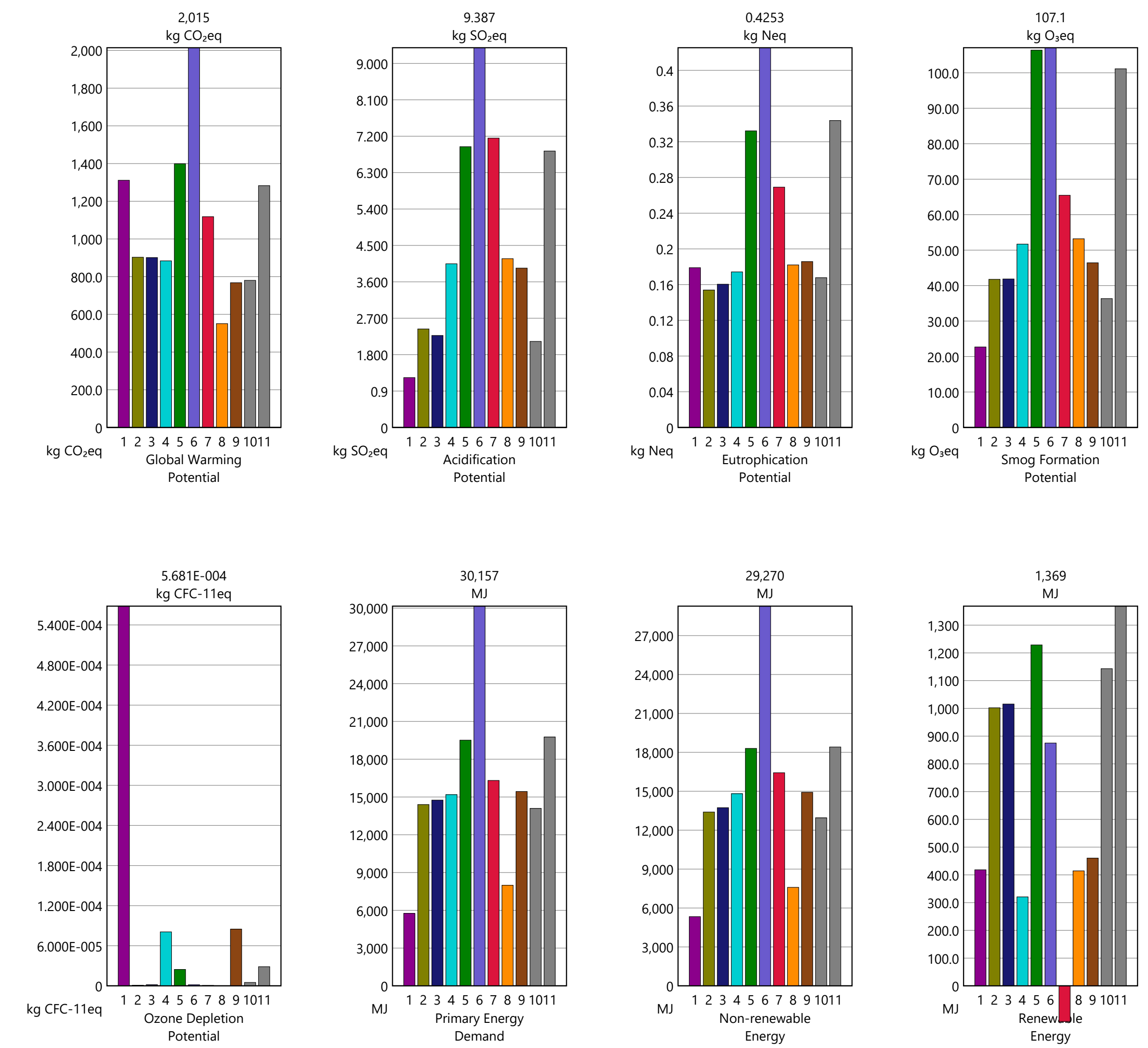
Report Summary (continued)



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Design Options

- CMU - EIFS
- CMU - Mineral Wool - Brick
- CMU - Polyiso - Brick
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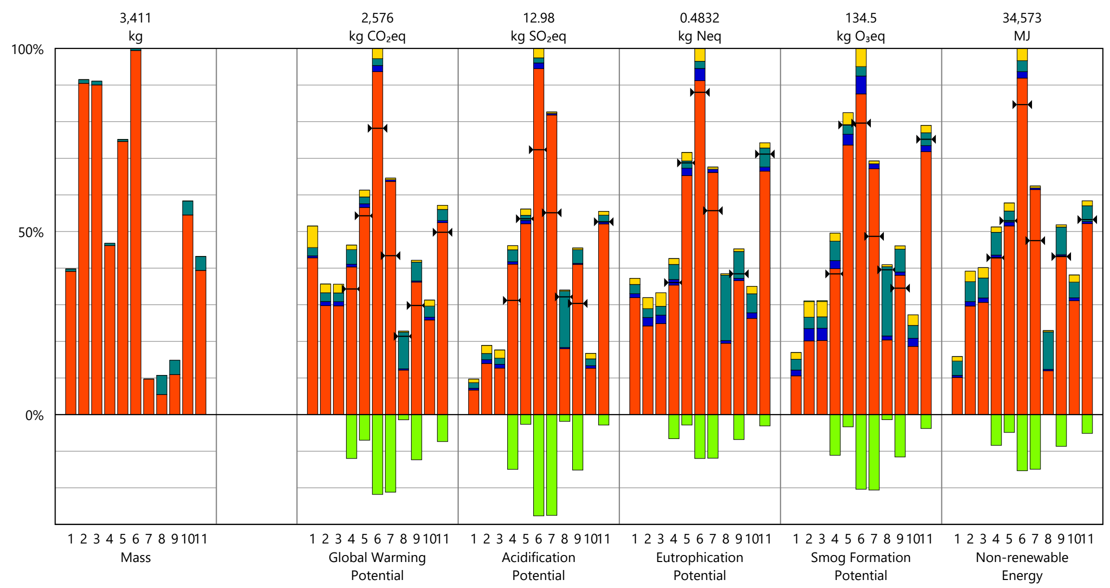
Results per Life Cycle Stage



Legend

⟼ Net value (impacts + credits)

Design Options

Option 1 - CMU - EIFS
Option 2 - CMU - Mineral Wool - Brick
Option 3 - CMU - Polyiso - Brick
Option 4 - CMU - Spray - ACM Panel
Option 5 - CMU - Spray - TAKTL
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Option 11 - Stud - Spray - TAKTL

Life Cycle Stages

- Product [A1-A3]
- Transportation [A4]
- Maintenance and Replacement [B2-B5]
- End of Life [C2-C4]
- Module D [D]

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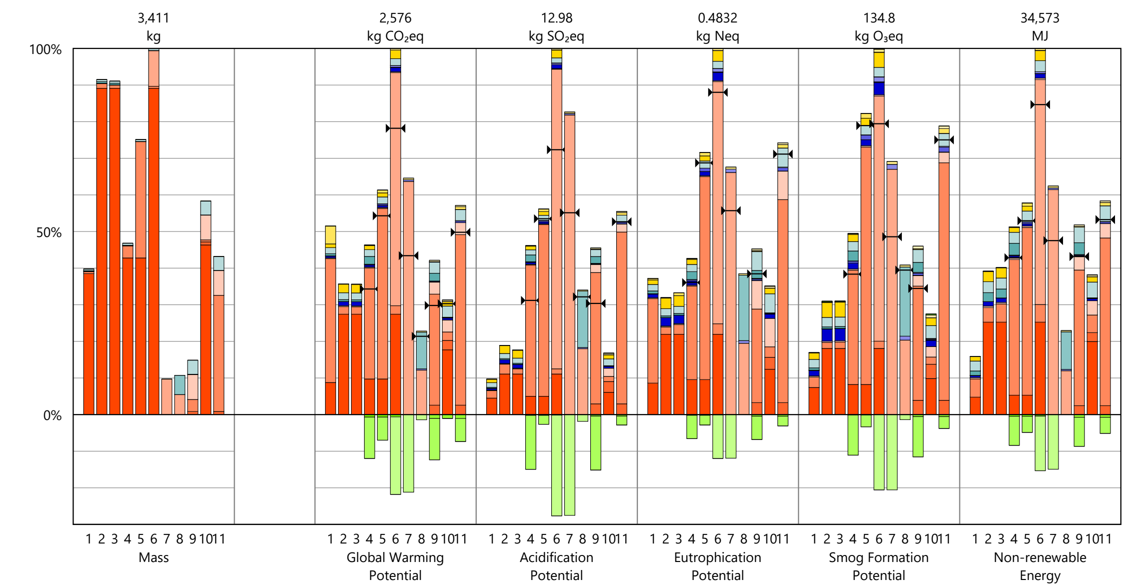
Results per Life Cycle Stage, itemized by Division



Legend

⟼ Net value (impacts + credits)

Design Options

Option 1 - CMU - EIFS
Option 2 - CMU - Mineral Wool - Brick
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Product [A1-A3]

- 04 - Masonry
- 05 - Metals
- 07 - Thermal and Moisture Protection
- 08 - Openings and Glazing
- 09 - Finishes

Transportation [A4]

- 04 - Masonry
- 05 - Metals
- 07 - Thermal and Moisture Protection
- 08 - Openings and Glazing
- 09 - Finishes

Maintenance and Replacement [B2-B5]

- 04 - Masonry
- 05 - Metals
- 07 - Thermal and Moisture Protection
- 08 - Openings and Glazing
- 09 - Finishes

End of Life [C2-C4]

- 04 - Masonry
- 05 - Metals
- 07 - Thermal and Moisture Protection
- 08 - Openings and Glazing
- 09 - Finishes

Module D [D]

- 04 - Masonry
- 05 - Metals
- 07 - Thermal and Moisture Protection
- 08 - Openings and Glazing
- 09 - Finishes

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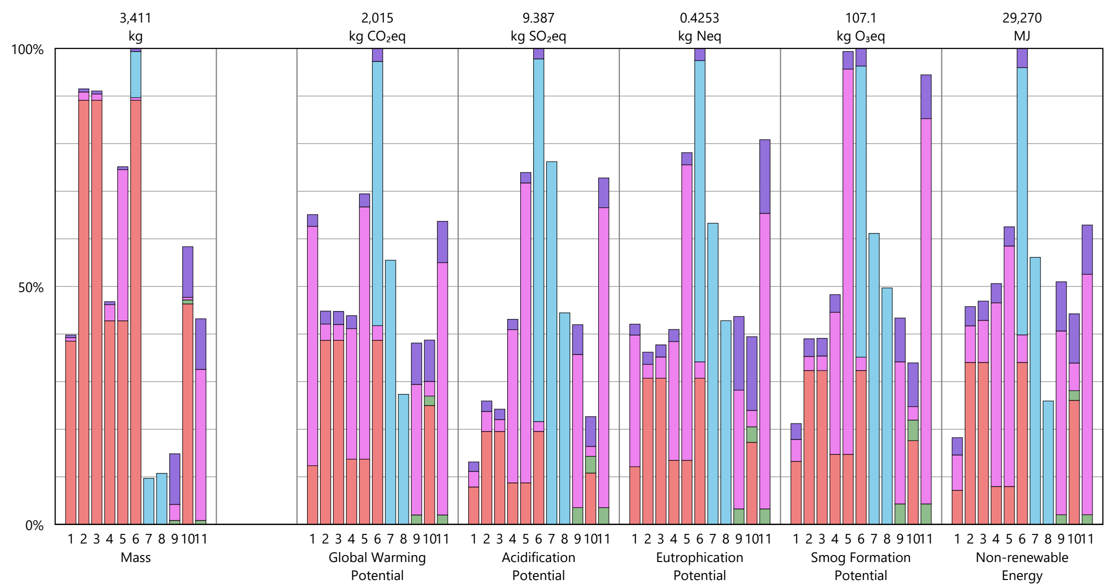
Results per Division



