A METHODOLOGY OF CALCULATING THE CARBON FOOTPRINT OF A BUILDING

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A DESIGN THESIS SUBMITTED TO THE DEPARTMENT OF ARCHITECTURE AND LANDSCAPE ARCHITECTURE OF NORTH DAKOTA STATE UNIVERSITY

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ABSTRACT

ENVIRONMENTALISM AND CONSERVATION ARE TWO THINGS THAT ARE VERY IMPORTANT TO ME. IT IS SO ENJOYABLE TO BE IN A PLACE WHERE SO LITTLE OTHERS HAVE BEEN. WALKING THROUGH THE WOODS WHERE NO HUMAN HAS ADAPTED IS PRECIOUS. ALTHOUGH THESE AREAS ARE PERFECT, THERE MUST ALSO BE SPACE FOR US TO ADAPT AND INHABIT, BUT WE MUST BE MINDFUL OF THE EXISTING ENVIRONMENT WHILE DOING SO.

IT IS WELL KNOWN THAT OUR CLIMATE HAS BEEN SIGNIFICANTLY IMPACTED BY CLIMATE CHANGE. CARBON DIOXIDE EMISSIONS IS THE LEADING DRIVER OF THE GLOBAL CLIMATE CHANGE. IT IS TALKED ABOUT WORLDWIDE HOW WE AS INHABITANTS NEED TO MAKE CHANGES. EVERYONE KNOWS THAT CHANGES NEED TO BE MADE FOR THE SAKE OF OUR ENVIRONMENT.

WHEN IT COMES TO DETERMINING WHO AND WHAT IS RESPONSIBLE FOR PRODUCING EMISSIONS, THEY CAN BE CATEGORIZED BY REGIONS, COUNTRIES AND INDIVIDUALS. WHEN WE REALLY BREAK IT DOWN, IT PANS OUT THAT EACH AND EVERY ONE OF US IS RESPONSIBLE.

IN TODAYS WORLD. EMPTY SPACES ARE BECOMING SCARCE. LOOKING AT THE BUILT ENVIRONMENT, WE AS A SOCIETY TEND TO CONSTANTLY WANT THE MOST NEW AND IMPROVED EVERYTHING.

THESIS PROPOSAL

FIGURE #2

THESIS EXPLANATION

THIS THESIS AIMS TO GIVE DIRECTION TO DESIGNERS TO BECOME AWARE OF CARBON EMISSIONS WITHIN A DESIGN AND HOW MATERIAL CHOICE PLAYS A LARGE ROLE IN A DESIGNS RESPONSIBILITY FOR CARBON EMISSIONS.

PROJECT TYPOLOGY

THE FOCUS OF THIS THESIS IS TO LOOK INTO THE DETAILS OF WHAT IT TAKES TO BUILD A DESIGN. NOT ONLY WILL IT FOCUS ON THE MATERIALS THAT ARE USED WITHIN A DESIGN BUT HOW MUCH EMISSIONS IT TAKES TO MAKE AND TRANSPORT THOSE MATERIALS. IT WILL ALSO PAY CLOSE ATTENTION TO THE METHODS USED TO CONTRUCT A PHYSICAL DESIGN. THEN THE FOCUS WILL BRING LIGHT TO THE LIFE CYCLE OF THE DESIGN. FIGURING OUT HOW MUCH CO2 EMISSIONS ARE PRODUCED DURING THE BUILDING PHASE IS WHERE THIS RESEARCH WILL END. THE DESIGN BEING BUILT IS NOT THE END OF THE ROAD FOR CO2 EMISSIONS. DETERMINING THE LIFE CYCLE OF THE MATERIALS AND ALSO THE DAILY EMISSIONS OF THE FUNCTIONING BUILDING ADD TO THE STRING OF CO2 EMISSIONS.

PROJECT EMPHASIS

ALTHOUGH TACKLING WHERE CARBON EMISSIONS COME FROM, THIS METHODOLOGY AIMS TO FOCUS ON MATERIAL SELECTION AND HOW DIFFERENT BUIDING MATERIALS CAN IMPACT A DESIGNS CARBON EMISSIONS.

PROJECT GOAL

THE GOAL OF THIS THESIS IS TO CREATE A METHODOLOGY FOR CALCULATING THE CARBON FOOTPRINT OF A NEW DESIGN OR EXISTING BUILDING SO THAT A DESIGNER, BUILDER OR USER CAN UNDERSTAND THEIR ROLE IN REDUCING CARBON EMISSIONS.

FIGURE #3

AUDIENCE DESCRIPTION

THE AUDIENCE FOR THIS THESIS METHODOLOGY IS DESIGNERS WITHIN THE AEC (ARCHITECTURE, ENGINEERING & CONSTRUCTION) FIELDS. THIS METHODOLOGY WILL ENCOURAGE THOSE WHO DESIGN WITH SIMILAR SOFTWARE PROGRAMS.

ANYONE WITHIN THE AEC FIELDS CAN LEARN AND UNDERSTAND EFFECTS OF MATERIAL CHOICE AND THEIR CARBON EMISSIONS.

RESEARCH DESIGN PLAN

THIS PROJECT WILL BE ACCOMPLISHED THROUGH THE USE OF A COUPLE DIFFERENT PATHS AND RESOURCE USE. THE TWO MAIN PATHS OF THIS PROJECT RESEARCH ARE:

1. MATERIAL SELECTION BASED ON CARBON EMISSIONS

2. SITE VEGETATION SELECTION BASED ON CARBON SEQUESTRATION RATES

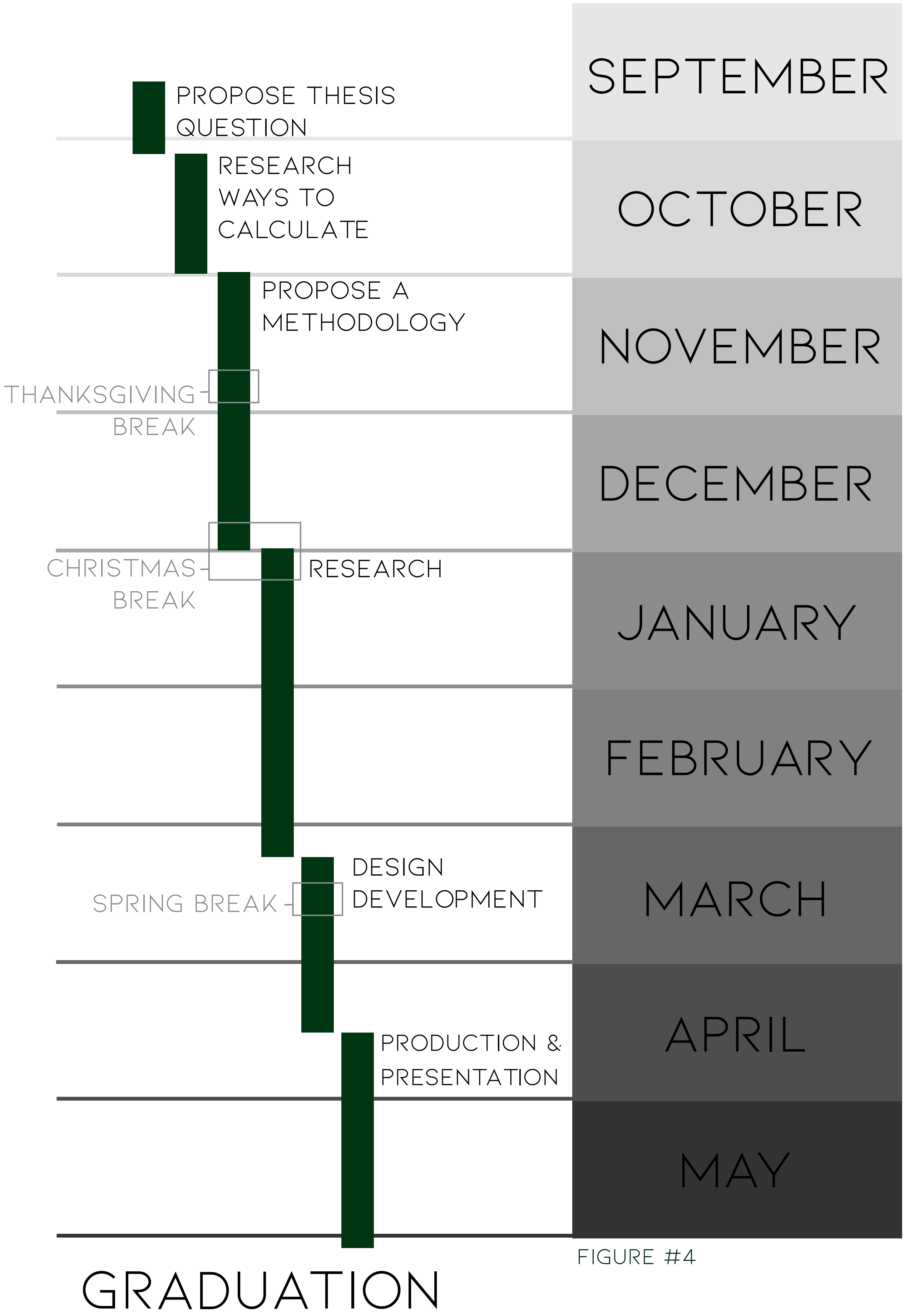

SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
PROPOSE THESIS QUESTION
RESEARCH WAYS TO CALCULATE
PROPOSE A METHODOLOGY
THANKSGIVING BREAK
CHRISTMAS BREAK
RESEARCH
SPRING BREAK
DESIGN DEVELOPMENT
PRODUCTION & PRESENTATION
GRADUATION

FIGURE #4

PROJECT JUSTIFICATION

PROJECT JUSTIFICATION

GREEN HOUSE GAS IS A HUGE CONCERN IN TODAYS WORLD. CARBON EMISSIONS TAKE BLAME FOR THE MAJORITY OF GREEN HOUSE GAS RATES. BUT WHO IS GOING TO TAKE BLAME FOR CARBON EMISSIONS?

THIS IS WHAT LEAD ME TO FOCUS ON UNDERSTAND CARBON EMISSIONS - NOT ONLY IN A GENERAL SENSE BUT TO FOCUS ON THE ARCHITECTURAL FIELD AND HOW WE AS DESIGNERS IMPACT OUR ENVIRONMENT.

I CHOSE TO DIG DEEPER INTO OUR RESPONSIBILTY AS DESIGNERS TO FIGURE OUT HOW I PERSONALLY COULD MAKE AN IMPACT IN MY DAY TO DAY ACTIONS ALONG WITH CREATING A METHOD THAT OTHERS COULD APPLY AND USE IN THEIR PERSONAL WORK.

EVERY INDIVIDUAL NEEDS TO TAKE RESPONSIBILITY FOR THEIR CARBON EMISSIONS BUT TO DO THAT, THEY NEED TO BE ABLE TO UNDERSTAND WHERE CARBON COMES FROM AND HOW IT IS PRODUCED SO THAT THE GREATEST CHANGE CAN BE MADE FOR THE GREATER GOOD OF OUR ENVIRONMENT.

INSPIRATION

AS AN AVID OUTDOORS WOMAN, I THOROUGHLY ENJOY SPENDING AS MUCH OF MY TIME IN NATURE AS POSSIBLE. I LOVE BEING IN A PLACE WHERE NOBODY ELSE IS, A PLACE WHERE IT IS JUST ME AND THE WORLD AROUND ME. ONE OF MY FAVORITE HOBBIES IS BOW HUNTING. BOW HUNTING REQUIRES YOU TO BLEND IN WITH NATURE AND BECOME ONE WITH YOUR SURROUNDINGS. IT IS SUCH A SURREAL AND PEACEFUL ACTIVITY THAT ALLOWS YOU TO BECOME A FLY-ON-THE-WALL SO TO SPEAK. SITTING IN A TREE STAND WATCHING NATURE AROUND YOU DOING WHAT IT DOES IS A THING OF BEAUTY. YOU TRULY GET TO SEE WHAT HAPPENS IN THE CORE OF NATURE.

WITH SUCH LOVE FOR THE BEAUTY OF UNTOUCHED NATURE, I CHOSE TO FOCUS MY THESIS PROJECT AROUND MY STRONG LOVE FOR SUSTAINING NATURE. I WANTED TO FIND A WAY WHERE TWO WORLDS COLLIDE WITHOUT CAUSING NEGATIVE IMPACT.

FIGURE #5

THESIS RESEARCH

THESIS RESULTS

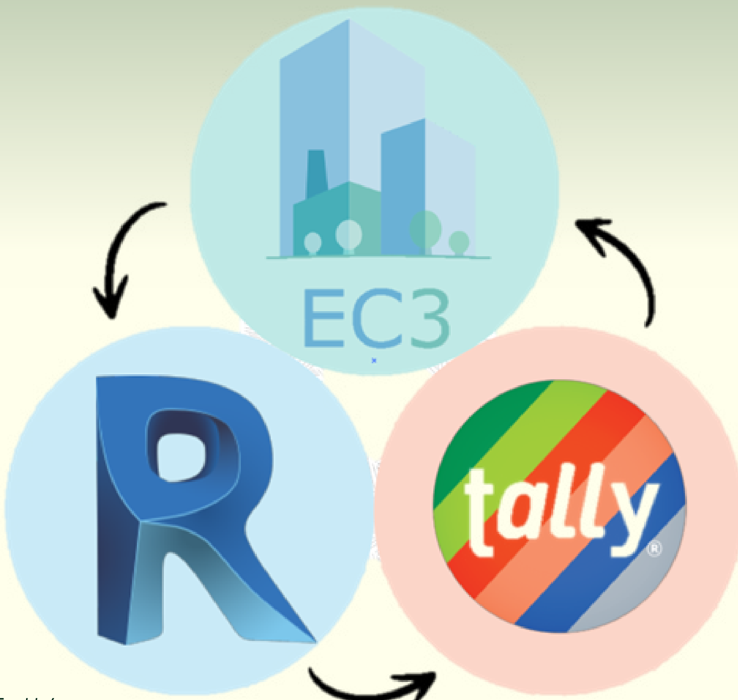


FIGURE #6

THROUGHOUT RESEARCHING, I HAVE FOUND A WAY OF USING MULTIPLE SOFTWARE THAT CAN BE USED TOGETHER TO CALCULATE EXISTING DATA. I HAVE CREATED A YOUTUBE VIDEO THAT ALLOWS ANYONE TO SEE THE PROCESS I USED TO COVERT A REVIT MODEL TO THE EC3 TOOL. I HAVE INCLUDED ALL OF MY SLIDES THAT MAKE UP MY VIDEO. THESE SLIDES CAPTURE THE MAJORITY OF WHAT I HAVE LEARNED WHILE RESEARCHING THE METHODOLOGY OF CALCULATING THE CARBON FOOTPRINT OF A BUILDING.