Legend

Design Options

Option 1 - CMU - EIFS
Option 2 - CMU - Mineral Wool - Brick
Option 3 - CMU - Polyiso - Brick
Option 4 - CMU - Spray - ACM Panel
Option 5 - CMU - Spray - TAKTL
Option 6 - CMU - Sprayfoam - Brick (primary)
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Option 8 - Storefront
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Option 11 - Stud - Spray - TAKTL

Divisions

04 - Masonry
05 - Metals
07 - Thermal and Moisture Protection
08 - Openings and Glazing
09 - Finishes

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Design option comparison

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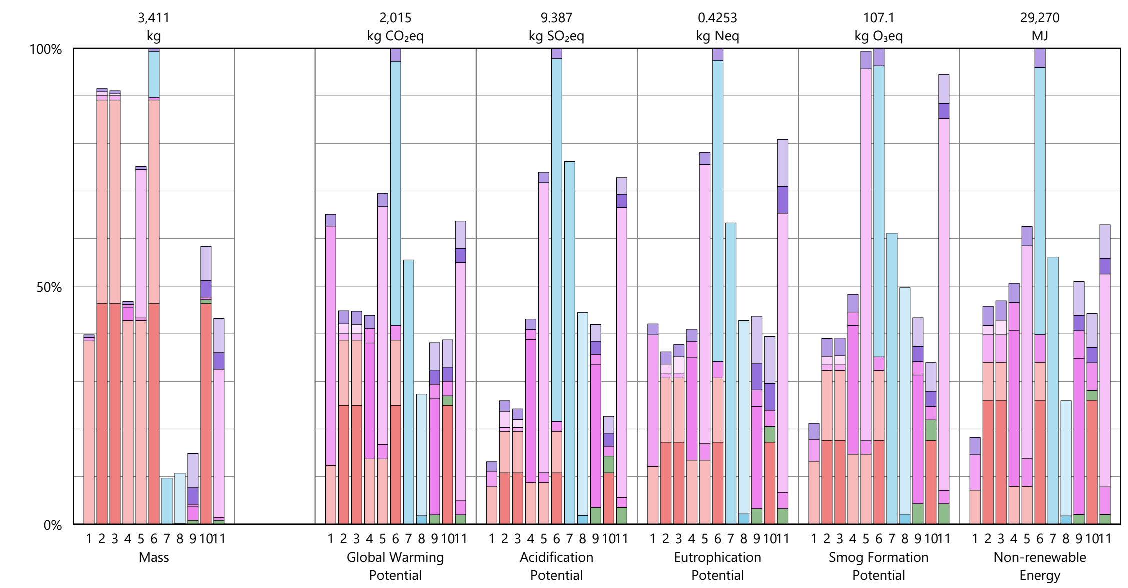
Results per Division, itemized by Tally Entry



Legend

Design Options

Option 1 - CMU - EIFS
Option 2 - CMU - Mineral Wool - Brick
Option 3 - CMU - Polyiso - Brick
Option 4 - CMU - Spray - ACM Panel
Option 5 - CMU - Spray - TAKTL
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Option 10 - Stud - Spray - Brick
Option 11 - Stud - Spray - TAKTL

04 - Masonry

Brick
Hollow-core CMU

05 - Metals

Steel, C-stud metal framing

07 - Thermal and Moisture Protection

Aluminum faced composite wall panel (ACM)
Closed cell, polyurethane foam, spray-applied
Exterior insulation and finish system (EIFS)
Fluid applied elastomeric air barrier
Glass fiber reinforced concrete (GFRC) panel
Mineral wool, board, generic
Polyisocyanurate (PIR), board

08 - Openings and Glazing

Aluminum mullion, inclusive of finish
Curtainwall System (including glazing)
Glazing, double pane IGU

09 - Finishes

Fiberglass mat gypsum sheathing
Paint
Wall board, gypsum

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Design option comparison

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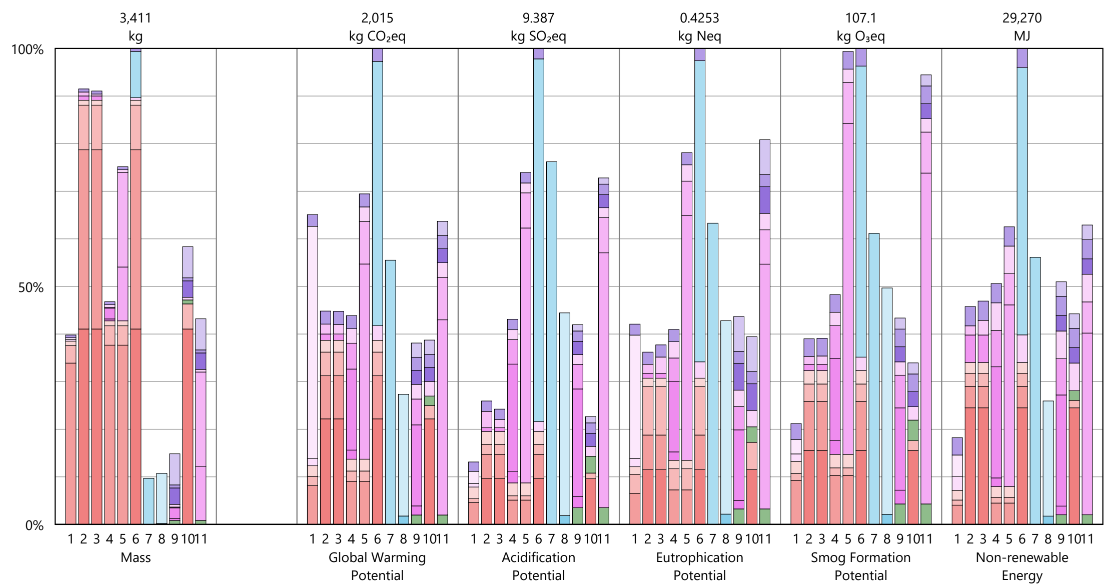
Results per Division, itemized by Material



Legend

Design Options

Option 1 - CMU - EIFS
Option 2 - CMU - Mineral Wool - Brick
Option 3 - CMU - Polyiso - Brick
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Option 7 - Curtain Wall
Option 8 - Storefront
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Option 11 - Stud - Spray - TAKTL

04 - Masonry

- Brick, generic
- Concrete masonry unit (CMU), hollow-core
- Lime mortar (Mortar type K)
- Steel, reinforcing rod

05 - Metals

- Un-coated cold-formed steel framing products, ClarkDietrich - EPD

07 - Thermal and Moisture Protection

- Aluminum extrusion, AEC - EPD
- Aluminum-faced composite wall panel (ACM), MCA - EPD
- Fluid applied elastomeric air barrier
- Fluoropolymer coating, metal stock
- Galvanized steel support
- GFRC
- Mineral wool, low density, NAIMA - EPD
- PIR rigid foam insulation, wall, R=14.6, PIMA - EPD
- Spray polyurethane foam, closed cell (HFO blowing agent), SPFA - EPD
- Stucco, synthetic
- XPS insulation, Foamular 250, Owens Corning - EPD

08 - Openings and Glazing

- Aluminum extrusion, thermally-improved mill-anodized, AEC - EPD
- Curtain wall system, Kawneer, 1600 Wall System - EPD
- Glazing, double, insulated (air)

09 - Finishes

- Fiberglass mat gypsum sheathing board
- Paint, interior acrylic latex
- Wall board, gypsum, moisture- and mold-resistant

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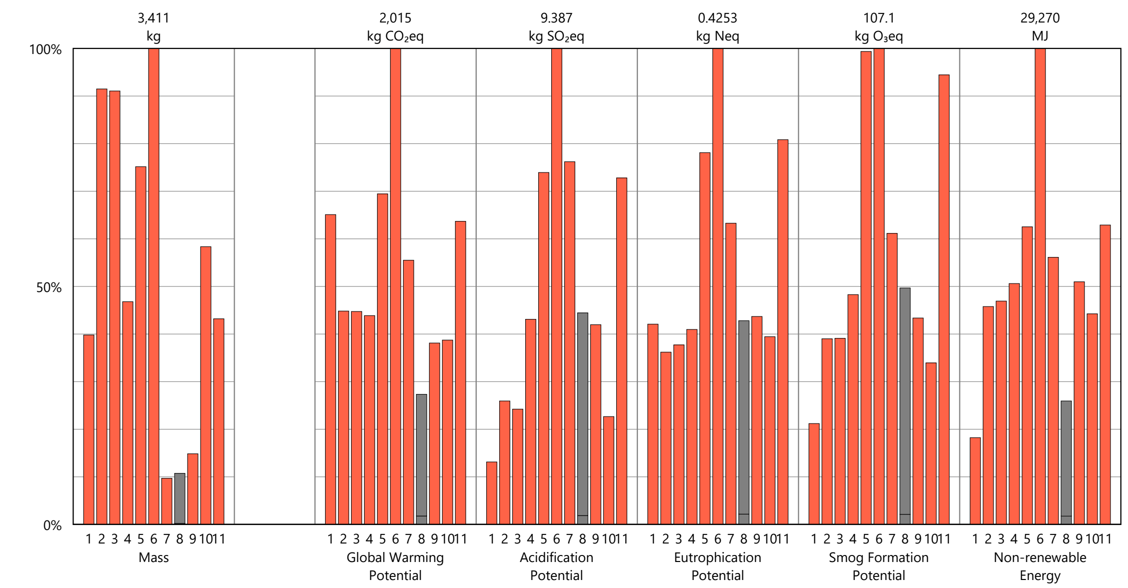
Results per Revit Category



Legend

Design Options

Option 1 - CMU - EIFS
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Revit Categories

- Curtainwall Mullions
- Curtainwall Panels
- Walls

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Design option comparison

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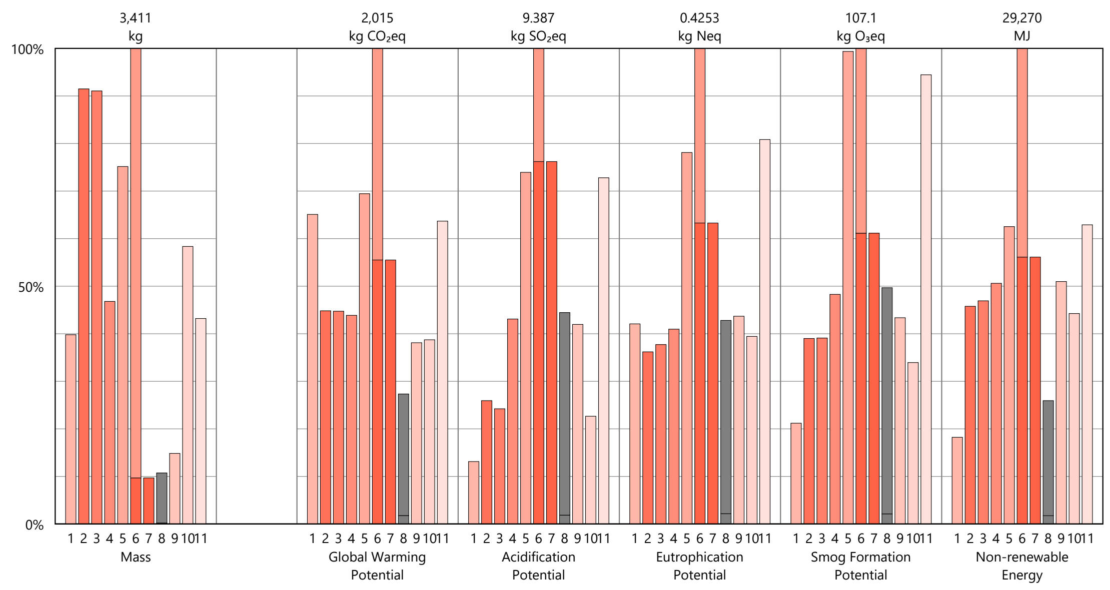
Results per Revit Category, itemized by Family



Legend

Design Options

Option 1 - CMU - EIFS
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Curtainwall Mullions

- Rectangular Mullion

Curtainwall Panels

- System Panel

Walls

- Curtain Wall Placeholder
- X0B8A - 8" CMU - 2" Mineral Wool - Air Barrier - Brick
- X0B8A - 8" CMU - 2" Rigid - Air Barrier - Brick
- X0B8A - 8" CMU - 2" Spray - ACM
- X0B8A - 8" CMU - 2" Spray - Brick
- X0B8A - 8" CMU - 2" Spray - TAKTL
- X0B8A - 8" CMU - 3.5 EPS EIFS
- X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - ACM
- X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - BRICK
- X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - TAKTL

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Calculation Methodology

LIFE CYCLE ASSESSMENT METHODS

The following provides a description of terms and methods associated with the use of Tally to conduct life cycle assessment for construction works and construction products. Tally methodology is consistent with LCA standards ISO 14040-14044, ISO 21930:2017, ISO 21931:2010, EN 15804:2012, and EN 15978:2011. For more information about LCA, please refer to these standards or visit www.choosetally.com.

Studied objects

The life cycle assessment (LCA) results reported represent an analysis of a single building, multiple buildings, or a comparative analysis of two or more building design options. The assessment may represent the complete architectural, structural, and finish systems of the building(s) or a subset of those systems. This may be used to compare the relative environmental impacts associated with building components or for comparative study with one or more reference buildings. Design options may represent a full or partial building across various stages of the design process, or they may represent multiple schemes of a full or partial building that are being compared to one another across a range of evaluation criteria.

Functional unit and reference unit

A functional unit is the quantified performance of a product, building, or system that defines the object of the study. The functional unit of a single building should include the building type (e.g. office, factory), relevant technical and functional requirements (e.g. regulatory requirements, energy performance), pattern of use (e.g. occupancy, usable floor area), and the required service life. For a design option comparison of a partial building, the functional unit is the complete set of building systems or products that perform a given function. It is the responsibility of the modeler to assure that reference buildings or design options are functionally equivalent in terms of scope and relevant performance. The expected life of the building has a default value of 60 years and can be modified by the modeler.

The reference unit is the full collection of processes and materials required to produce a building or portion thereof and is quantified according to the given goal and scope of the assessment over the full life of the building. If construction impacts are included in the assessment, the reference unit also includes the energy, water, and fuel consumed on the building site during construction. If operational energy is included in the assessment, the reference unit includes the electrical and thermal energy consumed on site over the life of the building.

Data source

Tally utilizes a custom designed LCA database that combines material attributes, assembly details, and architectural specifications with environmental impact data resulting from the collaboration between KieranTimberlake and thinkstep. LCA modeling was conducted in GaBi 8.5 using GaBi 2018 databases and in accordance with GaBi databases and modeling principles.

The data used are intended to represent the US and the year 2017. Where representative data were unavailable, proxy data were used. The datasets used, their geographic region, and year of reference are listed for each entry. An effort was made to choose proxy datasets that are technologically consistent with the relevant entry.

Data quality and uncertainty

Uncertainty in results can stem from both the data used and their application. Data quality is judged by: its measured, calculated, or estimated precision; its completeness, such as unreported emissions; its consistency, or degree of uniformity of the methodology applied on a study serving as a data source; and geographical, temporal, and technological representativeness. The GaBi LCI databases have been used in LCA models worldwide in both industrial and scientific applications. These LCI databases have additionally been used both as internal and critically reviewed and published studies. Uncertainty introduced by the use of proxy data is reduced by using technologically, geographically, and/or temporally similar data. It is the responsibility of the modeler to appropriately apply the predefined material entries to the building under study.

System boundaries and delimitations

The analysis accounts for the full cradle to grave life cycle of the design options studied across all life cycle stages, including material manufacturing, maintenance and replacement, and eventual end of life. Optionally, the construction impacts and operational energy of the building can be included within the scope. Product stage impacts are excluded for materials and components indicated as existing or salvaged by the modeler. The modeler defines whether the boundary includes or excludes the flow of biogenic carbon, which is the carbon absorbed and generated by biological sources (e.g. trees, algae) rather than from fossil resources.

Architectural materials and assemblies include all materials required for the product's manufacturing and use including hardware, sealants, adhesives, coatings, and finishing. The materials are included up to a 1% cut-off factor by mass except for known materials that have high environmental impacts at low levels. In these cases, a 1% cut-off was implemented by impact.

Calculation Methodology

LIFE CYCLE STAGES

The following describes the scope and system boudaries used to define each stage of the life cycle of a building or building product, from raw material acquisition to final disposal. For products listed in Tally as Environmental Product Declarations (EPD), the full life cycle impacts are included, even if the published EPD only includes the Product stage [A1-A3].

Product [EN 15978 A1 - A3]

This encompasses the full manufacturing stage, including raw material extraction and processing, intermediate transportation, and final manufacturing and assembly. The product stage scope is listed for each entry, detailing any specific inclusions or exclusions that fall outside of the cradle to gate scope. Infrastructure (buildings and machinery) required for the manufacturing and assembly of building materials are not included and are considered outside the scope of assessment.

Transportation [EN 15978 A4]

This counts transportation from the manufacturer to the building site during the construction stage and can be modified by the modeler.

Construction Installation [EN 15978 A5] (Optional)

This includes the anticipated or measured energy and water consumed on-site during the construction installation process, as specified by the modeler.

Maintenance and Replacement [EN 15978 B2-B5]

This encompasses the replacement of materials in accordance with their expected service life. This includes the end of life treatment of the existing products as well as the cradle to gate manufacturing and transportation to site of the replacement products. The service life is specified separately for each product. Refurbishment of materials marked as existing or salvaged by the modeler is also included.

Operational Energy [EN 15978 B6] (Optional)

This is based on the anticipated or measured energy and natural gas consumed at the building site over the lifetime of the building, as indicated by the modeler.

End of Life [EN 15978 C2-C4]

This includes the relevant material collection rates for recycling, processing requirements for recycled materials, incineration rates, and landfilling rates. The impacts associated with landfilling are based on average material properties, such as plastic waste, biodegradable waste, or inert material. Stage C2 encompasses the transport from the construction site to end-of-life treatment based on national averages. Stages C3-C4 account for waste processing and disposal, i.e., impacts associated with landfilling or incineration.

Module D [EN 15978 D]

This accounts for reuse potentials that fall beyond the system boundary, such as energy recovery and recycling of materials. Along with processing requirements, the recycling of materials is modeled using an avoided burden approach, where the burden of primary material production is allocated to the subsequent life cycle based on the quantity of recovered secondary material. Incineration of materials includes credit for average US energy recovery rates.

PRODUCT	CONSTRUCTION	USE	END-OF-LIFE	MODULE D
A1. Extraction	**A4. Transport (to site)**	B1. Use	C1. Demolition	**D. Benefits and loads beyond the system boundary from:**
A2. Transport (to factory)	***A5. Construction Installation***	**B2. Maintenance**	**C2. Transport (to disposal)**	**1. Reuse**
A3. Manufacturing		**B3. Repair**	**C3. Waste processing**	**2. Recycling**
		B4. Replacement	**C4. Disposal**	**3. Energy recovery**
		B5. Refurbishment		
		B6. Operational energy		
		B7. Operational water		

Life-Cycle Stages as defined by EN 15978. Processes included in Tally modeling scope are shown in bold. Italics indicate optional processes.

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Calculation Methodology

ENVIRONMENTAL IMPACT CATEGORIES

A characterization scheme translates all emissions and fuel use associated with the reference flow into quantities of categorized environmental impact. As the degree that the emissions will result in environmental harm depends on regional ecosystem conditions and the location in which they occur, the results are reported as impact potential. Potential impacts are reported in kilograms of equivalent relative contribution (eq) of an emission commonly associated with that form of environmental impact (e.g. kg CO_2eq).

The following list provides a description of environmental impact categories reported according to the TRACI 2.1 characterization scheme, the environmental impact model developed by the US EPA to quantify environmental impact risk associated with emissions to the environment in the United States. TRACI is the standard environmental impact reporting format for LCA in North America. Impacts associated with land use change and fresh water depletion are not included in TRACI 2.1. For more information on TRACI 2.1, reference Bare 2010, EPA 2012, and Guinée 2001. For further description of measurement of environmental impacts in LCA, see Simonen 2014.

Acidification Potential (AP) kg SO_2eq

A measure of emissions that cause acidifying effects to the environment. The acidification potential is a measure of a molecule's capacity to increase the hydrogen ion (H^+) concentration in the presence of water, thus decreasing the pH value. Potential effects include fish mortality, forest decline, and the deterioration of building materials.

Eutrophication Potential (EP) kg Neq

A measure of the impacts of excessively high levels of macronutrients, the most important of which are nitrogen (N) and phosphorus (P). Nutrient enrichment may cause an undesirable shift in species composition and elevated biomass production in both aquatic and terrestrial ecosystems. In aquatic ecosystems, increased biomass production may lead to depressed oxygen levels caused by the additional consumption of oxygen in biomass decomposition.

Global Warming Potential (GWP) kg CO_2eq

A measure of greenhouse gas emissions, such as carbon dioxide and methane. These emissions are causing an increase in the absorption of radiation emitted by the earth, increasing the natural greenhouse effect. This may, in turn, have adverse impacts on ecosystem health, human health, and material welfare.

Ozone Depletion Potential (ODP) kg CFC-11eq

A measure of air emissions that contribute to the depletion of the stratospheric ozone layer. Depletion of the ozone leads to higher levels of UVB ultraviolet rays reaching the earth's surface with detrimental effects on humans and plants. As these impacts tend to be very small, ODP impacts can be difficult to calculate and are prone to a larger margin of error than the other impact categories.

Smog Formation Potential (SFP) kg O_3eq

A measure of ground level ozone, caused by various chemical reactions between nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in sunlight. Human health effects can result in a variety of respiratory issues, including increasing symptoms of bronchitis, asthma, and emphysema. Permanent lung damage may result from prolonged exposure to ozone. Ecological impacts include damage to various ecosystems and crop damage.

Primary Energy Demand (PED) MJ (lower heating value)

A measure of the total amount of primary energy extracted from the earth. PED tracks energy resource use, not the environmental impacts associated with the resource use. PED is expressed in energy demand from non-renewable resources and from renewable resources. Efficiencies in energy conversion (e.g. power, heat, steam, etc.) are taken into account when calculating this result.

Non-Renewable Energy Demand MJ (lower heating value)

A measure of the energy extracted from non-renewable resources (e.g. petroleum, natural gas, etc.) contributing to the PED. Non-renewable resources are those that cannot be regenerated within a human time scale. Efficiencies in energy conversion (e.g. power, heat, steam, etc.) are taken into account when calculating this result.

Renewable Energy Demand MJ (lower heating value)

A measure of the energy extracted from renewable resources (e.g. hydropower, wind energy, solar power, etc.) contributing to the PED. Efficiencies in energy conversion (e.g. power, heat, steam, etc.) are taken into account when calculating this result.

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LCI Data

END-OF-LIFE [C2-C4]

A Life Cycle Inventory(LCI) is a compilation and quantification of inputs and outputs for the reference unit.The following LCI provides a summary of all energy, construction, transportation, and material inputs present in the study. Materials are listed in alphabetical order along with a list of all Revit families and Tally entries in which they occur, along with any notes and system boundaries accompanying their database entries.Each entry lists the detailed scope for the LCI data sources used from the GaBi LCI database and identifies the LCI data source.