CASE STUDIES

CARBON IMPACTS OF WOOD PRODUCTS 1

10 STEPS TO REDUCING EMBODIED CARBON 2

BERKELEY GREEN SKILLS CENTRE 3

WESTBOROUGH PRIMARY SCHOOL 4

CARBON IMPACTS OF WOOD PRODUCTS

WHAT IT TAKES TO PRODUCE LUMBER

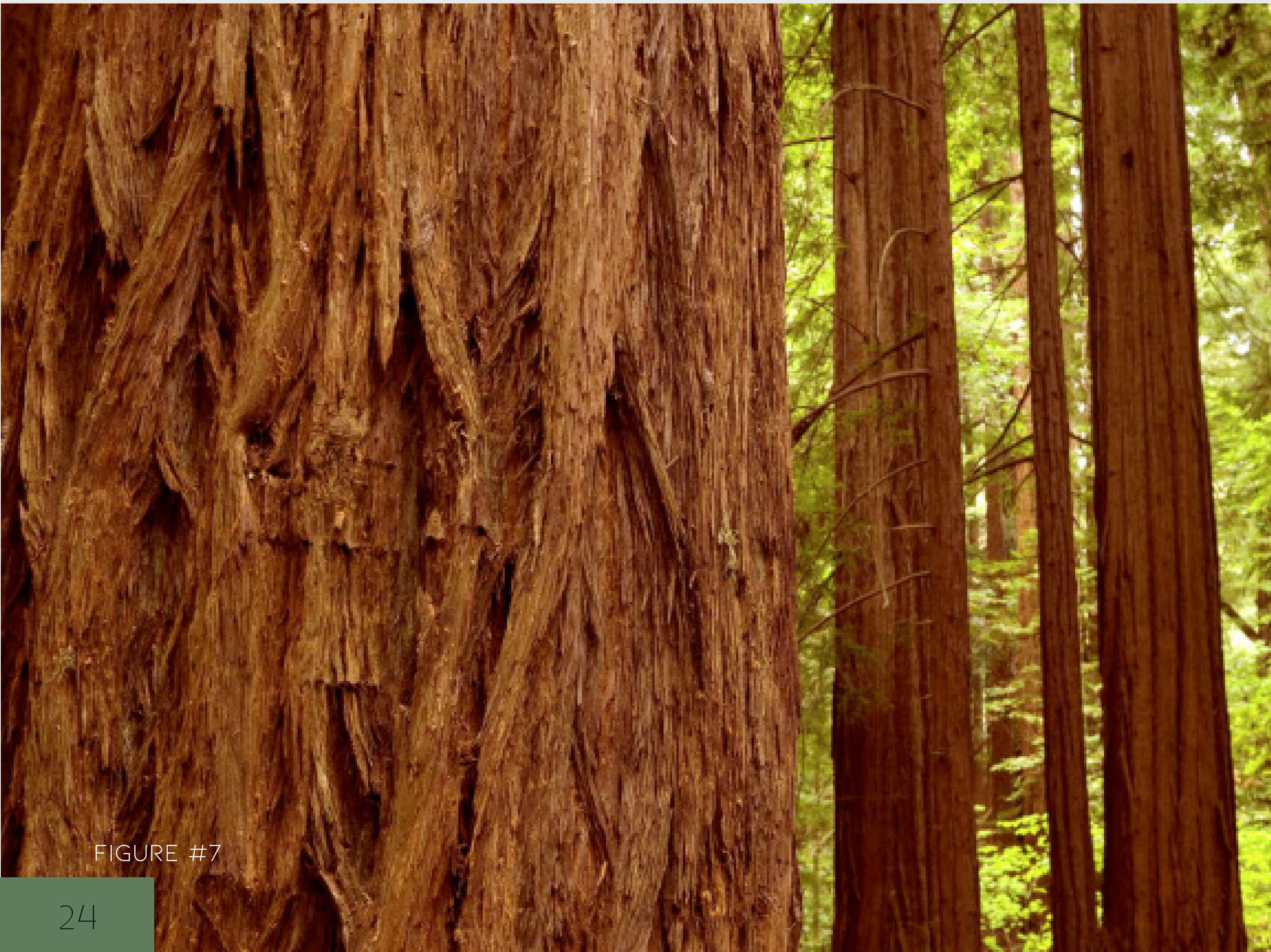


FIGURE #7

Carbon Impacts of Wood Products			A	B	C	D		A-B-C-D = E
Product	Units & Notes		Carbon[1] released during manufacture	Carbon from bio-fuel used in manufacturing (wood energy)	Carbon stored in the wood product	Substitution carbon (fossil carbon emissions avoided by using the wood instead of an alternative)	Alternative	TOTAL CARBON FOOTPRINT (Negative values represent a carbon credit)
Hardwood lumber	One board foot (12"x12"x1")	NE/NC region	0.9	0.6	1.8	2.6	PVC (plastic) molding	-4.2
		Southeast region	1.1	0.8	1.8	2.6		-4.1
Softwood lumber	One 2x4 'stud'	NE/NC region	1.8	1.2	6.6	7.0	steel stud	-13.0
		Southeast region	3.9	3.3	8.4	7.0		-14.9
Hardwood flooring	1 ft²	Solid strip flooring	1.1	0.7	2.1	0.0	vinyl	-1.8
		Engineered wood	1.0	0.5	1.1	-0.1		-0.5
Doors	One door	Solid wood	46.5	29.4	100.4	228.1	steel door	-311.5
Decking	One deck board	ACQ- treated pine	5.2	1.7	16.1	11.9	wood-plastic composite	-24.5
Siding	100 ft²	Western redcedar	37.7	6.0	77.7	20.4	vinyl	-66.3
Wood treated poles	One 45' pole	Pentachlorophenol-treated wood	454.5	430.9	1160.4	1377.1	concrete pole	-1136.8
OSB	One 4' x 8' sheet 3/8"	Southeast region	19.0	10.7	34.7	-	n/a	-26.3
Plywood	One 4' x 8' sheet 3/8"	PNW	5.7	4.1	25.5	-	n/a	-23.9
		Southeast region	10.1	6.5	30.9	-	n/a	-27.3
I-joist	One 16' long, 10" deep joist	PNW	22.8	18.9	63.9	56.4	steel joist	-59.9
		Southeast region	33.0	22.9	80.0	55.0		-70.0

FIGURE #8

THE RELEASE OF CARBON DIOXIDE DURING A PRODUCTS MANUFACTURE AND USE IS OFTEN REFERRED TO AS IT'S "CARBON FOOTPRINT". NATURAL MATERIALS SUCH AS: COAL, OIL, NATURAL GAS AND WOOD ALL CONTAINS SOLID CARBON THAT TURNS INTO CO2 WHEN THE MATERIAL IS BURNED FOR ENERGY. BECAUSE CO2 EMISSIONS HAVE SUCH A BIG ROLE IN CLIMATE CHANGE, THERE IS A DESIRE TO REDUCE THE FOOTPRINT OF PRODUCTS AND CHOOSE PRODUCTS THAT HAVE SMALLER CARBON FOOTPRINTS.

CARBON FOOTPRINT CAN BE CALCULATED BY MEASURING AND CATEGORIZING ALL OF THE ENERGY INPUTS.

WOOD PRODUCT CARBON IMPACT EQUATION

A-B-C-D=E

FIGURE #9

A

MANUFACTURING CARBON

MANUFACTURING USES ENERGY - MOST ENERGY PRODUCTION RESULTS IN CARBON DIOXIDE RELEASE

B

BIO FUEL

WOOD RESIDUES ARE OFTEN BURNED FOR ENERGY DURING THE PRODUCTION OF WOOD PRODUCTS. THESE EMISSIONS CAN BE ABSORBED BY NEIGHBORING TREES AND IS CONSIDERED AS "CARBON NEUTRAL". THIS "BIO-FUEL" USAGE REDUCES THE CARBON FOOTPRINT OF WOOD PRODUCTS.

C

CARBON STORAGE

CO2 IS ABSORBED FROM THE ATMOSPHERE DURING PHOTOSYNTHESIS. THE CO2 IS CONVERTED INTO WOOD. IF THAT TREE ROTS OR BURNS, THE SOLID CARBON IS RELEASED AGAIN INTO THE ATMOSPHERE. AS LONG AS THE TREE IS IN SERVICE, IT STORES CO2 GAS OUT OF THE ATMOSPHERE.

D

SUBSTITUTION

THERE ARE A LOT OF ALTERNATIVES TO WOOD PRODUCTS BUT THESE TEND TO REQUIRE MORE ENERGY TO MANUFACTURE. THEY ARE USUALLY MADE USING ENERGY FROM FOSSIL CARBON. WHEN FOSSIL CARBON ENERGY SOURCES ARE USED, THEY CONTRIBUTE TO THE CARBON FOOTPRINT AS WELL. SO IN SOME CASES, USING NATURAL WOOD IS A WAY OF REDUCING WOODS CARBON FOOTPRINT.

E

TOTAL CARBON FOOTPRINT OR CARBON CREDIT

THE BIO-FUEL (B), CARBON STORAGE (C) AND SUBSTITUTION (D) EFFECTS REDUCE THE CARBON FOOTPRINT OF WOOD PRODUCTS. MOST OF THE TIME THESE EFFECTS TOGETHER ARE ALMOST ALWAYS GREATER THAN THE MANUFACTURING CARBON (A), SO THE OVERALL CARBON EFFECT OF USING WOOD PRODUCTS IS A NEGATIVE CARBON FOOTPRINT.

10 STEPS TO REDUCING EMBODIED CARBON

UPFRONT STEPS ARCHITECTS CAN MAKE

FIGURE #10

FIGURE #11

WE AS ARCHITECTS NEED TO BE VERY MINDFUL OF THE WAY WE DESIGN. THE NEED FOR SUSTAINABILITY IN DESIGN, CONSTRUCTION, AND OPERATION OF BUILDINGS IS A REALITY. A STUDY BY "ENERGY INFORMATION ADMINISTRATION" SHOWED THAT IN 2015, 40% OF THE ENERGY CONSUMED IN THE U.S. WENT DIRECTLY OR INDIRECTLY TO OPERATING BUILDINGS. WHEN YOU ADD EMBODIED CARBON - THE ENERGY EMISSIONS FROM MATERIALS AND CONSTRUCTION - THAT NUMBER GROWS TO ALMOST 50%.

AS ARCHITECTS, WE HAVE THE ABILITY AND RESPONSIBILITY TO PROVIDE SOLUTIONS THAT MINIMIZE THE CLIMATE IMPACT OF THE STRUCTURES WE DESIGN.

10 STEPS

1 REUSE BUILDINGS INSTEAD OF CONSTRUCTING NEW ONES

RENOVATIONS AND REUSE PROJECTS TYPICALLY SAVE BETWEEN 50-70% OF THE EMBODIED CARBON EMISSIONS COMPARED TO CONSTRUCTING A NEW BUILDING. BESIDES, TAKING SOMETHING THAT IS OLD AND POOR-PERFORMING AND CREATING IT INTO SOMETHING BEAUTIFUL AND SUSTAINABLE IS VERY REWARDING.

2 SPECIFY LOW CARBON CONCRETE MIXES

EVEN THOUGH CONCRETE EMISSIONS PER TON ARE NOT RELATIVELY HIGH, ITS WEIGHT AND PREVALENCE USUALLY MAKE CONCRETE THE BIGGEST SOURCE OF EMBODIED CARBON IN ANY PROJECT. WORK TO DESIGN LOWER CARBON CONCRETE MIXES BY USING FLY ASH, SLAG, CALCINED CLAYS OR EVEN LOWER-STRENGTH CONCRETE WHERE FEASIBLE.

3 LIMIT CARBON INTENSIVE MATERIALS

FOR PRODUCTS WITH HIGH CARBON FOOTPRINTS LIKE ALUMINUM, PLASTICS, AND FOAM INSULATION, THOUGHTFUL USE IS ESSENTIAL. EVEN IF A MATERIAL COMPLEMENTS THE AESTHETICS OF THE PROJECT, FIND WAYS TO SUBSTITUTE OR USE IN SMALL AMOUNTS.

4 CHOOSE LOWER CARBON ALTERNATIVES

REALIZE THE OPTIONS. IN MOST CASES, IT IS PROBABLY NOT POSSIBLE TO AVOID CARBON INTENSIVE PRODUCTS LIKE METALS, PLASTICS OR ALUMINUM ALTOGETHER, BUT FINDING MORE NATURAL ALTERNATIVES FOR MOST MATERIALS CAN HELP LOWER THE CARBON COUNT.

5 CHOOSE CARBON SEQUESTERING MATERIALS

USING AGRICULTURAL PRODUCTS THAT SEQUESTER CARBON CAN MAKE A BIG IMPACT ON THE EMBODIED CARBON IN A PROJECT. SOME OPTIONS YOU MIGHT NOT THINK ABOUT RIGHT AWAY WOULD BE STRAW OR HEMP INSULATION, WHICH ARE ANNUALLY RENEWABLE.