For LCI data sourced from an Environmental Product Declaration (EPD), the product manufacturer, EPD identification number, and Program Operator are listed. Where the LCI source does not provide data for all life cycle stages, default North American average values are used. This is of particular importance for European EPD sources, as EPD data are generally only provided for the product stage, and North American average values are used for the remaining life cycle stages.

Where specific quantities are associated with a data entry, such as user inputs, energy values, or material mass, the quantity is listed on the same line as the title of the entry.

TRANSPORTATION [A4]

Default transportation values are based on the three-digit material commodity code in the 2012 Commodity Flow Survey by the US Department of Transportation Bureau of Transportation Statistics and the US Department of Commerce where more specific industry-level transportation is not available.

Transportation by Barge
Scope:
The data set represents the transportation of 1 kg of material from the manufacturer location to the building site by barge.

LCI Source:
GLO: Average ship, 1500t payload capacity/ canal ts (2017)
US: Diesel mix at filling station ts (2014)

Transportation by Container Ship
Scope:
The data set represents the transportation of 1 kg of material from the manufacturer location to the building site by container ship.

LCI Source:
GLO: Container ship, 27500 dwt payload capacity, ocean going ts (2017)
US: Heavy fuel oil at refinery (0.3wt.% S) ts (2014)

Transportation by Rail
Scope:
The data set represents the transportation of 1 kg of material from the manufacturer location to the building site by cargo rail.

LCI Source:
GLO: Rail transport cargo - Diesel, average train, gross tonne weight 1000t / 726t payload capacity ts (2017)
US: Diesel mix at filling station ts (2014)

Transportation by Truck
Scope:
The data set represents the transportation of 1 kg of material from the manufacturer location to the building site by diesel truck.

LCI Source:
US: Truck - Trailer, basic enclosed / 45,000 lb payload - 8b ts (2017)
US: Diesel mix at filling station ts (2014)

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LCI Data (continued)

END-OF-LIFE [C2-C4]

Specific end-of-life scenarios are detailed for each entry based on the US construction and demolition waste treatment methods and rates in the 2016 WARM Model by the US Environmental Protection Agency except where otherwise specified. Heterogeneous assemblies are modeled using the appropriate methodologies for the component materials.

End-of-Life Landfill
Scope:
Materials for which no recycling or incineration rates are known, no recycling occurs within the US at a commercial scale, or which are unable to be recycled are landfilled. This includes glass, drywall, insulation, and plastics. The solids contents of coatings, sealants, and paints are assumed to go to landfill, while the solvents or water evaporate during installation. Where the landfill contains biodegradable material, the energy recovered from landfill gas utilization is reflected as a credit in Module D.

LCI Source:
US: Glass/inert on landfill ts (2017)
US: Biodegradable waste on landfill, post-consumer ts (2017)
US: Plastic waste on landfill, post-consumer ts (2017)

Concrete End-of-Life
Scope:
Concrete (or other masonry products) are recycled into aggregate or general fill material or they are landfilled. It is assumed that 55% of the concrete is recycled. Module D accounts for both the credit associated with off-setting the production aggregate and the burden of the grinding energy required for processing.

LCI Source:
US: Diesel mix at refinery ts (2014)
GLO: Fork lifter (diesel consumption) ts (2016)
EU - 28 Gravel 2/32 ts (2017)
US: Glass/inert on landfill ts (2017)

Metals End-of-Life
Scope:
Metal products are modeled using the avoided burden approach. The recycling rate at end of life is used to determine how much secondary metal can be recovered after having subtracted any scrap input into manufacturing (net scrap). Net scrap results in an environmental credit in Module D for the corresponding share of the primary burden that can be allocated to the subsequent product system using secondary material as an input. If the value in Module D reflects an environmental burden, then the original product (A1-A3) contains more secondary material than is recovered.

LCI Source:
Aluminum - RNA: Primary Aluminum Ingot AA/ts (2010)
Aluminum - RNA: Secondary Aluminum Ingot AA/ts (2010)
Brass - GLO: Zinc mix ts (2012)
Brass - GLO: Copper (99.99% cathode) ICA (2013)
Brass - EU-28: Brass (CuZn20) ts (2017)
Copper - DE: Recycling potential copper sheet ts (2016)
Steel - GLO: Value of scrap worldsteel (2014)
Zinc - GLO: Special high grade zinc IZA (2012)

Wood End-of-Life
Scope:
End of Life waste treatment methods and rates for wood are based on the 2014 Municipal Solid Waste and Construction Demolition Wood Waste Generation and Recovery in the United States report by Dovetail Partners, Inc. It is assumed that 65.5% of wood is sent to landfill, 17.5% to incineration, and 17.5% to recovery.

LCI Source:
US: Untreated wood in waste incineration plant ts (2017)
US: Wood product (OSB, particle board) waste in waste incineration plant ts (2017)
US: Wood products (OSB, particle board) on landfill, post-consumer ts (2017)
US: Untreated wood on landfill, post-consumer ts (2017)
RNA: Softwood lumber CORRIM (2011)

BRENT ES
Design option comparison

9/18/2020

LCI Data

PRODUCT [A1-A3]

Materials and components are listed in alphabetical order along with a list of all Revit families and Tally entries in which they occur. The masses given here refer to the quantity of each material used over the building's life-cycle, which includes both Product [A1-A3] and Use [B2-B5] stages.

Additional provided data describing scope boundaries for each life cycle stage may be useful for interpretation of the impacts associated with the specific material or component. Each material or component is listed with its service life, or period of time after installation it is expected to meet the service requirements prior to replacement or repair. This value is indicated in parentheses next to the mass of the material associated with the listed Revit family. Values for transportation distance or service life shown with an asterisk (*) indicate user-defined changes to default values. Values for service life shown with a dagger (†) indicate materials identified by the modeler as existing or salvaged.

Aluminum extrusion, AEC - EPD **27.2 kg**

Used in the following Revit families:
X0B8A - 8" CMU - 2" Spray - ACM 13.6 kg (50 yrs)
X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - ACM 13.6 kg (50 yrs)

Used in the following Tally entries:
Aluminum faced composite wall panel (ACM)

Description:
Extruded aluminum part. Industry-wide EPD from the Aluminum Extruders Council.

Life Cycle Inventory:
For information and quantities, see EPD

Product Scope:
Cradle to gate

Transportation Distance:
By truck: 663 km

End-of-Life Scope:
95% Recovered
5% Landfilled (inert material)

Module D Scope:
Product has 36.4% scrap input while remainder is processed and credited as avoided burden

LCI Source:
RNA: Aluminum extrusion, mill finish - AEC (A1-A3) ts-EPD (2015)
RNA: Primary Aluminum Ingot AA/ts (2010)
RNA: Secondary Aluminum Ingot AA/ts (2010)

EPD Source:
11240237.101.1

EPD Designation Holder:
Aluminum Extruders Council (AEC)

EPD Program Operator:
UL Environment

EPD Expiration:
10/4/2021

Aluminum extrusion, thermally-improved mill-anodized, AEC - EPD **7.3 kg**

Used in the following Revit families:
Rectangular Mullion 7.3 kg (50 yrs)

Used in the following Tally entries:
Aluminum mullion, inclusive of finish

Description:
Anodized, thermally-improved, or thermal barrier, aluminum extrusions. Industry-wide EPD from the Aluminum Extruders Council. EPD representative of conditions in North America

Life Cycle Inventory:
For information and quantities, see EPD

Product Scope:
Cradle-to-gate

Transportation Distance:
By truck: 663 km

End-of-Life Scope:
95% Recovered
5% Landfilled (inert material)

Module D Scope:
Credit given for the avoided burden associated with recovered material

LCI Source:
EPD (US), American Extruders Council (2016)

EPD Source:
11240237.102.1

EPD Designation Holder:
Aluminum Extruders Council (AEC)

EPD Program Operator:
UL Environment

EPD Expiration:
10/4/2021

Aluminum-faced composite wall panel (ACM), MCA - EPD **153.7 kg**

Used in the following Revit families:
X0B8A - 8" CMU - 2" Spray - ACM 76.8 kg (50 yrs)
X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - ACM 76.8 kg (50 yrs)

Used in the following Tally entries:
Aluminum faced composite wall panel (ACM)

Description:
Aluminum facings bonded to both sides of a thermoplastic core. Overall thickness of aluminum-faced panels 0.157 (4mm). Entry includes necessary adhesives and fasteners. Industry-wide EPD from the Metal Construction Association.

Life Cycle Inventory:
For information and quantities, see EPD.

Product Scope:
Cradle to gate

Transportation Distance:
By truck: 663 km

End-of-Life Scope:
95% of aluminum recovered
5% of aluminum landfilled (inert waste)
100% of polyurethane landfilled (plastic waste)

Module D Scope:
All recovered aluminum is processed and credited as avoided burden

LCI Source:
US: Metal composite material (MCM) panel MCA (2010)

EPD Source:
13CA27321.101.1

EPD Designation Holder:
Metal Construction Association (MCA)

EPD Program Operator:
UL Environment

EPD Expiration:
8/27/2018

Brick, generic **5,602.6 kg**

Used in the following Revit families:
X0B8A - 8" CMU - 2" Mineral Wool - Air Barrier - Brick 1,400.6 kg (50 yrs)
X0B8A - 8" CMU - 2" Rigid - Air Barrier - Brick 1,400.6 kg (50 yrs)
X0B8A - 8" CMU - 2" Spray - Brick 1,400.6 kg (50 yrs)
X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - BRICK 1,400.6 kg (50 yrs)

Used in the following Tally entries:
Brick

Description:
Common extruded brick, excludes mortar.

BRENT ES
Design option comparison

9/18/2020

LCI Data (continued)

Life Cycle Inventory:
100% Fired brick

Product Scope:
Cradle to gate
excludes mortar
anchors, ties, and metal accessories outside of scope (<1% mass)

Transportation Distance:
By truck: 172 km

End-of-Life Scope:
55% Recycled into coarse aggregate
45% Landfilled (inert material)

Module D Scope:
Avoided burden credit for coarse aggregate, includes grinding energy

LCI Source:
DE: Stoneware tiles, unglazed (EN15804 A1-A3) ts (2017)

Concrete masonry unit (CMU), hollow-core **7,579.7 kg**

Used in the following Revit families:
X0B8A - 8" CMU - 2" Mineral Wool - Air Barrier - Brick 1,284.7 kg (50 yrs)
X0B8A - 8" CMU - 2" Rigid - Air Barrier - Brick 1,284.7 kg (50 yrs)
X0B8A - 8" CMU - 2" Spray - ACM 1,284.7 kg (50 yrs)
X0B8A - 8" CMU - 2" Spray - Brick 1,284.7 kg (50 yrs)
X0B8A - 8" CMU - 2" Spray - TAKTL 1,284.7 kg (50 yrs)
X0B8A - 8" CMU - 3.5 EPS EIFS 1,156.2 kg (50 yrs)

Used in the following Tally entries:
Hollow-core CMU

Description:
Hollow-Core Concrete Masonry Unit (CMU), excludes grout and mortar

Life Cycle Inventory:
100% Concrete masonry units

Product Scope:
Cradle to gate, excludes mortar
Anchors, ties, and metal accessories outside of scope (<1% mass)

Transportation Distance:
By truck: 172 km

End-of-Life Scope:
55% Recycled into coarse aggregate
45% Landfilled (inert material)

Module D Scope:
Avoided burden credit for coarse aggregate, includes grinding energy

LCI Source:
DE: Concrete bricks (EN15804 A1-A3) ts (2017)

Curtain wall system, Kawneer, 1600 Wall System - EPD **661.5 kg**

Used in the following Revit families:
Curtain Wall Placeholder 661.5 kg (50 yrs)

Used in the following Tally entries:
Curtainwall System (including glazing)

Description:
Thermally broken aluminum curtain wall system by Kawneer INCLUSIVE of glazing units, appropriate for low-to-mid-rise applications, including the 1600, 1620, 1630, 2250, and 7500 curtainwall system lines. Includes mullions, glazing, and all necessary gaskets and sealants. The reference window unit size is 1.5m x 1.6m. EPD representative of conditions in North America.