10 STEPS

6 REUSE MATERIALS

WHENEVER IT IS POSSIBLE, TRY TO SALVAGE AND EXISTING MATERIALS LIKE STONE, BRICK, METALS, CONCRETE OR WOOD. SALVAGED MATERIALS HAVE A MUCH LOWER EMBODIED CARBON FOOTPRINT BECAUSE THEY ARE NOT BEING "RE"MANUFACTURED. ALSO THESE MATERIALS WOULD PROBABLY REQUIRE LITTLE TO NO TRANSPORTATION.

7 USE HIGH RECYCLED CONTENT MATERIAL

THIS IS VERY IMPORTANT WHEN IT COMES TO METALS. VIRGIN STEEL CAN HAVE AN EMBODIED CARBON FOOTPRINT THAT IS FIVE TIMES GREATER THAN HIGH-RECYCLED CONTENT STEEL.

8 MAXIMIZE STRUCTURAL EFFICIENCY

EMBODIED CARBON IS MOSTLY IN THE STRUCTURE OF THE BUILDING; LOOKING FOR WAYS TO ACHIEVE MAXIMUM STRUCTURAL EFFICIENCY IS KEY. SOME EFFECTIVE METHODS INCLUDE USING OPTIMUM VALUE ENGINEERING WOOD FRAMING, EFFICIENT STRUCTURAL SECTIONS, AND SLABS.

9 USE FEWER FINISH MATERIALS

USING STRUCTURAL MATERIALS AS FINISHES CAN HELP REDUCE EMISSIONS. AN EXAMPLE WOULD BE USING POLISH CONCRETE SLAVS AS FINISHED FLOORING INSTEAD OF CARPET OR VINYL FLOOR PLANKS. UNFINISHED CEILINGS ARE ALSO A GOOD ALTERNATIVE.

10 MINIMIZE WASTE

PARTICULARLY IN WOOD-FRAMED RESIDENTIAL PROJECTS, DESIGNING IN MODULES CAN MINIMIZE WASTE.

BERKELEY GREEN SKILLS CENTRE

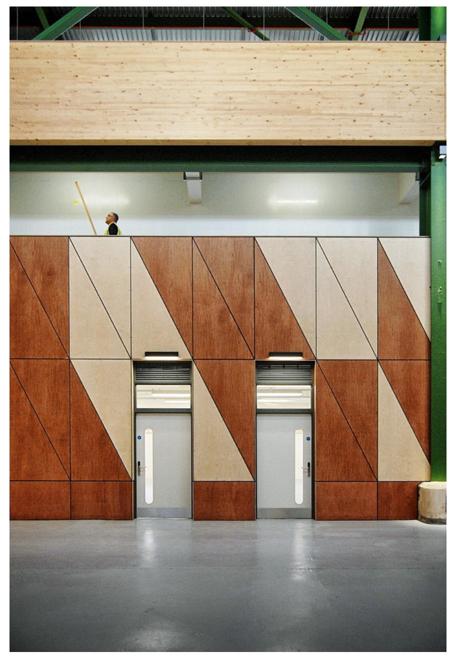
BERKELEY, UNITED KINGDOM

FIGURE #12

FIGURE #13

ARCHITECT	PROJECT YEAR	TYPOLOGY	SQUARE FOOTAGE	LOCATION
HEWITT STUDIOS	2016	UNIVERSITY	48,438 SQ FT	BERKELEY, UK

THIS UNIVERSITY HAS COMPLETED IT'S FIRST PHASE OF REFURBISHMENT OF A FORMER NUCLEAR RESEARCH AND ENGINEERING BUILIDLNG. THE PROJECT PROVIDES THE COLLEGE WITH A FACILITY THAT IS REINVIGORATED, DYNAMIC AND SUSTAINABLE. IT WAS DESIGNED TO BECOME AN EXAMPLE OF REGENERATIVE INVESTMENT AND AN EDUCATIONAL TOOL.



ELEMENTS OF THE BUILDING FABRIC WILL BE USED TO DELIVER SPECIFIC AREAS OF CURRICULUM (E.G. SOLAR PV AND TIMBER CONSTRUCTION), WHILE INCORPORATING RE-USE OF THE EXISTING BUILDING SETS A LOW-CARBON PRECEDENT FOR FUTURE DEVELOPMENTS TO FOLLOW. THEY INTEGRATED PHOTOVOLTAIC FACADE, THERMALLY EFFICIENT ENVELOPE, INNOVATIVE HEAT - RECOVERY SYSTEM, LED LIGHTING AND LOW - IMPACT TIMBER STRUCTURE.

THE LAMINATED VENEER LUMBER IS USED WIDELY FOR A VARIETY OF REASONS:

1. IT ALLOWED FOR A RAPID ON-SITE BUILD AND LIMITED THE ASSOCIATED ENVIRONMENTAL DISRUPTION.
2. IT WAS EFFECTIVELY SELF-FINISHED, REQUIRING NO LINING OR APPLIED FINISHES.
3. IT GAVE THE FLEXIBILITY FOR SERVICES TO BE FIXED ANYWHERE.
4. IT WAS CARBON-SEQUESTERING, WITH ONLY CERTIFIED TIMBER FROM SUSTAINABLY MANAGED SOURCES USED.
5. IT CREATED A BETTER ENVIRONMENT THAN A STEEL-FRAMED BUILDING; WARMER / SOFTER / QUIETER.
6. IT WAS COST-COMPARABLE WITH A STEEL FRAME
7. IT PROVIDES A STRIKING CONTRAST WITH THE EXISTING STRUCTURE, HELPING USERS TO READ THE BUILDINGS STORY.

FIGURE #14


West Elevation
Weathering Steel
Profiled Sheet Metal
Aluminium Framed Glazing
Translucent Cladding Screen
PPC Aluminium Surround
White Painted Brick
North Elevation
South Elevation
Weathering Steel
Profiled Sheet Metal
Aluminium Framed Glazing
Thin Film Photovoltaic Screen
PPC Aluminium Surround
Vertical Cedar Cladding
Anodised Aluminium, Perforated Panels
East Elevation

FIGURE #15

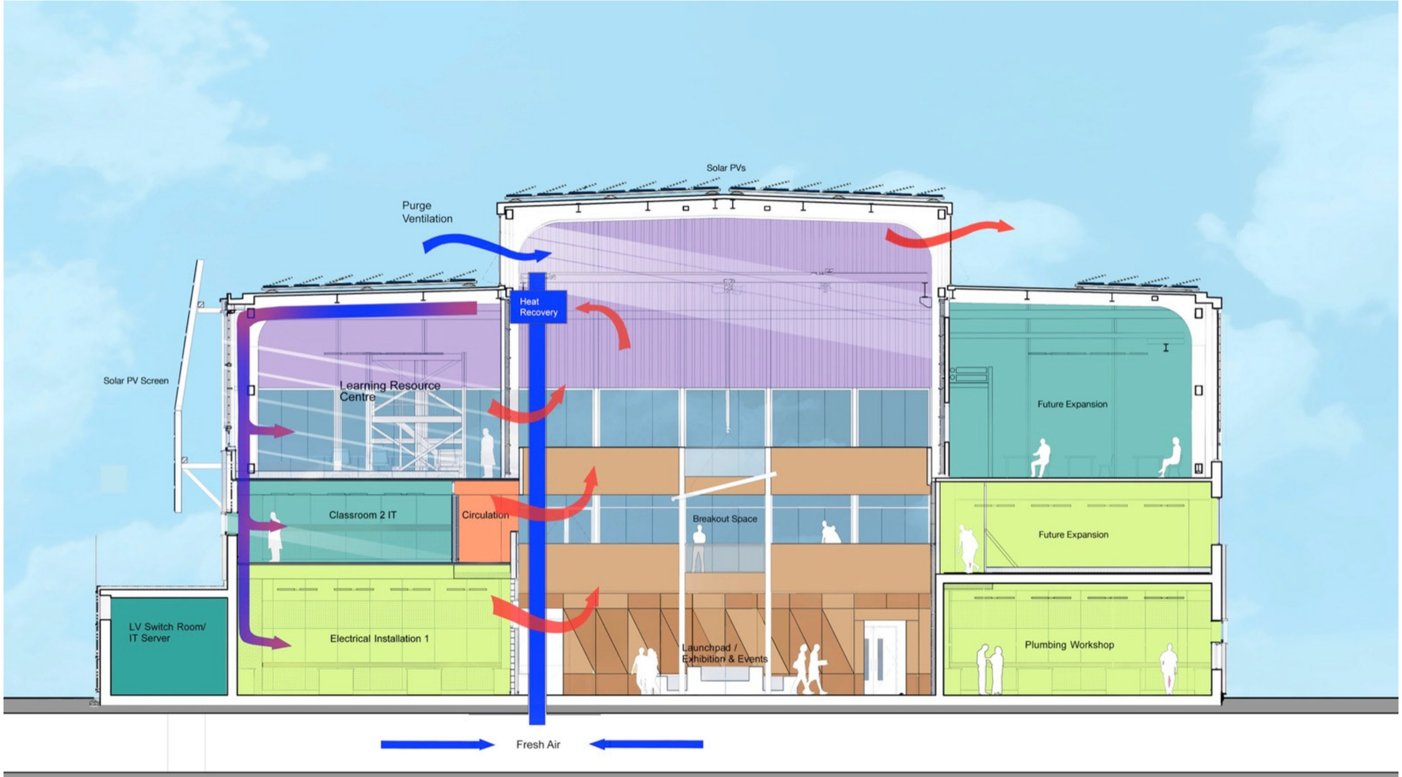


FIGURE #16

WESTBOROUGH PRIMARY SCHOOL

WESTCLIFF ON SEA, UNITED KINGDOM

FIGURE #17

FIGURE #18

ARCHITECT	PROJECT YEAR	TYPOLOGY	SQUARE FOOTAGE	LOCATION
COTTRELL AND VERMEULEN ARCHITECTURE LTD.		ELEMENTARY AND MIDDLE SCHOOL RENOVATION		WESTCLIFF, UK

THE UKS EDUCATIONAL BUILDINGS GENERATE APPROXIMATELY 15% OF THE UKS CARBON EMISSIONS. THE SCHOOL NEEDED TO BE REFURBISHED SO THEY DECIDED TO MAKE IMPROVEMENTS TO THEIR DESIGN TO BECOME A MORE SUSTAINBLE SCHOOL. THEY STRIVED TO FIND WAYS TO BECOME MORE SUSTAINABLE IN AN AFFORDABLE WAY IN A LOW CARBON MANNER.

REFURBISHMENT PROJECTS TEND TO BE MORE COMPLEX AND COSTLY, BUT BUILDING NEW ARE LESS ABLE TO MEET CARBON REDUCTION TARGETS BECAUSE OF THE EMBODIED ENERGY OF THE EXISTING BUILIDNG. STUDIES HAVE SHOWN THAT NEW BUILD CONSTRUCTIONS CAN EMIT OVER FOUR TIMES THE AMOUNT OF CO2 THAN RENOVATIONS.

THEIR SOLUTION TO REDUCING THEIR CARBON FOOTPRINT:

- UNDERSTANDING THE CARBON FOOTPRINT OF THE EXISTING CONDITION WHICH IS USED AS BASIS FOR ALL STRATEGIC INTERVENTIONS TO THE FABRIC OF THE SCHOOL

- MODIFYING BEHAVIOR OF THE SCHOOL BASED ON THE FINDING OF THE CARBON FOOTPRINT.

- IMPLEMENTING GREEN RENEWABLE ENERGY TO THE SCHOOL NAMELY BIOMASS HEATING AND PHOTO VOLTAICS.

- IMPLEMENTING A COMMUNITY EDUCATION PROGRAM THAT STARTS WITH THE CHILDREN AT THE SCHOOL TO RAISE AWARENESS OF ENERGY ISSUES WITHIN THE COMMUNITY

- IMPLEMENTING A PHASED CONSTRUCTION PROGRAM THAT CAN LEARN FROM THE SUCCESS OF THE FIRST PHASE

WAYS OF REDUCING CARBON EMISSIONS

INSULATION OF EXISTING WALLS

INSULATED DRY LINING BOARD ADDED TO IMPROVE THE THERMAL PERFORMANCE OF EXISTING EXTERNAL WALLS.

INSULATION OF ROOF AND INTRODUCTION OF INNER ROOF LINING

INSULATION BONDED TO THE EXISTING INTERNAL SURFACE WILL IMPROVE BOTH THERMAL AND ACOUSTIC PERFORMANCE OF THE ROOF.

INSTALLATION OF SECONDARY GLAZING

A COMBINATION OF DOUBLE GLAZING AND INTERNAL SECONDARY GLAZING IMPROVES THERMAL PERFORMANCE.

IMPROVEMENT OF BUILDING AIR TIGHTNESS

CONTROL AIRFLOW THROUGH EXISTING ROOF VENTS AND ENSURE WINDOWS AND DOORS ARE PROPERLY SEALED.

INSULATED DISTRIBUTION PIPEWORK

HOT WATER AND HEATING PIPEWORK HAS BEEN INSULATED TO REDUCE LOSSES AND IMPROVE CONTROL OF HEATING THE SPACE.

FIGURE #19

FIGURE #20

WAYS OF REDUCING CARBON EMISSIONS

MODIFICATION OF FLUORESCENT LIGHTS TO USE T5 LAMPS

EXISTING FLUORESCENT LIGHT FITTINGS MODIFIED TO ACCEPT MORE EFFICIENT T5 LAMPS. ENERGY CONSUMPTION REDUCED BY 45%.

LIGHTING CONTROL

PIR/DAYLIGHT SENSORS USED TO CONTROL CLASSROOM LIGHTING.