Life Cycle Inventory:
For information and quantities, see EPD

Product Scope:
Cradle to gate

Transportation Distance:
By truck: 663 km

End-of-Life Scope:
95% recovery rate
5% landfill (inert)

Module D Scope:
Credit given for the avoided burden associated with recovered material

LCI Source:
EPD (US), Kawneer North America (2015)

EPD Source:
47868332121.105.1

EPD Designation Holder:
Kawneer North America

EPD Program Operator:
UL Environment

EPD Expiration:
11/16/2020

Fiberglass mat gypsum sheathing board **354.0 kg**

Used in the following Revit families:
X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - ACM 118.0 kg (50 yrs)
X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - BRICK 118.0 kg (50 yrs)
X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - TAKTL 118.0 kg (50 yrs)

Used in the following Tally entries:
Fiberglass mat gypsum sheathing

Description:
Fiberglass treated gypsum sheathing product appropriate for use in high-moisture environments.

Life Cycle Inventory:
92% Gypsum
8% Fiberglass mat

Product Scope:
Cradle to gate

Transportation Distance:
By truck: 172 km

End-of-Life Scope:
100% Landfilled (inert waste)

LCI Source:
DE: Gypsum plaster board (Moisture resistant) (EN15804 A1-A3) ts (2017)
US: Fiberglass Duct Board NAIMA (2007)

Fluid applied elastomeric air barrier **61.8 kg**

Used in the following Revit families:
X0B8A - 8" CMU - 2" Mineral Wool - Air Barrier - Brick 30.9 kg (40 yrs)
X0B8A - 8" CMU - 2" Rigid - Air Barrier - Brick 30.9 kg (40 yrs)

Used in the following Tally entries:
Fluid applied elastomeric air barrier

Description:
Water-based asphalt emulsion with SBS polymers

Life Cycle Inventory:
35% Naphtha
50% Bitumen
10% SBR
5% Silica

Product Scope:
Cradle to gate for materials only, neglects manufacturing requirements

Transportation Distance:
By truck: 172 km

End-of-Life Scope:
100% Landfilled (plastic waste)

LCI Source:
US: Styrene-butadiene rubber (SBR) ts (2017)
US: Naphtha at refinery ts (2014)
US: Bitumen at refinery ts (2014)
US: Silica sand (flour) ts (2017)
US: Electricity grid mix ts (2014)

BRENT ES
Design option comparison

9/18/2020

LCI Data (continued)

Fluoropolymer coating, metal stock **12.0 kg**
Used in the following Revit families:
X0B8A - 8" CMU - 2" Spray - ACM 6.0 kg (30 yrs)
X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - ACM 6.0 kg (30 yrs)

Used in the following Tally entries:
Aluminum faced composite wall panel (ACM)

Description:
Standard fluoropolymer coating for metals. This entry is used as a part of the larger MCA EPD for Roll Formed Steel Panels (EPD ID 13CA27321.101.1).

Life Cycle Inventory:
100% Fluoropolymer coating

Product Scope:
Cradle to gate, including application

Transportation Distance:
N/A

End-of-Life Scope:
100% Landfilled (inert waste)

LCI Source:
US: Coil coating MCA (2010)
US: Electricity grid mix ts (2014)
US: Thermal energy from natural gas ts (2014)

Galvanized steel support **771.1 kg**
Used in the following Revit families:
X0B8A - 8" CMU - 2" Spray - TAKTL 385.6 kg (50 yrs)
X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - TAKTL 385.6 kg (50 yrs)

Used in the following Tally entries:
Glass fiber reinforced concrete (GFRC) panel

Description:
Hot dipped galvanized steel profile, for use with cladding systems.

Life Cycle Inventory:
100% Steel, hot dip galvanized

Product Scope:
Cradle to gate for deck only.

Transportation Distance:
By truck: 431 km

End-of-Life Scope:
98% Recovered
2% Landfilled (inert material)

Module D Scope:
Product has 44% scrap input while remainder is processed and credited as avoided burden

LCI Source:
RNA: Steel hot dip galvanized worldsteel (2007)
GLO: Steel sheet stamping and bending (5% loss) ts (2014)
US: Electricity grid mix ts (2014)
US: Lubricants at refinery ts (2014)
GLO: Compressed air 7 bar (medium power consumption) ts (2014)
US: Metal roll forming M CA (2010)
GLO: Value of scrap worldsteel (2014)

GFRC **1,356.8 kg**
Used in the following Revit families:
X0B8A - 8" CMU - 2" Spray - TAKTL 678.4 kg (50 yrs)
X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - TAKTL 678.4 kg (50 yrs)

Used in the following Tally entries:
Glass fiber reinforced concrete (GFRC) panel

Description:
Glass fiber reinforced concrete (GFRC), applied manually. Appropriate for exterior facade panels and precast elements.

Life Cycle Inventory:
12% Cement
5% Glass fibers
39% Gravel
38% Sand
7% Water

Product Scope:
Cradle to gate, excludes mortar
Anchors, ties, and metal accessories outside of scope (<1% mass)

Transportation Distance:
By truck: 24 km

End-of-Life Scope:
55% Recycled into coarse aggregate
45% Landfilled (inert material)

Module D Scope:
Avoided burden credit for coarse aggregate, includes grinding energy

LCI Source:
US: Portland cement PCA/ts (2014)
DE: Gravel (Grain size 2/32) (EN15804 A1-A3) ts (2017)
US: Tap water from groundwater ts (2017)
US: Silica sand (Excavation and processing) ts (2017)
US: Glass fibres ts (2017)

Glazing, double, insulated (air) **358.9 kg**
Used in the following Revit families:
System Panel 358.9 kg (40 yrs)

Used in the following Tally entries:
Glazing, double pane IGU

Description:
Glazing, double, insulated (air filled), 1/8" (4 mm) float glass clear, inclusive of sealant, and spacers

Life Cycle Inventory:
Double-pane glass IGU (Air filled, with spacer and sealant)

Product Scope:
Cradle to gate

Transportation Distance:
By truck: 940 km

End-of-Life Scope:
100% Landfilled (inert waste)

LCI Source:
DE: Double glazing unit ts (2017), modified to exclude coating and argon

Lime mortar (Mortar type K) **1,541.4 kg**
Used in the following Revit families:
X0B8A - 8" CMU - 2" Mineral Wool - Air Barrier - Brick 319.2 kg (50 yrs)
X0B8A - 8" CMU - 2" Rigid - Air Barrier - Brick 319.2 kg (50 yrs)
X0B8A - 8" CMU - 2" Spray - ACM 139.2 kg (50 yrs)
X0B8A - 8" CMU - 2" Spray - Brick 319.2 kg (50 yrs)
X0B8A - 8" CMU - 2" Spray - TAKTL 139.2 kg (50 yrs)
X0B8A - 8" CMU - 3.5 EPS EIFS 125.3 kg (50 yrs)
X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - BRICK 180.0 kg (50 yrs)

Used in the following Tally entries:
Brick
Hollow-core CMU

Description:
Lime mortar, traditionally used for historic masonry.

Life Cycle Inventory:
20-65% Sand
40-70% Limestone
5-15% Hydrated lime
7-15% Cement

Product Scope:
Cradle to gate

Transportation Distance:
By truck: 172 km

End-of-Life Scope:
55% Recycled into coarse aggregate
45% Landfilled (inert material)

Module D Scope:
Avoided burden credit for coarse aggregate, includes grinding energy

LCI Source:
DE: Light plaster (lime-cement) ts (2017)

BRENT ES
Design option comparison

9/18/2020

LCI Data (continued)

Mineral wool, low density, NAIMA - EPD **28.3 kg**
Used in the following Revit families:
X0B8A - 8" CMU - 2" Mineral Wool - Air Barrier - Brick 28.3 kg (50 yrs)

Used in the following Tally entries:
Mineral wool, board, generic

Description:
Rockwool (mineral wool) board
light density. Industry-wide EPD from the North America Insulation Manufacturers Association. EPD representative of conditions in North America.

Life Cycle Inventory:
For information and quantities, see EPD

Product Scope:
Cradle to gate

Transportation Distance:
By truck: 172 km

End-of-Life Scope:
100% Landfilled (inert waste)

LCI Source:
US: Rock board insulation (light density) NAIMA (2007)

EPD Source:
4786060412.102.1

EPD Designation Holder:
North American Insulation Manufacturer's Association (NAIMA)

EPD Program Operator:
UL Environment

EPD Expiration:
11/8/2018

Paint, interior acrylic latex **193.8 kg**
Used in the following Revit families:
X0B8A - 8" CMU - 2" Mineral Wool - Air Barrier - Brick 21.8 kg (7 yrs)
X0B8A - 8" CMU - 2" Rigid - Air Barrier - Brick 21.8 kg (7 yrs)
X0B8A - 8" CMU - 2" Spray - ACM 21.8 kg (7 yrs)
X0B8A - 8" CMU - 2" Spray - Brick 21.8 kg (7 yrs)
X0B8A - 8" CMU - 2" Spray - TAKTL 21.8 kg (7 yrs)
X0B8A - 8" CMU - 3.5 EPS EIFS 19.6 kg (7 yrs)
X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - ACM 21.8 kg (7 yrs)
X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - BRICK 21.8 kg (7 yrs)
X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - TAKTL 21.8 kg (7 yrs)

Used in the following Tally entries:
Paint
Wall board, gypsum

Description:
Acrylic-based paint for interior applications

Life Cycle Inventory:
21% Binding agent
35% Pigments and fillers
42% Water
2% Organic solvents

Product Scope:
Cradle to gate, including emissions during application

Transportation Distance:
By truck: 642 km

End-of-Life Scope:
100% to landfill (plastic waste)

LCI Source:
DE: Application paint emulsion (building, interior, white, wear resistant) ts (2017)

PIR rigid foam insulation, wall, R=14.6, PIMA - EPD **13.8 kg**
Used in the following Revit families:
X0B8A - 8" CMU - 2" Rigid - Air Barrier - Brick 13.8 kg (50 yrs)

Used in the following Tally entries:
Polyisocyanurate (PIR), board

Description:
Polyisocyanurate rigid foam wall insulation with aluminum foil over kraft paper facers, R-value of 14.6, 2.25" thickness (57.2 mm). Industry-wide EPD from the Polyisocyanurate Insulation Manufacturers Association.