COMPUTER ENERGY MANAGEMENT

IMPROVEMENTS TO ENERGY MANAGEMENT OF EXISTING IT INFRASTRUCTURE.

OPTIMISED SCHEDULING OF HEATING PLANT OPERATION

NEW BOILER CONTROLLERS ALLOW OPTIMISED SCHEDULING TO REDUCE UNNECESSARY RUNNING HOURS.

FIGURE #21

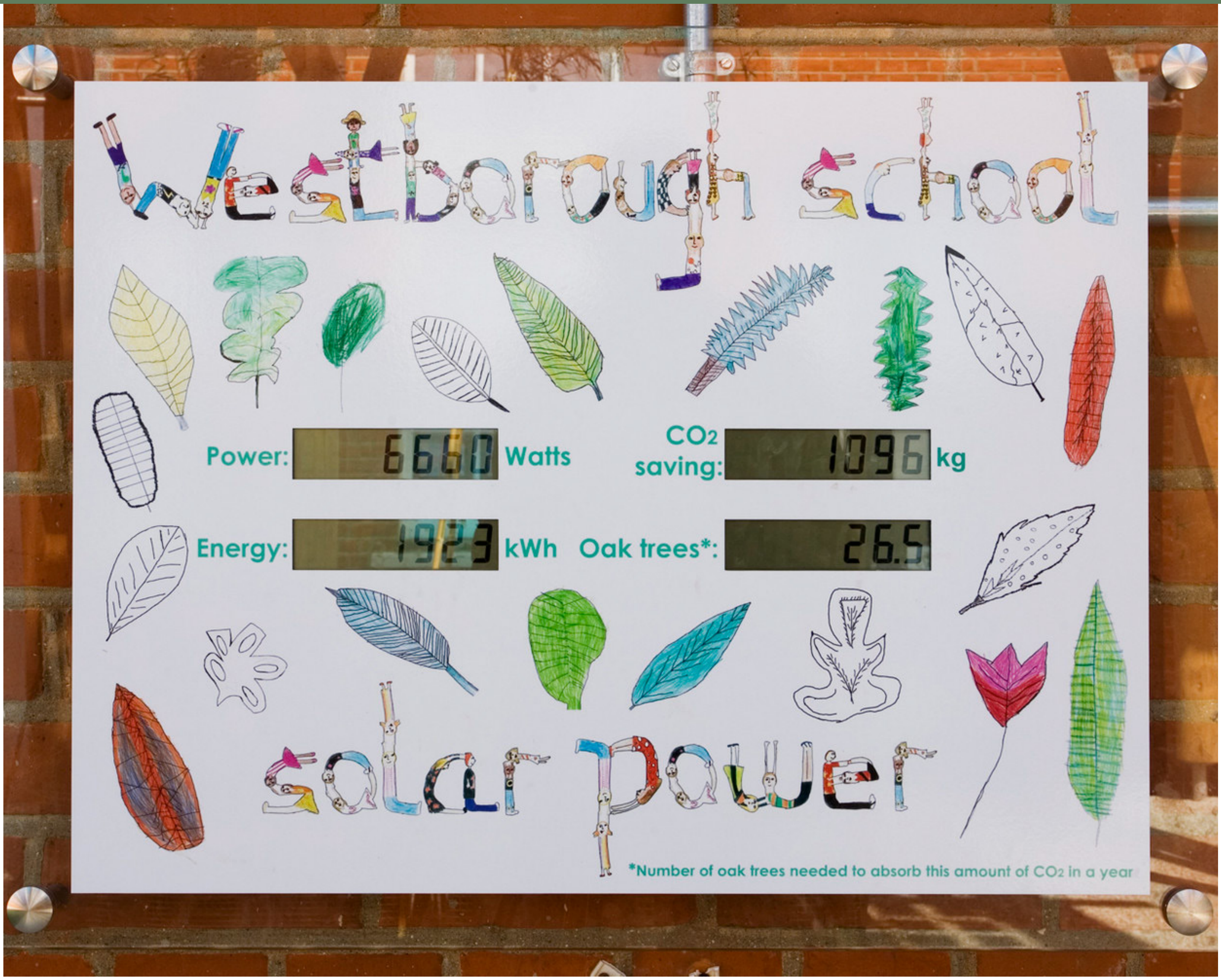


FIGURE #22

HOT WATER ALTERNATIVE GENERATION

PROVIDING 'REGIONAL' WATER HEATERS REDUCES HOT WATER CARBON EMISSIONS BY UP TO 50%.

SUBMETERING AND ENERGY MANAGEMENT

SUBMETERING OF ENERGY CONSUMPTION WILL ALLOW A DETAILED IMAGE OF HOW AND WHERE ENERGY IS CONSUMED THROUGHOUT THE SCHOOL.

HEAT EXCHANGE

HEAT EXCHANGE SYSTEMS HAVE BEEN INSTALLED TO MAXIMISE THE USE OF ENERGY WITHIN THE VENTILATION AND HEATING SYSTEM.

SOLAR PHOTOVOLTAIC

THE SOLAR PHOTO VOLTAICS HAVE BEEN INSTALLED ON THE SOUTH FACING PITCH OF THE NEW ROOF STRUCTURE. OUTPUTS FROM A TYPICAL, UK BASED, SOLAR PHOTO VOLTAIC ARRAY CAN ACHIEVE YEARLY ELECTRICAL YIELDS OF APPROXIMATELY 100 KWH/M2/YEAR.

BIOMASS BOILER

AS AN ALTERNATIVE TO GAS BOILERS, A NEW BIOMASS BOILER IS A WAY OF MEETING THE HEATING DEMANDS OF THE SCHOOL. THE SCHOOL CURRENTLY USES 150KW. BY INSTALLING A BIOMASS BOILER, IT IS ESTIMATED THAT 66% OF THE ANNUAL HEATING CARBON EMISSIONS WILL BE SAVED.

RAINWATER HARVESTING

A RAINWATER HARVESTING TANK HAS BEEN INSTALLED FOR TOILET FLUSHING.

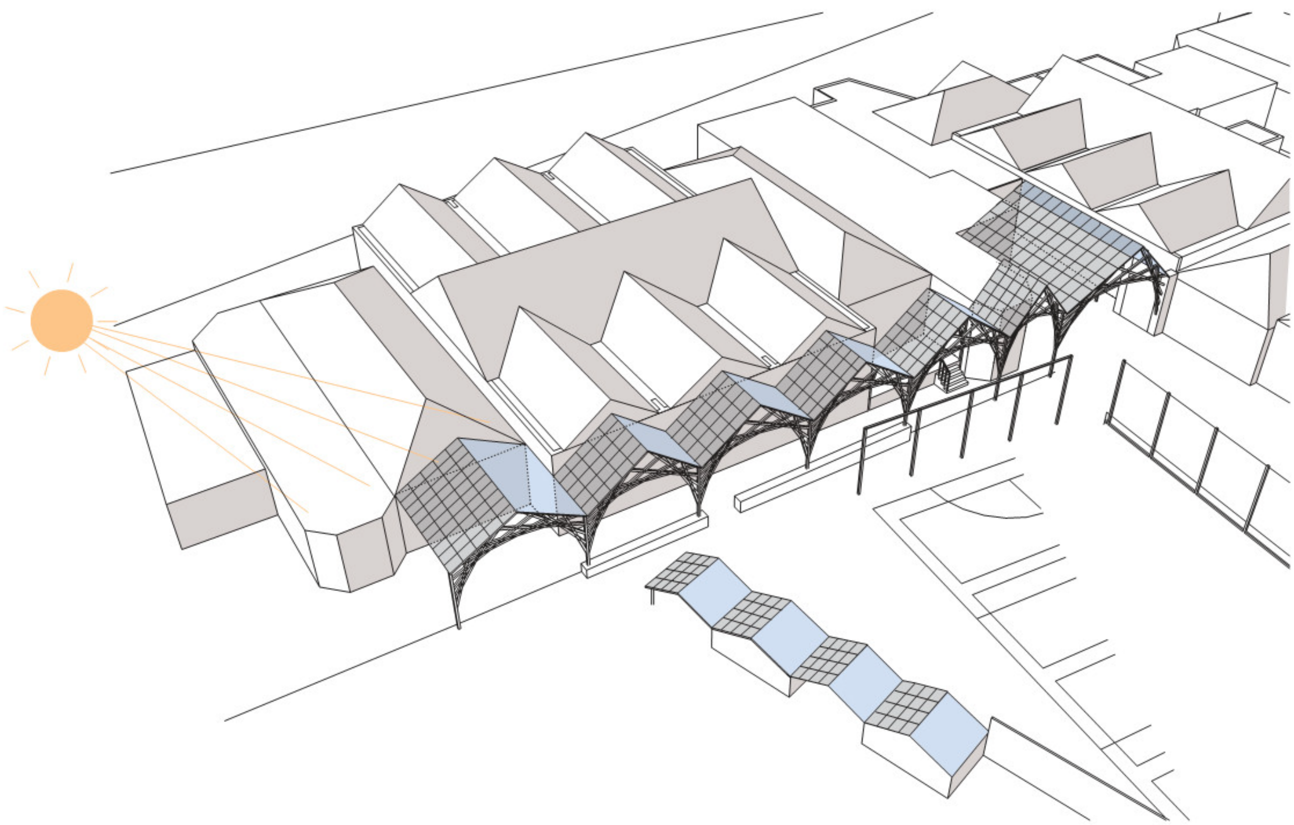


FIGURE #23

FIGURE #24

FIGURE #25

HISTORICAL, SOCIAL AND CULTURAL CONTEXT

FIGURE #26

EARLY MATERIALS

IN NEOLITHIC TIMES, BONE, GRASSES, HIDE, AND ANIMAL FIBERS WERE USED. NATURAL BUILDING MATERIALS WERE DOMINANT. IT WAS COMMON TO USE MAMMOTH RIBS, TREE BARK, LOGS, CLAY, AND LIME PLASTER TO SHAPE AND ASSEMBLE USING SIMPLE TOOLS. THE FIRST STRUCTURES WERE LIKELY SIMILAR TO HUTS AND TENTS. IN ANCIENT TIMES, AS TOOLS AND TECHNIQUES ADVANCED, AVAILABLE MATERIALS RANGED FROM WHAT COULD BE FOUND IN NATURE TO MATERIALS THAT SEEM MORE FAMILIAR TODAY.

STONE

EVEN WHERE THERE WAS A LACK OF METAL TOOLS, BUILDERS COULD CREATE STONE STRUCTURES. STONES WERE PLACED TOGETHER WITHOUT MORTAR TO CREATE A STURDY SHELTER. STONE IS STILL USED TODAY FOR BUILIDNGS, BRIDGES AND SCULPTURES.

MUD

MUD BRICKS WERE CREATED BY MIXING MUD AND STRAW. THIS PROCESS EVOLVED INTO THE USE OF MORTAR ALLOWING STONEMASONS TO CARVE AND SET THEM TO TIGHT TOLERANCES.

WOOD

WOOD IS ONE OF THE FIRST BUILDING MATERIALS. WOOD REMAINS POPULAR AND IS A RENEWABLE RESOURCE. TODAY, LUMBER IS USED TO FRAME HOMES AND OTHER STRUCTURES, AND VARIOUS TYPES OF WOOD ARE USED FOR INTERIOR/EXTERIOR BUILDING MATERIALS AND FURNISHINGS.

BRONZE

BRONZE AND COPPER WERE USED TO MAKE MORE DURABLE TOOLS.BRONZE CAN BE RESHAPED AND IT COULD ALSO BE RECAST IS DAMAGED. THIS EVENTUALLY LED TO THE USE OF IRON, WHICH IS SIMILAR IN HARDNESS. STEEL WAS CREATED BY ADDING CARBON TO IRON

FIGURE #27

EVOLUTION OF BUILDING MATERIALS

BUILDING MATERIALS HAVE NOT ONLY EVOLVED WITH TRENDS, BUT ALSO WITH DEMANDS FOR DURABILITY, SIZE, AND CONTROL OVER INTERIOR ENVIRONMENTS. THE ENERGY AVAILABLE TO SUPPORT CONSTRUCTION HAS ALSO INFLUENCED THE KINDS OF BUILDING MATERIALS USED.

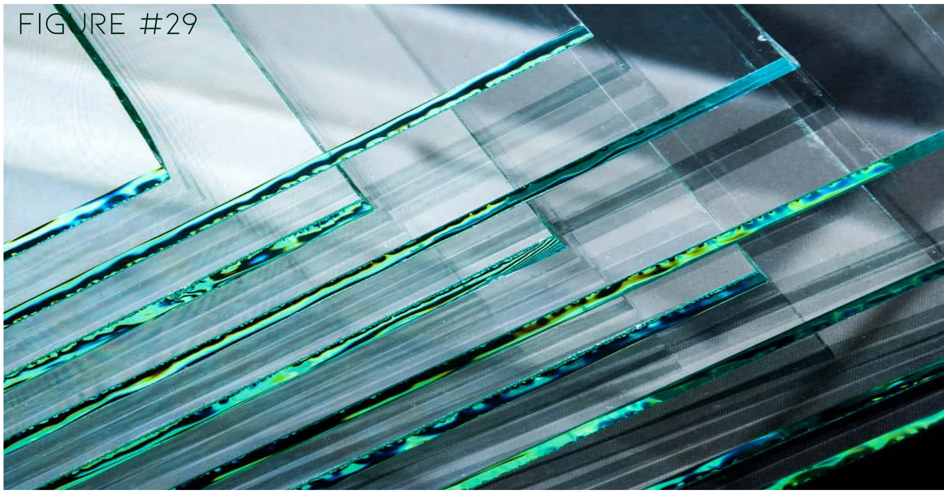
TIMBER AND BRICK WERE USED THROUGH MANY DIFFERENT TIME PERIODS. TIMBER ROOFS WER USED IN ANCIENT ROME AND WOODEN TIMBER FRAMES WERE USED IN ANCIENT CHINA. TRADITIONAL TIMBER FRAMING BECAME LESS POPULAR DURING THE INDUSTRIAL REVOLUTION, AS STEEL COULD BE MASS PRODUCED, BUT WOOD HAS REGAINED POPULARITY AS AN ECO FRIENDLIER MATERIAL WITH MORE OPTIONS FOR CUSTOM MACHINING, INTEGRATION, STYLING, AND FIREPROOFING.