Life Cycle Inventory:
For information and quantities, see EPD

Product Scope:
Cradle to gate

Transportation Distance:
By truck: 250 km

End-of-Life Scope:
100% Landfilled (plastic waste)

LCI Source:
RNA: Polyisocyanurate rigid foam board wall insulation, R=14.6 (A1-A3) ts-EPD (2013)

EPD Source:
EPD10042

EPD Designation Holder:
Polyisocyanurate Insulation Manufacturers Association

EPD Program Operator:
NSF International

EPD Expiration:
2/6/2020

Spray polyurethane foam, closed cell (HFO blowing agent), SPFA - EPD **113.3 kg**
Used in the following Revit families:
X0B8A - 8" CMU - 2" Spray - ACM 18.9 kg (50 yrs)
X0B8A - 8" CMU - 2" Spray - Brick 18.9 kg (50 yrs)
X0B8A - 8" CMU - 2" Spray - TAKTL 18.9 kg (50 yrs)
X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - ACM 18.9 kg (50 yrs)
X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - BRICK 18.9 kg (50 yrs)
X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - TAKTL 18.9 kg (50 yrs)

Used in the following Tally entries:
Closed cell, polyurethane foam, spray-applied

Description:
Two-component polyurethane mixture insulation spray applied at installation site. Closed-cell, or medium density foam, (ccSPF) provides a water-resistant insulation, air-sealing, water vapor control and delivers added structural performance to the building envelope. HFO blowing agent is used. R Value: 6.2 (ft^2hr°F/Btu)/in

Life Cycle Inventory:
For information and quantities, see EPD

Product Scope:
Cradle to gate, includes emission of blowing agent during use (24% of total blowing agent)

Transportation Distance:
By truck: 1683 km

End-of-Life Scope:
100% landfilled (plastic), including emission of blowing agent (16% of total blowing agent
50% of blowing agent remains in product after disposal)

Module D Scope:
Energy recovered from landfilling of packaging waste

LCI Source:
EPD (US), SPFA (2018)

EPD Source:
ASTM-EPD085

EPD Designation Holder:
Spray Polyurethane Foam Alliance

EPD Program Operator:
ASTM International

EPD Expiration:
10/29/2023

LCI Data (continued)

Steel, reinforcing rod **209.3 kg**

Used in the following Revit families:

X0B8A - 8" CMU - 2" Mineral Wool - Air Barrier - Brick	35.5 kg (50 yrs)
X0B8A - 8" CMU - 2" Rigid - Air Barrier - Brick	35.5 kg (50 yrs)
X0B8A - 8" CMU - 2" Spray - ACM	35.5 kg (50 yrs)
X0B8A - 8" CMU - 2" Spray - Brick	35.5 kg (50 yrs)
X0B8A - 8" CMU - 2" Spray - TAKTL	35.5 kg (50 yrs)
X0B8A - 8" CMU - 3.5 EPS EIFS	31.9 kg (50 yrs)

Used in the following Tally entries:
Hollow-core CMU

Description:
Common unfinished tempered steel rod suitable for structural reinforcement (rebar)

Life Cycle Inventory:
100% Steel rebar

Product Scope:
Cradle to gate

Transportation Distance:
By truck: 431 km

End-of-Life Scope:
70% Recovered
30% Landfilled (inert material)

Module D Scope:
Product has a 16.4% scrap input while remainder is processed and credited as avoided burden.

LCI Source:
GLO: Steel rebar worldsteel (2014)

Stucco, synthetic **11.4 kg**

Used in the following Revit families:

X0B8A - 8" CMU - 3.5 EPS EIFS	11.4 kg (30 yrs)

Used in the following Tally entries:
Exterior insulation and finish system (EIFS)

Description:
Acrylic latex stucco layer, typically applied over a PVC lath. Base stucco layer with a default thickness of 3/8" (9.5 mm).

Life Cycle Inventory:
90% Acrylic resin
10% Quartz sand
2.2% NMVOC emissions during application

Product Scope:
Cradle to gate, including emissions during application

Transportation Distance:
By truck: 642 km

End-of-Life Scope:
97.8% Solids landfilled (plastic waste)

LCI Source:
DE: Acrylate resin (solvent systems) PE (2015)
US: Silica sand (excavation and processing) ts (2017)

Un-coated cold-formed steel framing products, ClarkDietrich - EPD **85.2 kg**

Used in the following Revit families:

X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - ACM	28.4 kg (50 yrs)
X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - BRICK	28.4 kg (50 yrs)
X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - TAKTL	28.4 kg (50 yrs)

Used in the following Tally entries:
Steel, C-stud metal framing

Description:
Bare steel framing products by ClarkDietrich. Thicknesses in the range of 0.0120 inches to 0.1180 inches. Appropriate for use as interior framing, interior finishing trims and accessories, exterior framing, floor framing, clips/connectors, expanded metal lath, plaster trim and accessories. EPD representative of conditions in the US.

Life Cycle Inventory:
For information and quantities, see EPD

Product Scope:
Cradle-to-gate

Transportation Distance:
By truck: 431 km

End-of-Life Scope:
98% Recovered
2% Landfilled (inert material)

Module D Scope:
Credit given for the avoided burden associated with recovered material

LCI Source:
EPD (US), ClarkDietrich Building Systems (2016)

EPD Source:
EPD10056

EPD Designation Holder:
ClarkDietrich Building Systems

EPD Program Operator:
NSF International

EPD Expiration:
6/30/2020

Wall board, gypsum, moisture- and mold-resistant **669.0 kg**

Used in the following Revit families:

X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - ACM	223.0 kg (30 yrs)
X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - BRICK	223.0 kg (30 yrs)
X0M6A - GWB - 6" Stud - Sheathing - 2" Spray - TAKTL	223.0 kg (30 yrs)

Used in the following Tally entries:
Wall board, gypsum

Description:
Moisture- and mold-resistant gypsum board

Life Cycle Inventory:
100% Moisture-resistant gypsum wallboard (Gypsum, Boric acid, Cement, Sodium lignin sulfonate, Glass fibres, Silane, Polyglucose, Perlite, Paper, Casein glue)

Product Scope:
Cradle to gate

Transportation Distance:
By truck: 172 km

End-of-Life Scope:
100% Landfilled (inert waste)

LCI Source:
DE:Gypsum plaster board (Moisture resistant) (EN15804 A1-A3) ts (2017)

XPS insulation, Foamular 250, Owens Corning - EPD **13.2 kg**

Used in the following Revit families:

X0B8A - 8" CMU - 3.5 EPS EIFS	13.2 kg (50 yrs)

Used in the following Tally entries:
Exterior insulation and finish system (EIFS)

Description:
FOAMULAR 250 XPS (polystyrene) insulation board, HFC foaming agent. EPD representative of US manufacturing condition. FOAMULAR insulation board is available with a variety of R-values and compressive strengths. This entry is based on a compressive strength of 25 psi. If the intended R-value is known, use the drop-down menu to designate a specific board thickness.

Note: This temporary entry is sourced directly from third-party verified EPD data and replaces a Tally entry that is undergoing a quality assurance review. This entry developed using data from ecoinvent and modeled in SimaPro but adheres to

Life Cycle Inventory:
For information and quantities, see EPD.

Product Scope:
Cradle to gate.
Note: Product stage expanded to include blowing agent emissions during distribution and installation, and diffusion from product over service life (B1). As these impacts make a significant contribution to GWP they have been included in the product stage.

Transportation Distance:
By truck: 1190 km

End-of-Life Scope:
100% Landfilled (plastic waste), includes blowing agent emissions released during disposal

LCI Data (continued)

LCI Source:
US: Extruded polystyrene (XPS) insulation board, FOAMULAR - Owens Corning EPD (2018), modeled with Simapro 8, source for secondary data is ecoinvent 3.4

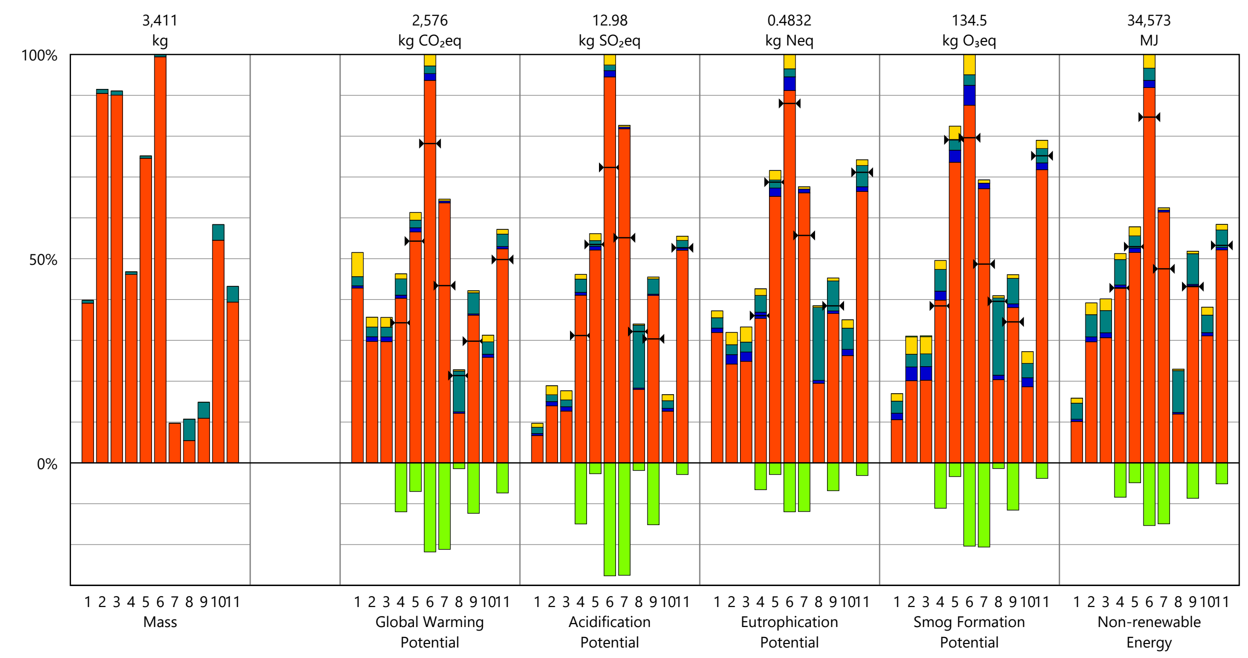
EPD Source:
4788721182.101.1

EPD Designation Holder:
Owens Corning

EPD Program Operator:
UL Environment

EPD Expiration:
1/1/2024

Results per Life Cycle Stage



Legend

Net value (impacts + credits)

Design Options

Option 1 - CMU - EIFS
Option 2 - CMU - Mineral Wool - Brick
Option 3 - CMU - Polyiso - Brick
Option 4 - CMU - Spray - ACM Panel
Option 5 - CMU - Spray - TAKTL
Option 6 - CMU - Sprayfoam - Brick (primary)
Option 7 - Curtain Wall
Option 8 - Storefront
Option 9 - Stud - Spray - ACM
Option 10 - Stud - Spray - Brick
Option 11 - Stud - Spray - TAKTL

Life Cycle Stages

Product [A1-A3]
Transportation [A4]
Maintenance and Replacement [B2-B5]
End of Life [C2-C4]
Module D [D]

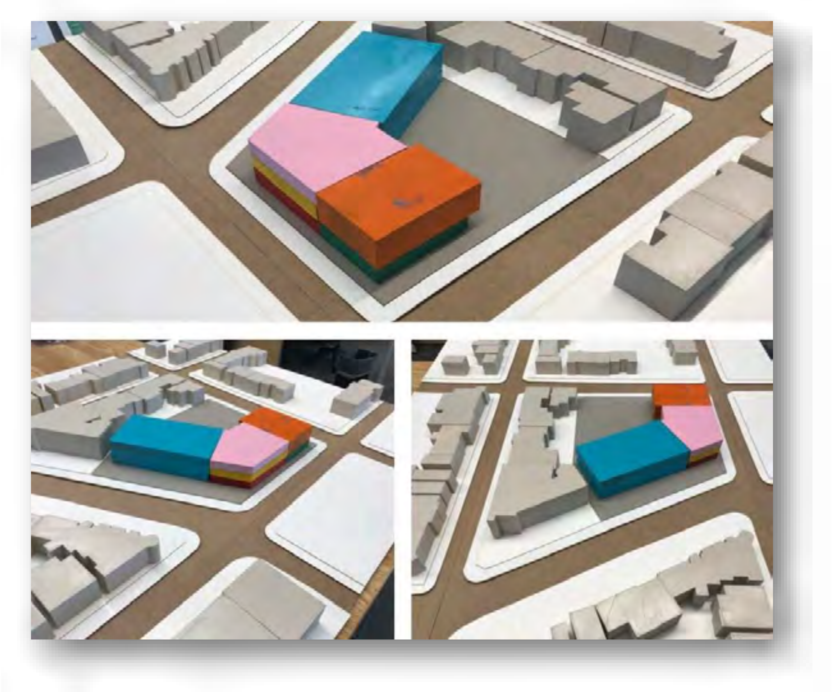
NZE Strategies Estimate

Hanscomb Consulting

Brent Elementary School
District of Columbia Public Schools

Washington, DC

NetZero Study Estimates



Moya Design Partners / Hord Coplan Macht
555 12th Street NW, Suite 620
Washington, DC 20004

Hanscomb Consulting, Inc.
225 Reinekers Lane, Suite 200
Alexandria, VA 22314

September 21, 2020

www.HanscombConsult.com

Brent Elementary School
District of Columbia Public Schools

NetZero Study

21-Sep-20

Summary of Estimates

Item Description	Total
Estimate - Iteration #1	
Baseline - 40% Window/Wall ratio	$5,548,978
Estimate - Iteration #2	
35% Window/Wall ratio in lieu of Baseline	($37,493)
Estimate - Iteration #3	
35% Window/Wall ratio; North 60% in lieu of Baseline	$0
Estimate - Iteration #4	
35% Window/Wall ratio; North 70% in lieu of Baseline	$14,997
Estimate - Iteration #5	
HVAC - Watercooled VRF System in lieu of Baseline VAV System	$5,865,695

Brent Elementary School
District of Columbia Public Schools

NetZero Study

Estimate - Iteration #1

Item Description	Quantity	Unit	Rate	Total
Baseline - 40% Window/Wall ratio				
Windows - 40%	17,079	SF	$80.00	$1,366,310
Walls - 60%	25,618	SF	$70.00	$1,793,282
Sub-Total				$3,159,593
Markups (as per Concept Estimate dated 3/9/2019)			75.62%	$2,389,385
Total				$5,548,978

Brent Elementary School
District of Columbia Public Schools

NetZero Study

Hanscomb Consulting

Estimate - Iteration #2

Item Description	Quantity	Unit	Rate	Total
35% Window/Wall ratio				
DEDUCT BASELINE:				
Windows - 40%	17,079	SF	$80.00	$1,366,310
Walls - 60%	25,618	SF	$70.00	$1,793,282
Sub-Total				($3,159,593)
ADD:				
Windows - 35%	14,944	SF	$80.00	$1,195,522
Walls - 65%	27,753	SF	$70.00	$1,942,723
Sub-Total				$3,138,244
Sub-Total				($21,349)
Markups (as per Concept Estimate dated 3/9/2019)			75.62%	($16,144)
Total				($37,493)

ESTIMATE #2

Brent Elementary School
District of Columbia Public Schools

NetZero Study

Hanscomb Consulting

Estimate - Iteration #3

Item Description	Quantity	Unit	Rate	Total
35% Window/Wall ratio; North 60%				
DEDUCT BASELINE:				
Windows - 40%	17,079	SF	$80.00	$1,366,310
Walls - 60%	25,618	SF	$70.00	$1,793,282
Sub-Total				($3,159,593)
ADD:				
Windows S, E & W - 35%	11,955	SF	$80.00	$956,417
Walls S, E & W - 65%	22,203	SF	$70.00	$1,554,178
Windows, North - 60%	5,124	SF	$80.00	$409,893
Walls, N - 40%	3,416	SF	$70.00	$239,104
Sub-Total				$3,159,593
Sub-Total				$0
Markups (as per Concept Estimate dated 3/9/2019)			75.62%	$0
Total				$0

ESTIMATE #3

Brent Elementary School
District of Columbia Public Schools

NetZero Study

Estimate - Iteration #4

Item Description	Quantity	Unit	Rate	Total
35% Window/Wall ratio; North 70%				
DEDUCT BASELINE:				
Windows - 40%	17,079	SF	$80.00	$1,366,310
Walls - 60%	25,618	SF	$70.00	$1,793,282
Sub-Total				($3,159,593)
ADD:				
Windows S, E & W - 35%	11,955	SF	$80.00	$956,417
Walls S, E & W - 65%	22,203	SF	$70.00	$1,554,178
Windows, North - 70%	5,978	SF	$80.00	$478,209
Walls, N - 30%	2,562	SF	$70.00	$179,328
Sub-Total				$3,168,132
Sub-Total				$8,539
Markups (as per Concept Estimate dated 3/9/2019)			75.62%	$6,458
Total				$14,997

Brent Elementary School
District of Columbia Public Schools

NetZero Study

Estimate - Iteration #5

Item Description	Quantity	Unit	Rate	Total
HVAC - Watercooled VRF System				
DEDUCT BASELINE:				
Packaged VAV System with Reheat				
Phase 1				
D3010 Energy Supply				
Temporary pacakged rooftop unit - 30 tons	1	EA	$45,000.00	$45,000
D3040 Distribution Systems				
Ductwork smacna standards	12,142	GSF	$5.25	$63,746
Registers, grilles, & diffusers	12,142	GSF	$2.00	$24,284
Misc. volume dampers, fire dampers, motorized dampers.	1	LS	$2,500.00	$2,500
Fiberglass duct insulation	12,142	GSF	$3.00	$36,426
D3060 Controls & Instrumentation				
Stand alone thermostat for rooftop unit	1	EA	$1,000.00	$1,000
D3080 Systems Testing & Balancing				
Certified air balance	1	LS	$3,000.00	$3,000
Start up, test, & check	16	HRS	$125.00	$2,000
Permit & inspections	1	LS	$6,000.00	$6,000
D3090 Other HVAC Systems & Equipment				
Crane to rig rooftop unit in place	1	EA	$10,500.00	$10,500
Phase 2				
D3010 Energy Supply				
100% dedicated outside air unit with energy recovery wheel (assume 100 cfm of outside air per 600 square feet of space)	14,500	CFM	$8.00	$116,000
D3020 Heat Generating Systems				
4'x10' Solar thermal collection panels (assume quanity)	750	EA	$2,250.00	$1,687,500
Hot water storage tank, heat exchanger, expansion tank, controllers , valves & specailties.	1	LS	$25,000.00	$25,000
Radiant floor heating system using pex piping with crimped joints (includes; zone control valves, zone thermostats, zone manifolds/header, flooring membrane, & circulating pump)	89,330	GSF	$12.50	$1,116,625
Heating water piping (sch. 40 black steel)	89,330	GSF	$3.15	$281,390
Fiberglass pipe insulation	89,330	GSF	$1.75	$156,328
Glycol fill 40/60 mixture for solar thermal system	1	EA	$5,000.00	$5,000

Brent Elementary School
District of Columbia Public Schools

NetZero Study

Estimate - Iteration #5

Item Description	Quantity	Unit	Rate	Total
D3030 Cooling Generating Systems (Packaged VAV with reheat)				
Packaged water cooled VAV Unit- 30,000 cfm	3	EA	$275,000.00	$825,000
VAV Boxes with reheat coils	119	EA	$2,500.00	$297,767
Cooling tower with centrifugal pumps (allowance, assume 300 tons)	1	EA	$150,000.00	$150,000
Condenser water piping to absorption chiller (allowance, assume sch. 40 black steel grooved with mechanical fittings)	200	LF	$200.00	$40,000
Absorbtion chiller (assume 300 tons, allowance)	1	EA	$450,000.00	$450,000
Centrifugal pump for chilled water system with VFD	1	EA	$25,000.00	$25,000
Centrifugal pump for condenser water system with VFD	1	EA	$25,000.00	$25,000
Cold water storage tank (allowance, assume 2,000 gal or less)	1	EA	$35,000.00	$35,000
Plate to frame heat exchanger	1	EA	$60,000.00	$60,000
Chilled water piping (sch. 40 black steel)	89,330	GSF	$3.15	$281,390
Fiberglass insulation for chilled water piping	89,330	GSF	$1.75	$156,328
Fan coil units with valve kits, heating & chilled water coils (assume 1,400 cfm per fcu)	60	EA	$3,500.00	$210,000
D3040 Distribution Systems				
Ductwork smacna standards	89,330	GSF	$12.00	$1,071,960
Registers, grilles, & diffusers	89,330	GSF	$3.00	$267,990
Misc. volume dampers, fire dampers, motorized dampers.	1	LS	$75,000.00	$75,000
Fiberglass duct insulation	89,330	GSF	$3.00	$267,990
Kitchen HVAC system (make up air unit, grease exhaust fan, grease exhaust duct, dish washer duct, dish washer hood & fan)	1	LS	$67,200.00	$67,200
D3060 Controls & Instrumentation				
Building automation system (includes; software, start up, control devices & laptop)	89,330	GSF	$7.50	$669,975
D3080 Systems Testing & Balancing				
Certified air & water balance	1	LS	$25,000.00	$25,000
Start up, test, & check	180	HRS	$125.00	$22,500
Commissioning assistance	180	HRS	$125.00	$22,500
D3090 Other HVAC Systems & Equipment				
Crane for rigging HVAC equipment	1	EA	$50,000.00	$50,000
Permit & inspections	1	EA	$65,000.00	$65,000
Demolish (1) rooftop unit from phase-1 (includes crane)	1	EA	$11,700.00	$11,700
Sub-Total				($8,754,596)

ESTIMATE #5 8 of 11

Brent Elementary School
District of Columbia Public Schools

NetZero Study

Estimate - Iteration #5

Item Description	Quantity	Unit	Rate	Total
ADD:				
Watercooled VRF System-Geothermal System				
Phase 1				
D3010 Energy Supply				
Temporary pacakged rooftop unit - 30 tons	1	EA	$45,000.00	$45,000
D3040 Distribution Systems				
Ductwork smacna standards	12,142	GSF	$5.25	$63,746
Registers, grilles, & diffusers	12,142	GSF	$2.00	$24,284
Misc. volume dampers, fire dampers, motorized dampers.	1	LS	$2,500.00	$2,500
Fiberglass duct insulation	12,142	GSF	$3.00	$36,426
D3060 Controls & Instrumentation				
Stand alone thermostat for rooftop unit	1	EA	$1,000.00	$1,000
D3080 Systems Testing & Balancing				
Certified air balance	1	LS	$3,000.00	$3,000
Start up, test, & check	16	HRS	$125.00	$2,000
Permit & inspections	1	LS	$6,000.00	$6,000
D3090 Other HVAC Systems & Equipment				
Crane to rig rooftop unit in place	1	EA	$10,500.00	$10,500
Phase 2				
D3010 Energy Supply				
100% dedicated outside air unit with energy recovery wheel (assume 100 cfm of outside air per 600 square feet of space)	14,500	CFM	$8.00	$116,000
D3020 Heat Generating Systems				
4'x10' Solar thermal collection panels (assume quanity)	750	EA	$2,250.00	$1,687,500
Hot water storage tank, heat exchanger, expansion tank, controllers , valves & specailties.	1	LS	$25,000.00	$25,000
Radiant floor heating system using pex piping with crimped joints (includes; zone control valves, zone thermostats, zone manifolds/header, flooring membrane, & circulating pump)	89,330	GSF	$12.50	$1,116,625
Heating water piping (sch. 40 black steel)	89,330	GSF	$3.15	$281,390
Fiberglass pipe insulation	89,330	GSF	$1.75	$156,328
Glycol fill 40/60 mixture for solar thermal system	1	EA	$5,000.00	$5,000
D3030 Cooling Generating Systems				
Watercooled 3-pipe heat recovery vrf system	115	TONS	$5,500.00	$632,500
ACR clean and capped refrigerant piping	89,330	GSF	$7.25	$647,643
Closed cell armaflex refrigerant pipe insulation	89,330	GSF	$2.45	$218,859
Nitrogen tanks for brazing refrigerant piping	1	LS	$7,500.00	$7,500
R-410 refrigerant to charge vrf system	1	LS	$10,000.00	$10,000