MUD BRICKS WERE USED THROUGHOUT ANCIENT TIMES. LIME MORTAR WAS USED IN ANCIENT GREECE, AND STONE BRICKS WERE USED IN CHINA. THE PRODUCTION PROCESS CHANGED LITTLE OVER TIME. ALTHOUGH NOW MASS-PRODUCED RATHER THAN HANDMADE, BRICK REMAINS A POPULAR ARCHITECTURAL MATERIAL TODAY.

FIGURE #28

GLASS

FIGURE #29



GLASS WAS USED FROM WINDOWS TO HOME FURNISHINGS TO SKYSCRAPER WALLS. GLASS HAS BEEN MANUFACTURED SINCE THE SEVENTEENTH CENTURY. ONCE IT COULD BE MASS-PRODUCED, GLASS BECAME MORE COMMONLY USED IN STRUCTURES AND NOT JUST AS A LUXURY.

FIGURE #30

INSULATION

THE FIRST FORM OF INSULATION WAS ASBESTOS WHICH WAS USED WELL INTO THE 20TH CENTURY. THE FIRST MODERN ADVANCE IN INSULATION HAPPENED IN THE 1930S WITH THE ACCIDENTAL INVENTION OF FIBERGLASS INSULATION. FIBERGALSS WAS POPULAR IN THE 1940S WHILE CELLULOSE WAS POPULAR FROM 1950S-1970S. POLYURETHANE SPRAY FOAM BECAME POPULAR IN HOME CONSTRUCTION IN THE 1980S WHILE, TODAY, THERE ARE MANY DIFFERENT TYPES OF INSULATION TO CHOOSE FROM.

FLOORING

FIGURE #31

STONE AND WOOD WERE VERY DOMINANT BUILDING MATERIALS IN EARLY HISTORY. THEY ARE STILL COMMONLY USED FOR MANY OCCASIONS. LINOLEUM, VINYL, BAMBOO, AND HARDWOOD ARE ALL COMMON FLOORING TYPES THAT HAVE BEEN USED OVER THE LAST 50 YEARS OR SO.

FIGURE #32

INDUSTRIAL REVOLUTION

MANY NEW TECHNOLOGIES EMERGED DURING THE INDUSTRIAL REVOLUTION WHICH LED TO CONSTRUCTION ADVANCEMENTS. MACHINES AND TOOLS DEVELOPED FOR CUTTING, GRINDING, BORING, AND OTHER PROCESSES ALLOWED FOR MORE BUILDING FLEXIBILITY. STEAM ENGINES, EXPLOSIVES, AND TRANSPORTATION OPTIONS LIKE CANALS AND RAILWAYS EXPANDED BUILDING POTENTIAL AS WELL.

ONCE STEEL COULD BE MASS-PRODUCED, I-BEAMS AND REINFORCED CONCRETE WERE POSSIBLE. THIS ALSO LED TO THE WIDESPREAD USE OF PLUMBING TO PROVIDE ORDINARY HOMES WITH FRESH WATER. THE CREATION AND REFINING OF BUILDING CODES HAVE LED TO IMPROVEMENTS IN MATERIAL QUALITY AND FIRE SAFETY.

HEAVY EQUIPMENT, ELEVATORS, CRANES, AND PREFABRICATION EXPANDED CONSTRUCTION CAPABILITIES IN THE 20TH CENTURY. EVENTUALLY, COMPUTER-AIDED DESIGN ALLOWED FOR MORE PRECISE MATERIAL DEVELOPMENT, PRODUCTION, AND SELECTION. IN THE LATE 20TH CENTURY, SUSTAINABILITY BECAME A HIGHER PRIORITY IN THE CONSTRUCTION INDUSTRY, WITH RESOURCE CONSERVATION, ENVIRONMENTAL PROTECTION, AND REDUCED ENERGY CONSUMPTION BEING TOP GOALS.

FUTURE OF BUILDING MATERIALS

We're now in an age of computer-enabled smart appliances, lighting, security, and more, but modern building materials are also shaping the home construction industry. Numerous types of materials are in development that will continue to revolutionize construction.

One of these is solar panels. Increased efficiency and reduced costs have made solar panels more popular. By May 2019, more than two million solar systems had been installed in the United States, according to the Solar Energy Industries Association.2 They save on energy costs and come with perks such as federal and local tax incentives and the option to sell power back to the grid.

There are many advanced materials that are raising the potential for changes unlike anything seen in the past.

FIGURE #33

FUTURE OF BUILDING MATERIALS

SELF HEALING CONCRETE

Bacteria in the mixture produce calcite when exposed to water, which can essentially heal cracks, reducing maintenance and greenhouse gases associated with repair and replacement processes.

LIGHT GENERATING CONCRETE

Tiny glass balls embedded in the material reflect light to potentially create signage, underground lighting, and warning signs. It is non-flammable and may have artistic uses as well.

3D GRAPHENE

A carbon that is 3D-printed and 200 times stronger than steel, despite being just 5% as dense, it has potential uses in vehicles and supertall skyscrapers.

LAMINATED TIMBER

Laminated timber: This is a water-resistant, high-strength prefabricated timber that is strong enough for building skyscrapers, while significantly reducing carbon emissions.

MODULAR BAMBOO

Fast-growing and low-cost, modular bamboo can be made into different shapes. It is earthquake-resistant and can be reinforced with steel bars.

TRANSPARENT ALUMINUM

This is a corrosion-resistant ceramic alloy that can resist radiation and oxidation, with potential uses for windows and marine and space vehicle domes.

TRANSLUCENT WOOD

Stripped of its color, this wood offers good insulating properties and strength. It may be a viable replacement for window glass and could be used as solar panel cells.

WOOL BRICK

Stronger than conventional brick, this material is fused with wool and seaweed polymer, reducing greenhouse gases. It also resists cold-air intrusion.

FIGURE #34

DESIGN SOLUTION

CARBON FOOTPRINT CALCULATING METHODOLOGY

FIGURE #35

FIGURE #36

1

TALLY EXTENSION

DOWNLOAD TALLY EXTENSION FOR REVIT

2

REVIT MODEL

OPEN EXISTING OR CREATE A NEW MODEL THAT WILL BE ANALYZED

3

TALLY MATERIAL IDENTITY

IDENTIFY ALL MATERIALS USED WITHIN THE MODEL FOR TALLY TO EXPORT

4

EXPORT TO EC3

EXPORT MATERIAL IDENTITIES TO BUILDING TRANSPARENCY'S EC3 TOOL

5

EC3 ANALYSIS

ANALYIZE IMPORTED DATA TO REVIEW AND LEARN FROM

I HAVE CREATED A VIDEO THAT WALKS THROUGH THE REVIT-TALLY-EC3 PROCESS.

FIGURE #37

SCAN THE QR CODE ABOVE TO ACCESS THE VIDEO DIRECTLY - OR VISIT:

HTTPS://WWW.YOUTUBE.COM/
WATCH?V=SFGVYCZDCMO&T=1S

TALLY EXTENSION

DOWNLOAD TALLY EXTENSION FOR REVIT

1

BUILDING TRANSPARENY IS A ONLINE RESOURCE THAT WORKS ON COLLABORATION BETWEEN SOFTWARE PROGRAMS TO PROVIDE OPEN ACCESS DATA AND TOOLS THAT ARE NECESSARY TO ENAVLE BROAD AND SWEIFT ACTION ACROSS THE BUILDING INDUSTRY IN ADDRESSING EMBODIED CARBON'S ROLE IN CLIMATE CHANGE.

BUILDING TRANSPARENCY HAS TEAMED UP WITH TALLY - A REVIT PLUG-IN THAT SUPPORTS THE EXPORT OF MATERIAL QUANTITIES FROM REVIT TO EC3 AND ALLOWS SYNCHRONIZATION BETWEEN THEM

FIGURE #38

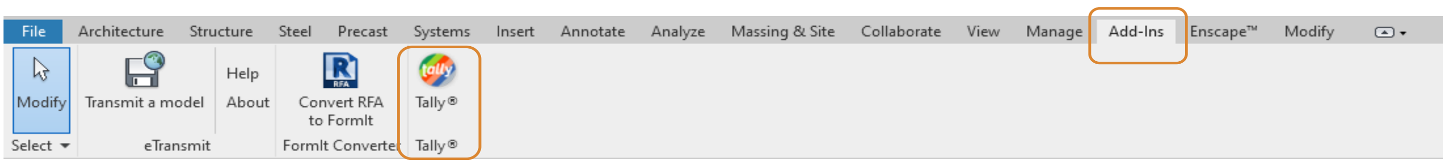


FIGURE #39

TALLYCAT IS IN ONGOING DEVELOPMENT BY C CHANGE LABS, P&W AND BUILDING-TRANSPARENCY. WE GRATEFULLY ACKNOWLEDGE THE FINANCIAL SUPPORT OF THE PROVINCE OF BRITISH COLUMBIA THROUGH THE MINISTRY OF ENERGY, MINES AND LOW CARBON INNOVATION, WHICH MADE CREATION OF THIS TOOL POSSIBLE.

FIGURE #40

REVIT MODEL

2

OPEN EXISTING OR CREATE A NEW MODEL THAT WILL BE ANALYZED

I CHOSE TO CREATE A NEW MODEL OF AN EXISTING BUILDING FOR MY THESIS. THE EXISTING SITE/DESIGN THAT I CHOSE TO MODEL IS MY PARENTS' CABIN. I CHOSE THIS DESIGN BECAUSE I AM FAMILIAR WITH THE DESIGN AND LAYOUT. ANOTHER REASON WHY I CHOSE THIS IS BECAUSE I WAS ABLE TO FOCUS ON A SMALLER DESIGN THAT DID NOT COMPLICATE THE MATERIAL IMPORTING SO THAT I COULD SEE RESULTS IN A FOCUSED WAY.

FIGURE #41

FIGURE #42

FIGURE #43

FIGURE #44

SITE CONTEXT

EXISTING CABIN IMAGE FIGURE #45

EXISTING CABIN MODEL FIGURE #46

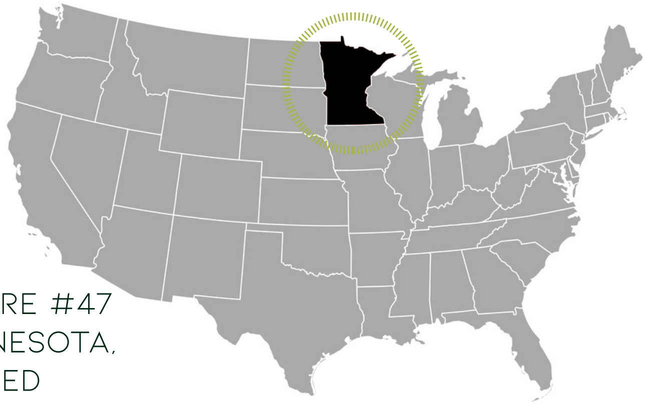


FIGURE #47
MINNESOTA,
UNITED
STATES

MINNESOTA

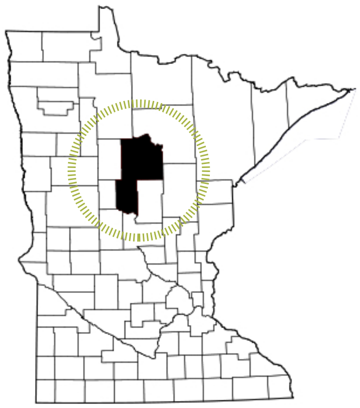


FIGURE #48
CASS
COUNTY,
MINNESOTA

CASS COUNTY

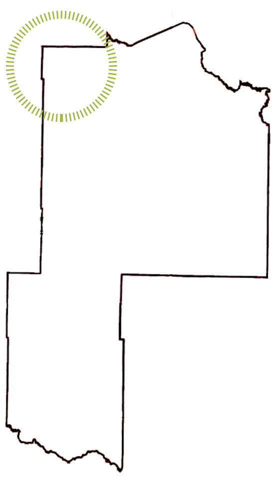


FIGURE #49
CASS LAKE,
CASS COUNTY

CASS LAKE

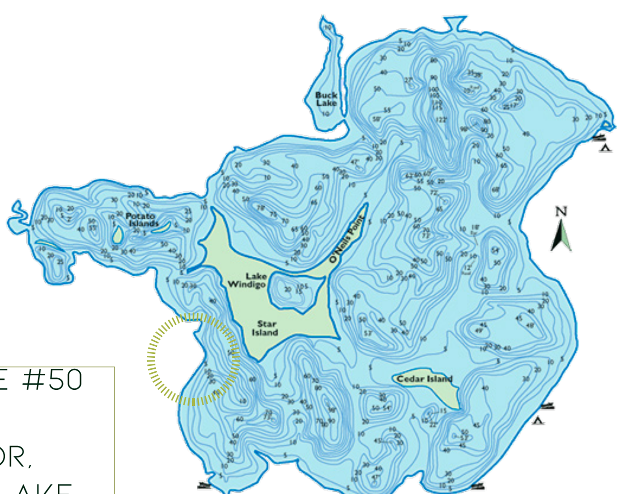


FIGURE #50
TOM'S
HARBOR,
CASS LAKE

TOMS HARBOR

TOMS HARBOR

FIGURE #51

16622 HIGHTOP WAY NW

FIGURE #52

TALLY MATERIAL IDENTITY

IDENTIFY ALL MATERIALS USED WITHIN THE MODEL FOR TALLY TO EXPORT

3

THE NEXT STEP IS TO ACCESS THE TALLY EXTENSION IN REVIT. AFTER SELECTING THE TALLY EXTENSION, A BOX WILL APPEAR AND WILL REQUIRE YOU TO DEFINE THE EXISTING BUILDING MATERIAL CATEGORIES.