ESTIMATE #5 9 of 11

Brent Elementary School
District of Columbia Public Schools

NetZero Study

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Estimate - Iteration #5

Item Description	Quantity	Unit	Rate	Total
Geothermal header/manifold	1	LS	$10,000.00	$10,000
Geothermal centrifugal pump with VFD	1	EA	$15,000.00	$15,000
Cooling tower with centrifugal pumps (allowance, assume 200 tons)	1	EA	$75,000.00	$75,000
Condenser water piping to absorption chiller (allowance, assume sch. 40 black steel grooved with mechanical fittings)	200	LF	$125.00	$25,000
Absorbtion chiller (assume 200 tons, allowance)	1	EA	$350,000.00	$350,000
Centrifugal pump for chilled water system with VFD	1	EA	$15,000.00	$15,000
Centrifugal pump for condenser water system with VFD	1	EA	$15,000.00	$15,000
Cold water storage tank (allowance, assume 2,000 gal or less)	1	EA	$35,000.00	$35,000
Plate to frame heat exchanger	1	EA	$60,000.00	$60,000
Chilled water piping (sch. 40 black steel)	89,330	GSF	$3.15	$281,390
Fiberglass insulation for chilled water piping	89,330	GSF	$1.75	$156,328
Fan coil units with valve kits, heating & chilled water coils (assume 1,400 cfm per fcu)	60	EA	$3,500.00	$210,000
Geothermal wells includes backfill (70 wells)	35,000	VLF	$45.00	$1,575,000
Verticle HDPE geothermal piping (fusion weld)	70,000	LF	$34.75	$2,432,500
Geothermal headers (zone control valves in HVAC scope)	1	LS	$20,000.00	$20,000
D3040 Distribution Systems				
Ductwork smacna standards	89,330	GSF	$5.25	$468,983
Registers, grilles, & diffusers	89,330	GSF	$2.00	$178,660
Misc. volume dampers, fire dampers, motorized	1	LS	$30,000.00	$30,000
Fiberglass duct insulation	89,330	GSF	$3.00	$267,990
Kitchen HVAC system (make up air unit, grease exhaust fan, grease exhaust duct, dish washer duct, dish washer hood & fan)	1	LS	$67,200.00	$67,200
D3060 Controls & Instrumentation				
Building automation system (includes; software, start up, control devices & laptop)	89,330	GSF	$6.00	$535,980
D3080 Systems Testing & Balancing				
Certified air & water balance	1	LS	$25,000.00	$25,000
Start up, test, & check	180	HRS	$125.00	$22,500
Commissioning assistance	180	HRS	$125.00	$22,500
D3090 Other HVAC Systems & Equipment				
Crane for rigging HVAC equipment	1	EA	$25,000.00	$25,000
Permit & inspections	1	EA	$65,000.00	$65,000

Brent Elementary School
District of Columbia Public Schools

NetZero Study

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Estimate - Iteration #5

Item Description	Quantity	Unit	Rate	Total
Demolish (1) rooftop unit from phase-1 (includes crane)	1	EA	$11,700.00	$11,700
Sub-Total				$12,094,528
Sub-Total				$3,339,932
Markups (as per Concept Estimate dated 3/9/2019)			75.62%	$2,525,763
Total				$5,865,695

Outputs of Energy Modeling

Option 1

Brent ES - Option-1-Full GSHP DOE-2.3-50h 9/30/2020 14:36:58 BDL RUN 1

REPORT- BEPS Building Energy Performance WEATHER FILE- WASHINGTON, DC

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY MBTU	732.0	0.0	387.0	165.8	175.0	0.0	367.4	264.1	0.0	0.0	0.0	211.7	2303.1
FM1 NATURAL-GAS MBTU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	212.0	0.0	212.0
MBTU	732.0	0.0	387.0	165.8	175.0	0.0	367.4	264.1	0.0	0.0	212.0	211.7	2515.1

TOTAL SITE ENERGY 2515.08 MBTU 28.9 KBTU/SQFT-YR GROSS-AREA 28.9 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 7121.24 MBTU 81.9 KBTU/SQFT-YR GROSS-AREA 81.9 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 0.00
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 0
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 0

NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.

Brent ES - Option-1-Full GSHP DOE-2.3-50h 9/30/2020 14:36:58 BDL RUN 1

REPORT- ES-D Energy Cost Summary WEATHER FILE- WASHINGTON, DC

UTILITY-RATE	RESOURCE	METERS	METERED ENERGY UNITS/YR	TOTAL CHARGE ($)	VIRTUAL RATE ($/UNIT)	RATE USED ALL YEAR?
Custom Elec Rate	ELECTRICITY	EM1	674802. KWH	81786.	0.1212	YES
Custom Gas Rate	NATURAL-GAS	FM1	2120. THERM	2417.	1.1400	YES
				84203.		

ENERGY COST/GROSS BLDG AREA: 0.97
ENERGY COST/NET BLDG AREA: 0.97

Option 2

Brent ES - Option-2-Hybrid GSHP DOE-2.3-50h 9/30/2020 14:39:18 BDL RUN 1

REPORT- BEPS Building Energy Performance WEATHER FILE- WASHINGTON, DC

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY MBTU	732.0	0.0	387.0	166.2	181.2	0.0	327.7	235.4	0.0	0.0	0.0	211.7	2241.2
FM1 NATURAL-GAS MBTU	0.0	0.0	0.0	15.6	0.0	0.0	0.0	0.0	0.0	0.0	212.0	0.0	227.6
MBTU	732.0	0.0	387.0	181.8	181.2	0.0	327.7	235.4	0.0	0.0	212.0	211.7	2468.8

TOTAL SITE ENERGY 2468.77 MBTU 28.4 KBTU/SQFT-YR GROSS-AREA 28.4 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 6951.15 MBTU 79.9 KBTU/SQFT-YR GROSS-AREA 79.9 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 0.75
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 0
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 21

NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.

Brent ES - Option-2-Hybrid GSHP DOE-2.3-50h 9/30/2020 14:39:18 BDL RUN 1

REPORT- ES-D Energy Cost Summary WEATHER FILE- WASHINGTON, DC

UTILITY-RATE	RESOURCE	METERS	METERED ENERGY UNITS/YR	TOTAL CHARGE ($)	VIRTUAL RATE ($/UNIT)	RATE USED ALL YEAR?
Custom Elec Rate	ELECTRICITY	EM1	656668. KWH	79588.	0.1212	YES
Custom Gas Rate	NATURAL-GAS	FM1	2276. THERM	2594.	1.1400	YES
				82183.		

ENERGY COST/GROSS BLDG AREA: 0.94
ENERGY COST/NET BLDG AREA: 0.94

Option 3

Brent -Option-3-VRF DOE-2.3-50h 9/30/2020 14:49:35 BDL RUN 1

REPORT- BEPS Building Energy Performance WEATHER FILE- WASHINGTON, DC

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY													
MBTU	732.0	0.0	387.0	451.1	269.7	0.0	42.3	124.3	0.0	0.0	0.0	211.7	2218.1
FM1 NATURAL-GAS													
MBTU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	212.0	0.0	212.0
MBTU	732.0	0.0	387.0	451.1	269.7	0.0	42.3	124.3	0.0	0.0	212.0	211.7	2430.1

TOTAL SITE ENERGY 2430.12 MBTU 27.9 KBTU/SQFT-YR GROSS-AREA 27.9 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 6866.40 MBTU 78.9 KBTU/SQFT-YR GROSS-AREA 78.9 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 59.94
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 0
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 1670

NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.

Brent -Option-3-VRF DOE-2.3-50h 9/30/2020 14:49:35 BDL RUN 1

REPORT- ES-D Energy Cost Summary WEATHER FILE- WASHINGTON, DC

UTILITY-RATE	RESOURCE	METERS	METERED ENERGY UNITS/YR	TOTAL CHARGE ($)	VIRTUAL RATE ($/UNIT)	RATE USED ALL YEAR?
Custom Elec Rate	ELECTRICITY	EM1	649914. KWH	78770.	0.1212	YES
Custom Gas Rate	NATURAL-GAS	FM1	2120. THERM	2417.	1.1400	YES
				81186.		

ENERGY COST/GROSS BLDG AREA: 0.93
ENERGY COST/NET BLDG AREA: 0.93

Option 4

Brent ES - Baseline DOE-2.3-50h 9/30/2020 14:32:34 BDL RUN 1

REPORT- BEPS Building Energy Performance WEATHER FILE- WASHINGTON, DC

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY													
MBTU	732.0	0.0	387.0	0.0	735.6	0.0	18.7	175.1	0.0	0.0	0.0	211.7	2260.0
FM1 NATURAL-GAS													
MBTU	0.0	0.0	0.0	1902.0	0.0	0.0	0.0	0.0	0.0	0.0	212.1	0.0	2113.9
MBTU	732.0	0.0	387.0	1902.0	735.6	0.0	18.7	175.1	0.0	0.0	212.1	211.7	4373.9

TOTAL SITE ENERGY 4373.90 MBTU 50.3 KBTU/SQFT-YR GROSS-AREA 50.3 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 8893.96 MBTU 102.2 KBTU/SQFT-YR GROSS-AREA 102.2 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 0.07
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 0
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 2

NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.

Brent ES - Baseline DOE-2.3-50h 9/30/2020 14:32:34 BDL RUN 1

REPORT- ES-D Energy Cost Summary WEATHER FILE- WASHINGTON, DC

UTILITY-RATE	RESOURCE	METERS	METERED ENERGY UNITS/YR	TOTAL CHARGE ($)	VIRTUAL RATE ($/UNIT)	RATE USED ALL YEAR?
Custom Elec Rate	ELECTRICITY	EM1	662187. KWH	80257.	0.1212	YES
Custom Gas Rate	NATURAL-GAS	FM1	21139. THERM	24098.	1.1400	YES
				104355.		

ENERGY COST/GROSS BLDG AREA: 1.20
ENERGY COST/NET BLDG AREA: 1.20

Option 5

Brent -Option-5-VRF DOE-2.3-50h 9/11/2020 11:38:40 BDL RUN 1

REPORT- BEPS Building Energy Performance WEATHER FILE- WASHINGTON, DC

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY MBTU	391.9	0.0	387.0	416.8	230.3	0.0	40.2	117.5	0.0	0.0	0.0	56.6	1640.4
FM1 NATURAL-GAS MBTU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	211.8	0.0	211.8
MBTU	391.9	0.0	387.0	416.8	230.3	0.0	40.2	117.5	0.0	0.0	211.8	56.6	1852.2

TOTAL SITE ENERGY 1852.24 MBTU 21.3 KBTU/SQFT-YR GROSS-AREA 21.3 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 5133.07 MBTU 59.0 KBTU/SQFT-YR GROSS-AREA 59.0 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 63.82
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.00
HOURS ANY ZONE ABOVE COOLING THROTTLING RANGE = 0
HOURS ANY ZONE BELOW HEATING THROTTLING RANGE = 1778

NOTE: ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.

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REPORT- ES-D Energy Cost Summary WEATHER FILE- WASHINGTON, DC

UTILITY-RATE	RESOURCE	METERS	METERED ENERGY UNITS/YR	TOTAL CHARGE ($)	VIRTUAL RATE ($/UNIT)	RATE USED ALL YEAR?
Custom Elec Rate	ELECTRICITY	EM1	480641. KWH	58254.	0.1212	YES
Custom Gas Rate	NATURAL-GAS	FM1	2118. THERM	2415.	1.1400	YES
				60668.		

ENERGY COST/GROSS BLDG AREA: 0.70
ENERGY COST/NET BLDG AREA: 0.70

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1275 K St NW Suite 1000 Washington DC 20005
+1 202.816.6692 MOYA / www.moyadesignpartners.com