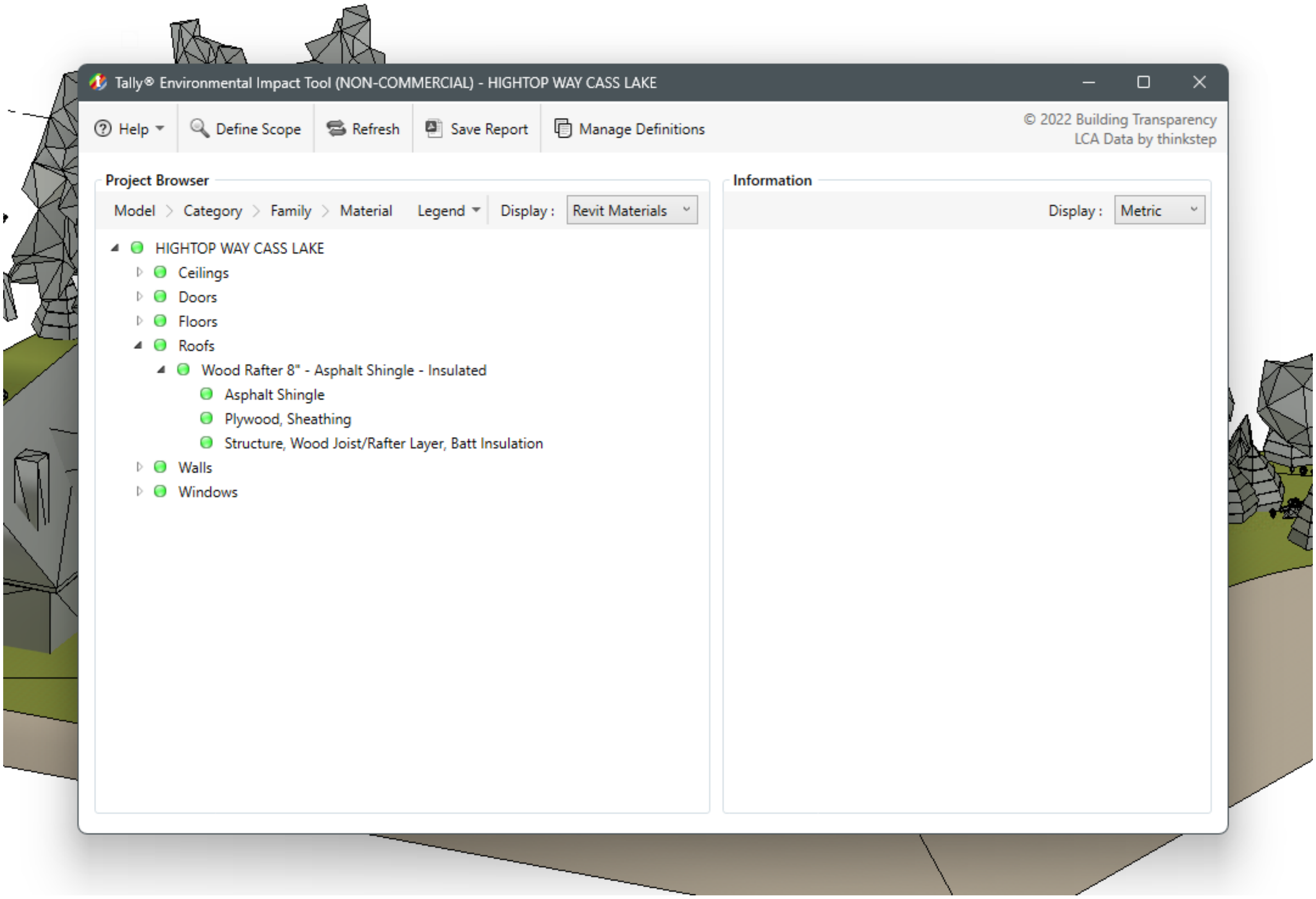
A COLOR CODED DOT SYSTEM WILL HELP GUIDE YOU THROUGHOUT THE MATERIAL DEFINING PROCESS.

RED = UNDEFINED

YELLOW = PARTIALLY DEFINED

GREEN = FULLY DEFINED

FIGURE #53


Tally® Environmental Impact Tool (NON-COMMERCIAL) - HIGHTOP WAY CASS LAKE
Help
Define Scope
Refresh
Save Report
Manage Definitions
© 2022 Building Transparency
LCA Data by thinkstep
Project Browser
Model
Category
Family
Material
Legend
Display :
Revit Materials
Information
Display :
Metric
HIGHTOP WAY CASS LAKE
Ceilings
Doors
Floors
Roofs
Wood Rafter 8" - Asphalt Shingle - Insulated
Asphalt Shingle
Plywood, Sheathing
Structure, Wood Joist/Rafter Layer, Batt Insulation
Walls
Windows

EXPORT TO EC3

EXPORT MATERIAL IDENTITIES TO BUILDING TRANSPARENCY'S EC3 TOOL

4

AFTER IDENTIFYING ALL OF THE MODELS MATERIALS THROUGH TALLY, THE NEXT STEP IS TO EXPORT THE DATA TO THE EC3 TOOL WHICH WILL COLLECT THE INFORMATION AND DISPLAY IT SO THAT YOU CAN COMPARE YOUR DESIGNS.

FIGURE #54

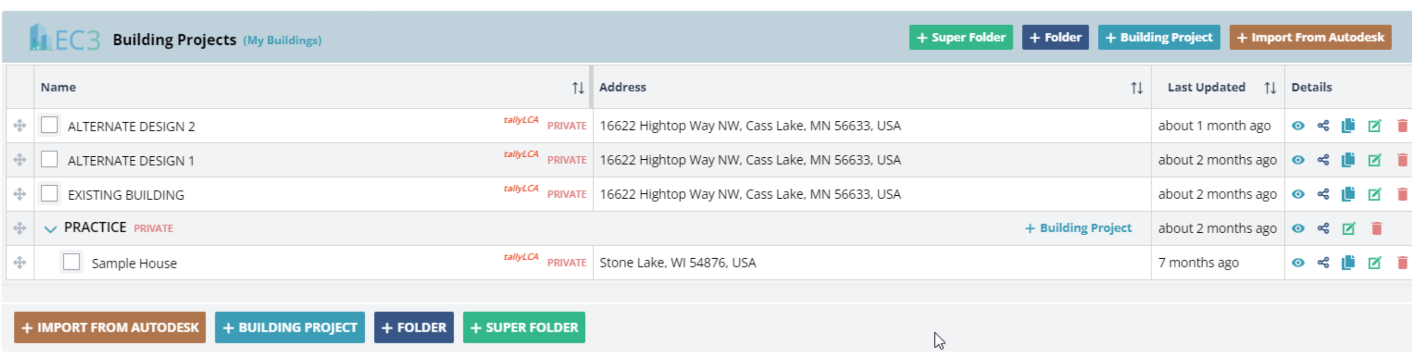
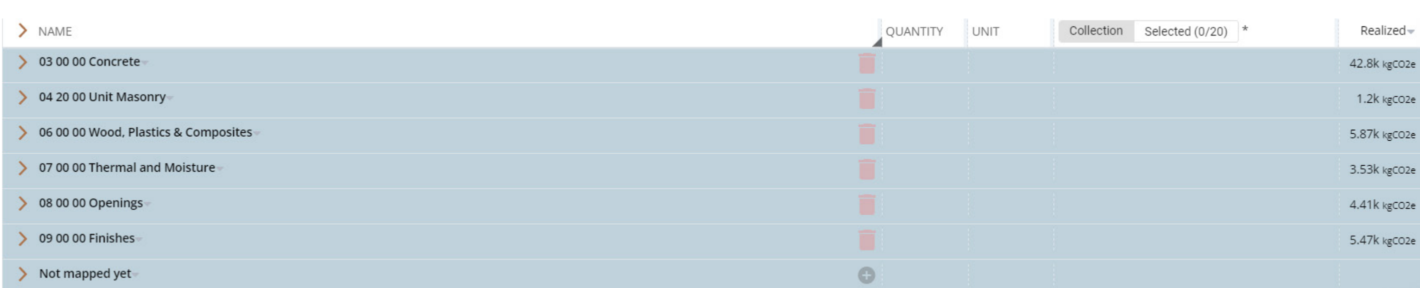


FIGURE #55



EC3 ANALYSIS

ANALYIZE IMPORTED DATA TO REVIEW AND LEARN FROM

5

WITHIN THE EC3 TOOL, YOU CAN VIEW EACH IMPORT DESIGN AND ANALYZE THE CALCULATED RESULTS. EC3 WILL ASK FOR A FEW MORE DESIGN DEFINING QUESTIONS WHICH WILL HELP THE CALCULATION OF CARBON EMISSIONS. I USED THE EC3 TOOL TO COMPARE THREE DIFFERENT DESIGNS TO SEE HOW MATERIAL CHANGE IMPACTS CARBON EMISSIONS.

ALTERNATE DESIGN 1

	Achievable	Realized	Conservative
EC Building Total	19.5k kgCO2e	36k kgCO2e	36k kgCO2e

EXISTING DESIGN

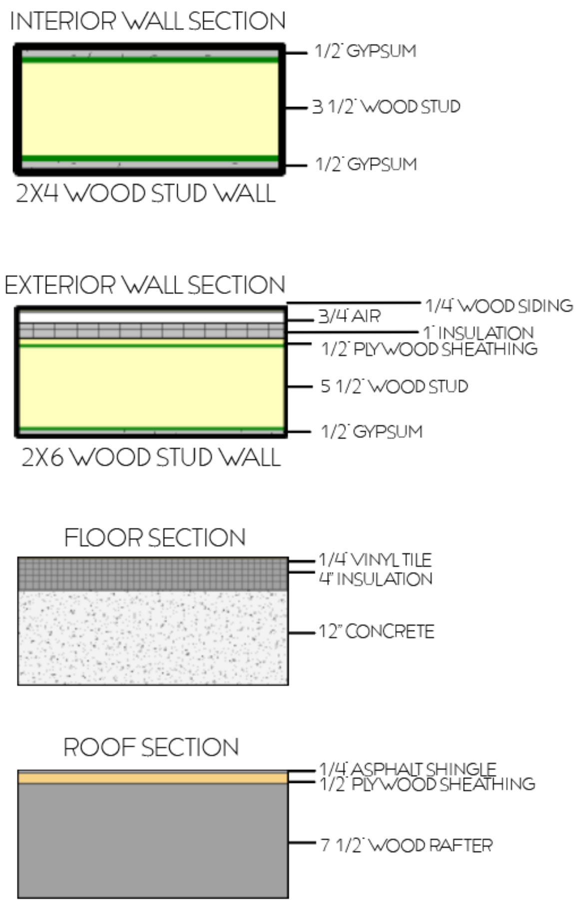
	Achievable	Realized	Conservative
EC Building Total	39.7k kgCO2e	71.7k kgCO2e	71.7k kgCO2e

ALTERNATE DESIGN 2

	Achievable	Realized	Conservative
EC Building Total	69.5k kgCO2e	115k kgCO2e	115k kgCO2e

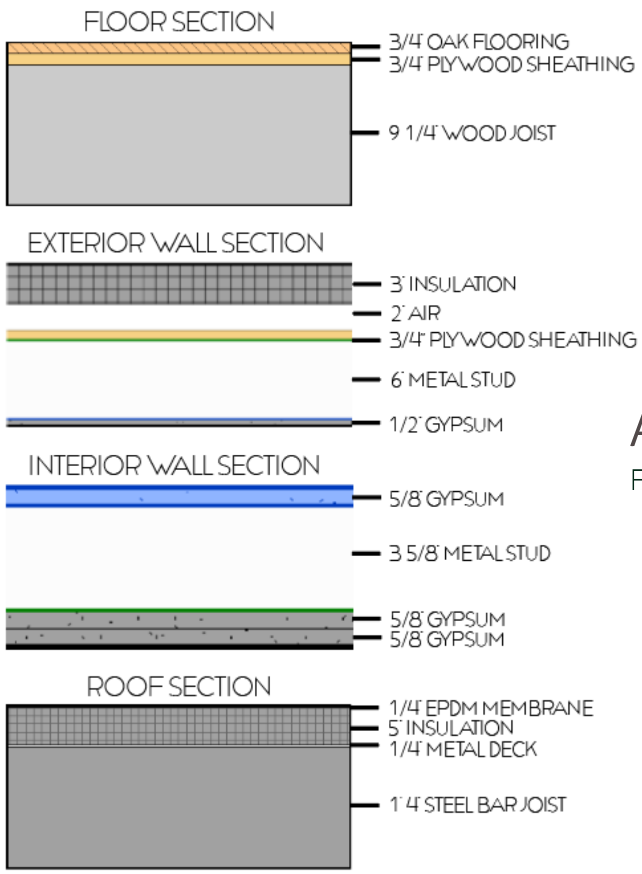
FIGURE #56

COMPARING DESIGN MATERIAL SELECTION



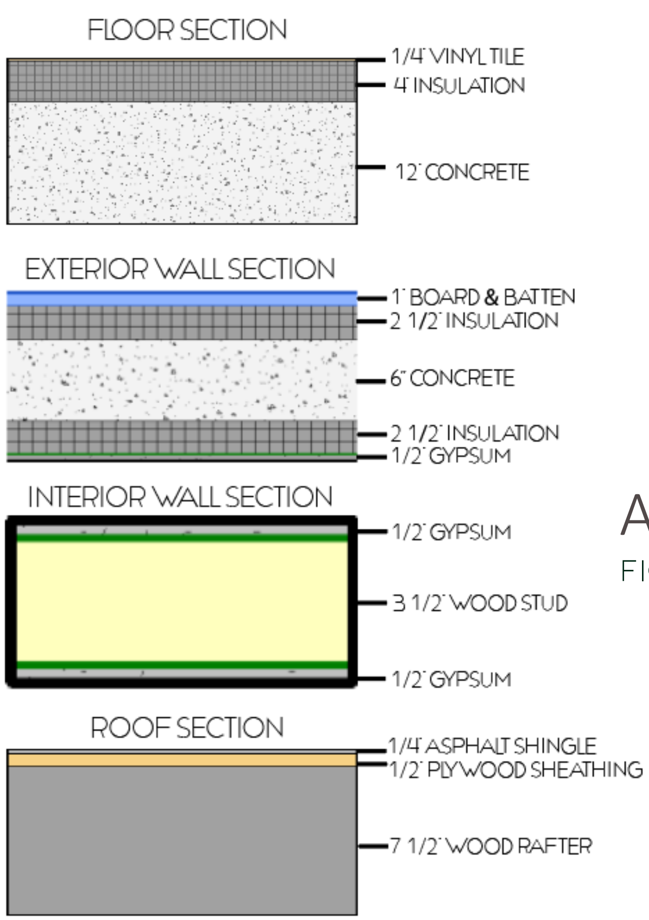
EXISTING DESIGN

FIGURE #57



ALTERNATE DESIGN 1

FIGURE #58



ALTERNATE DESIGN 2

FIGURE #59

COMPARING DE

ALTERNATE DESIGN 1
TARGET: 4.37 KGCO2E
ACHEIVABLE: 19.1 KGCO2E
CONSERVATIVE: 35.6 KGCO2E

EXISTING BUILDING
TARGET: 8.4 KGCO2E
ACHEIVABLE: 39.7 KGCO2E
CONSERVATIVE: 71.7 KGCO2E

ALTERNATE DESIGN 2
TARGET: 9.31 KGCO2E
ACHEIVABLE: 69.5 KGCO2E
CONSERVATIVE: 115 KGCO2E

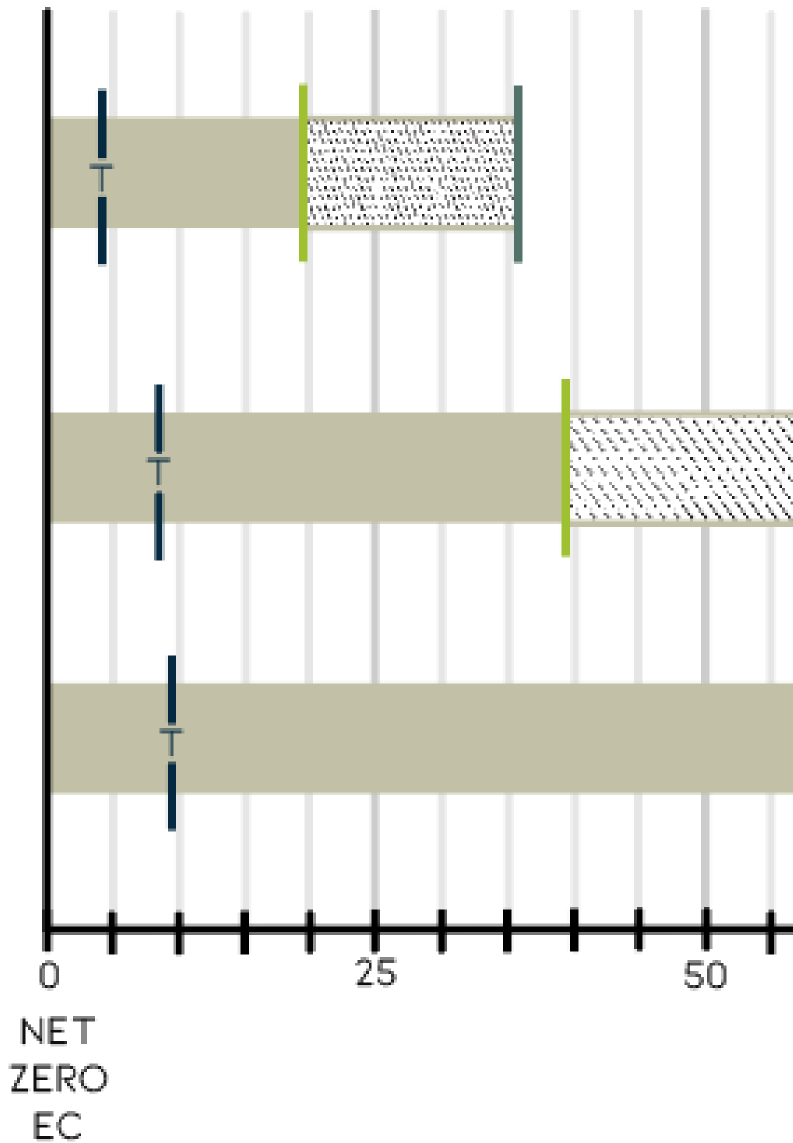
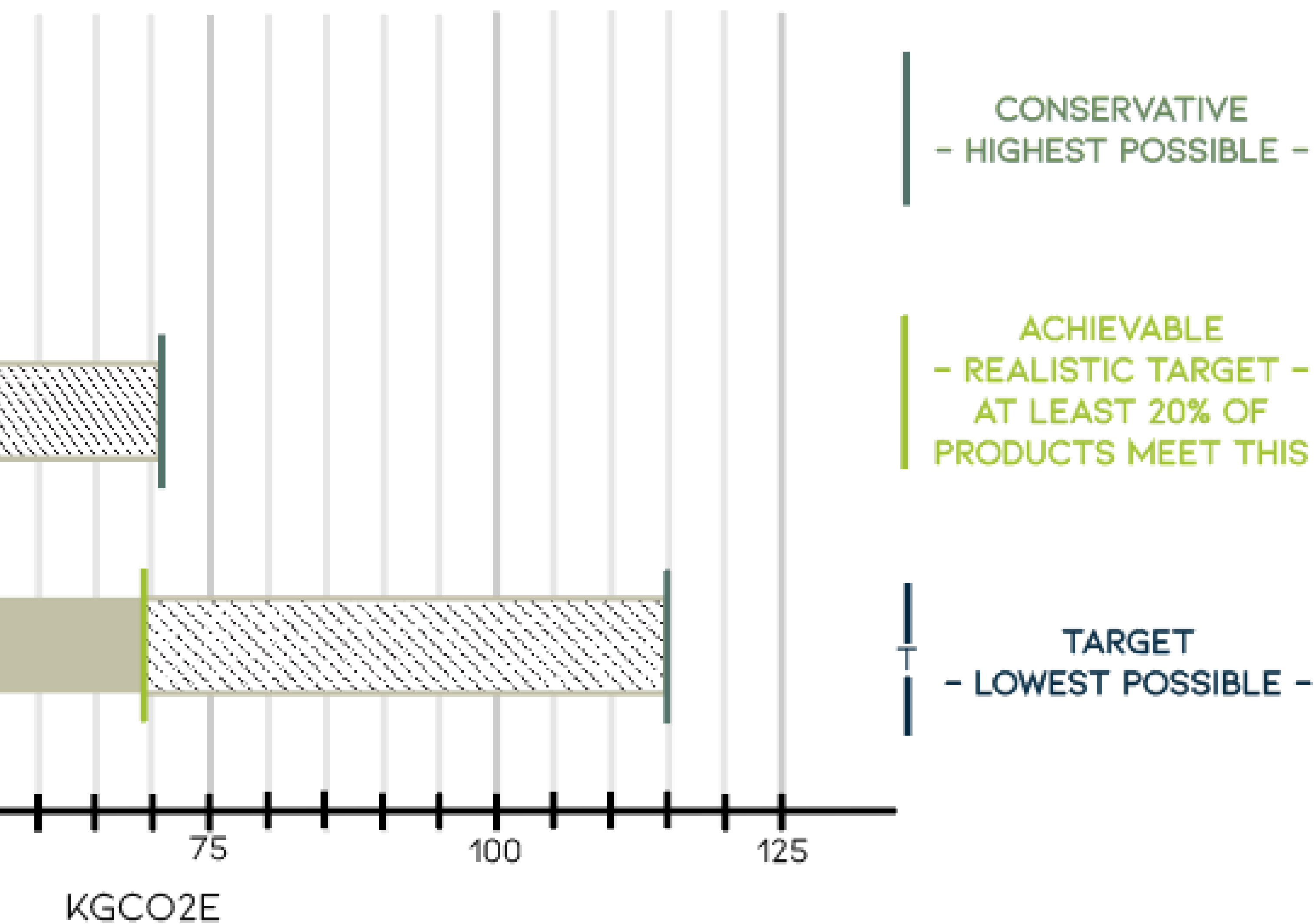


FIGURE #60

ESIGN OPTIONS



COMPARING DE

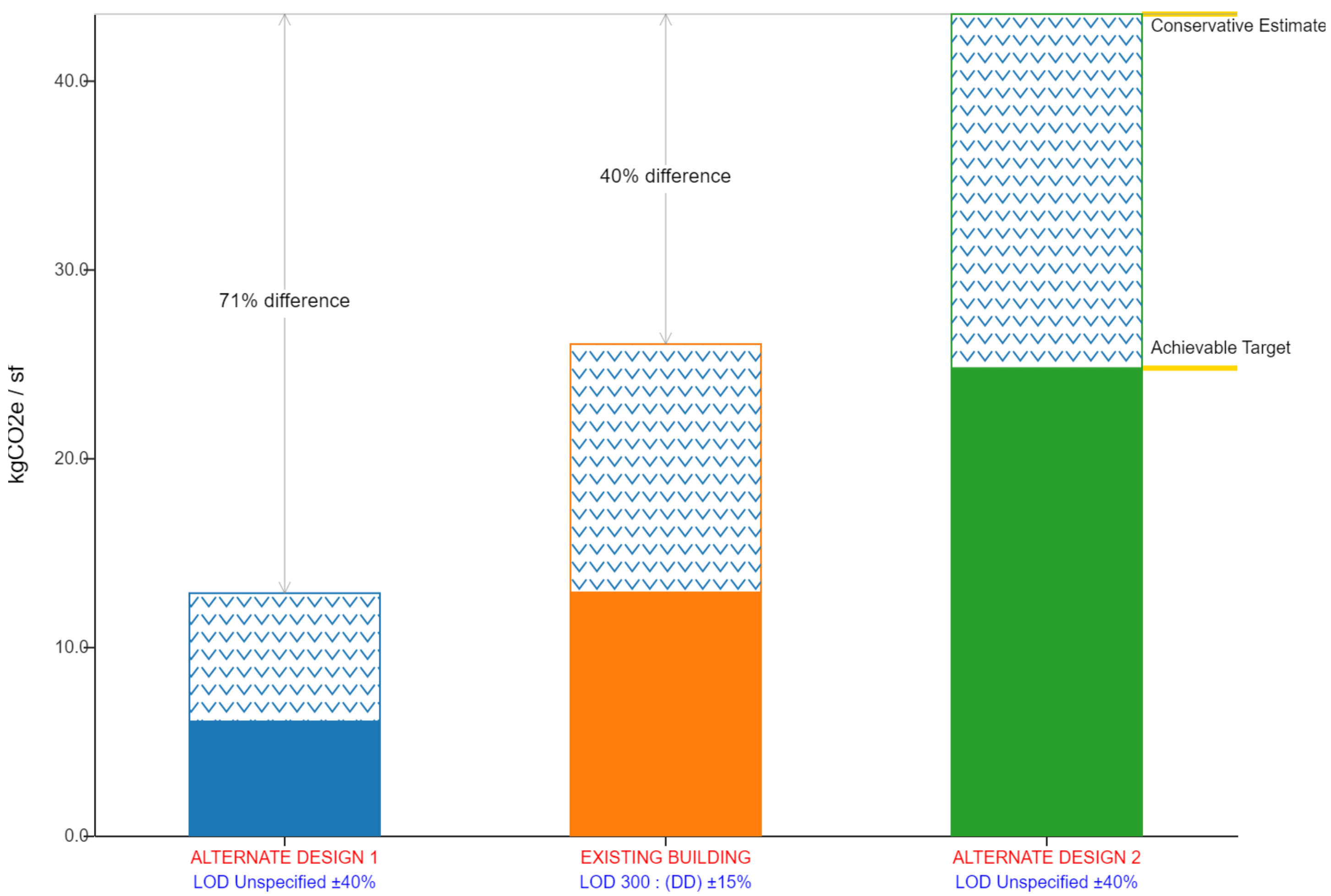


FIGURE #61

ESIGN OPTIONS

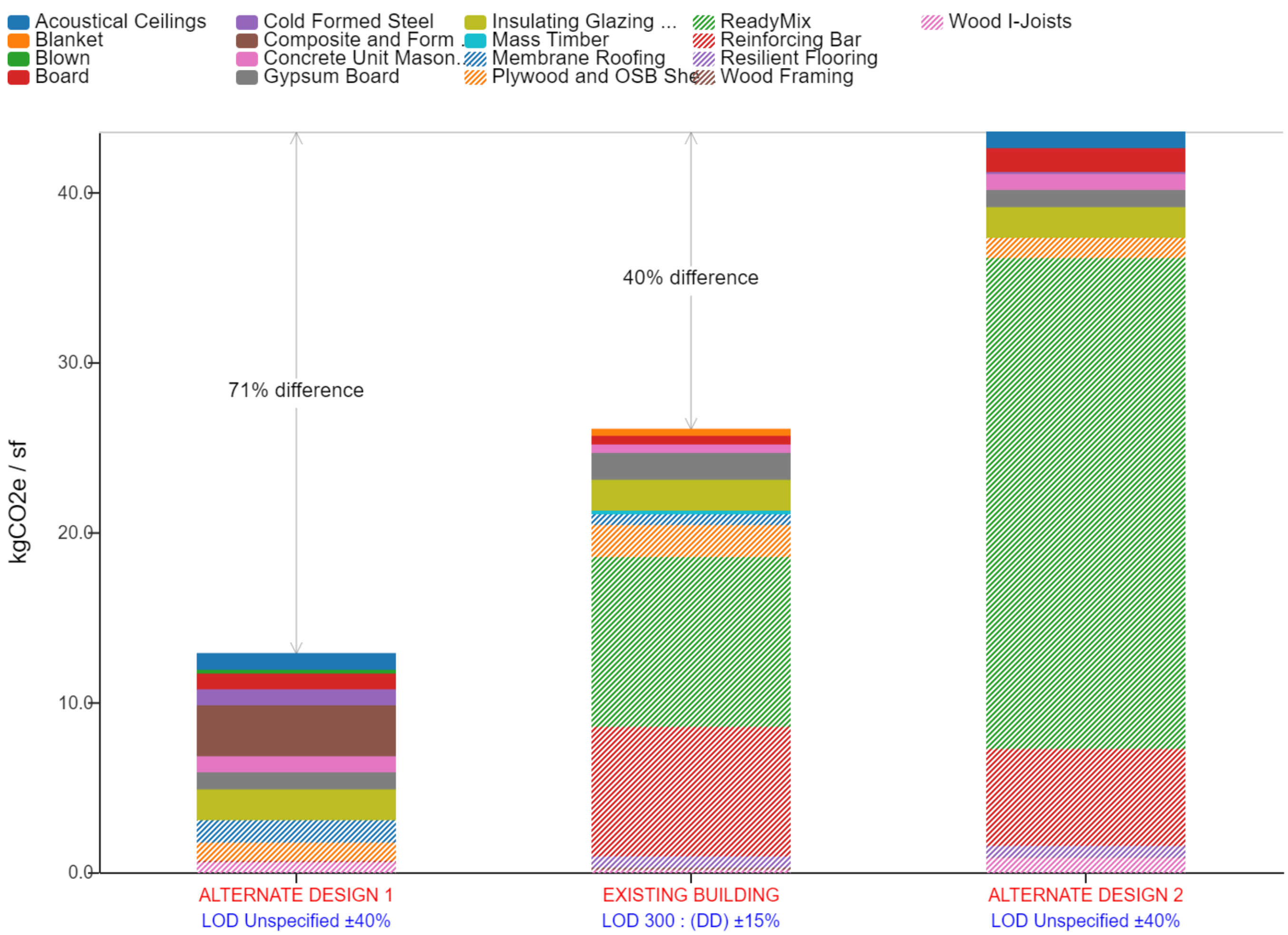


FIGURE #62

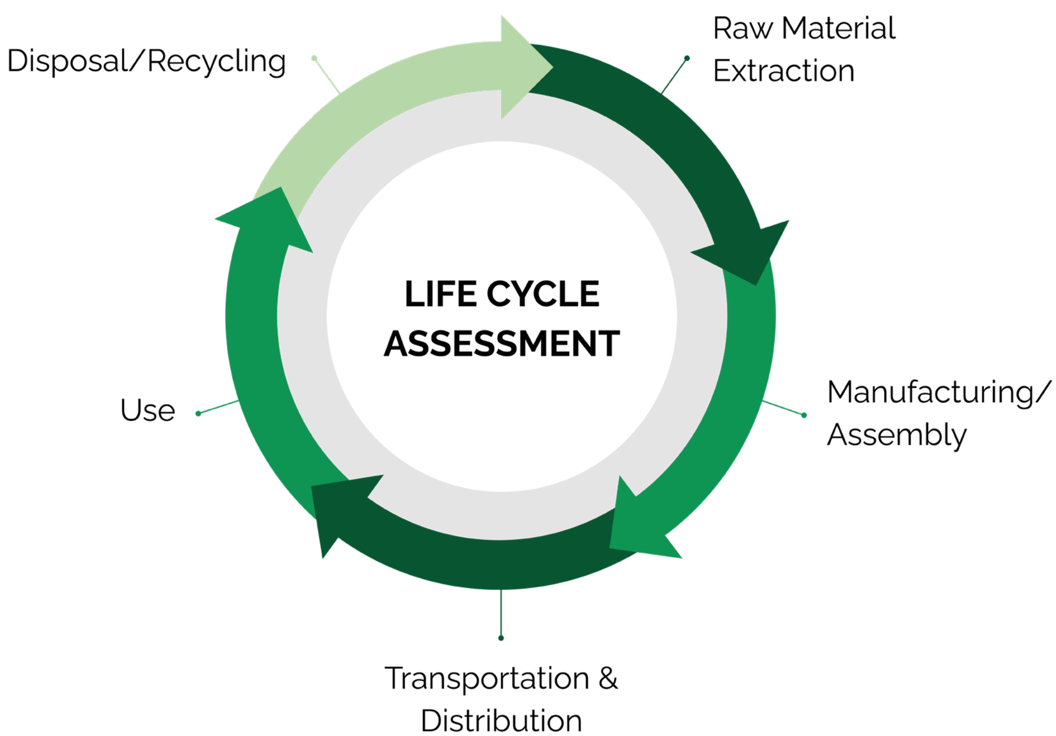


FIGURE #63

THE LIFE CYCLE ASSESMENT LOOKS AT THE PROCESS THAT EACH MATERIAL GOES THROUGH FROM EXTRACTING RAW MATERIAL TO END OF USE.

EACH MATERIAL HAS A DIFFERENT LIFE CYCLE AND CARBON EMISSION RATE THROUGHOUT IT'S LIFE CYCLE.

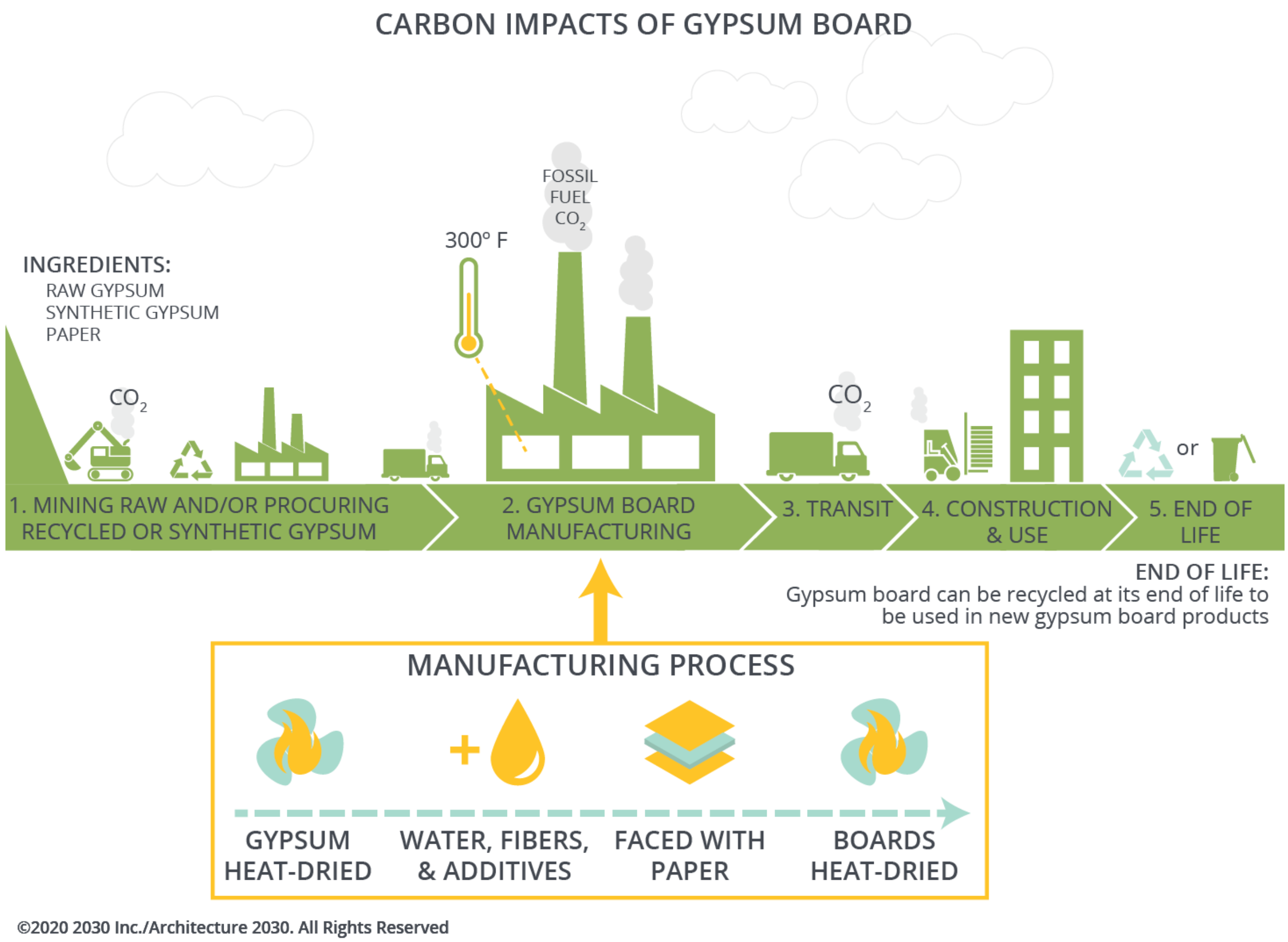

CARBON IMPACTS OF GYPSUM BOARD
INGREDIENTS:
RAW GYPSUM
SYNTHETIC GYPSUM
PAPER
CO2
FOSSIL FUEL CO2
300° F
CO2
or
1. MINING RAW AND/OR PROCURING RECYCLED OR SYNTHETIC GYPSUM
2. GYPSUM BOARD MANUFACTURING
3. TRANSIT
4. CONSTRUCTION & USE
5. END OF LIFE
END OF LIFE:
Gypsum board can be recycled at its end of life to be used in new gypsum board products
MANUFACTURING PROCESS
GYPSUM HEAT-DRIED
WATER, FIBERS, & ADDITIVES
FACED WITH PAPER
BOARDS HEAT-DRIED
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FIGURE #64

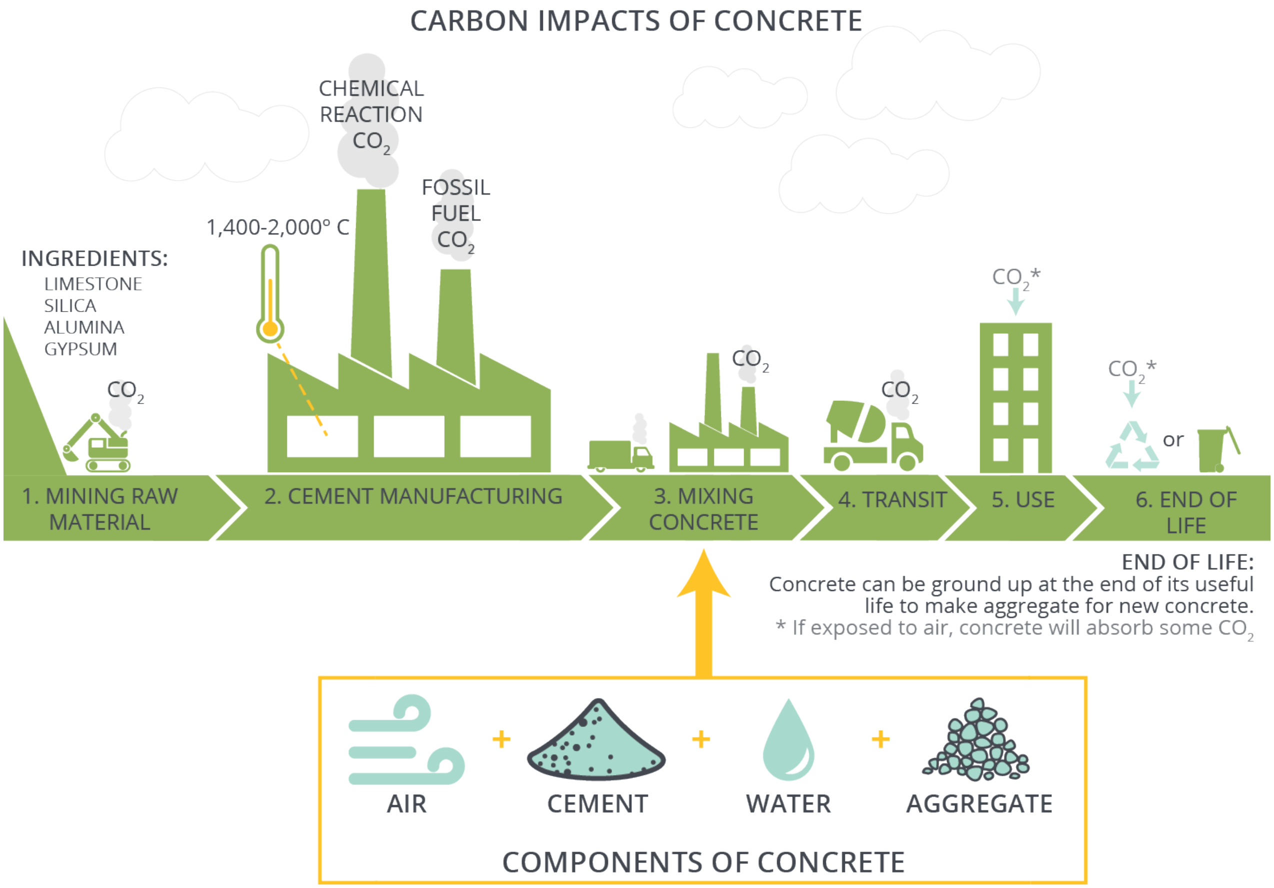
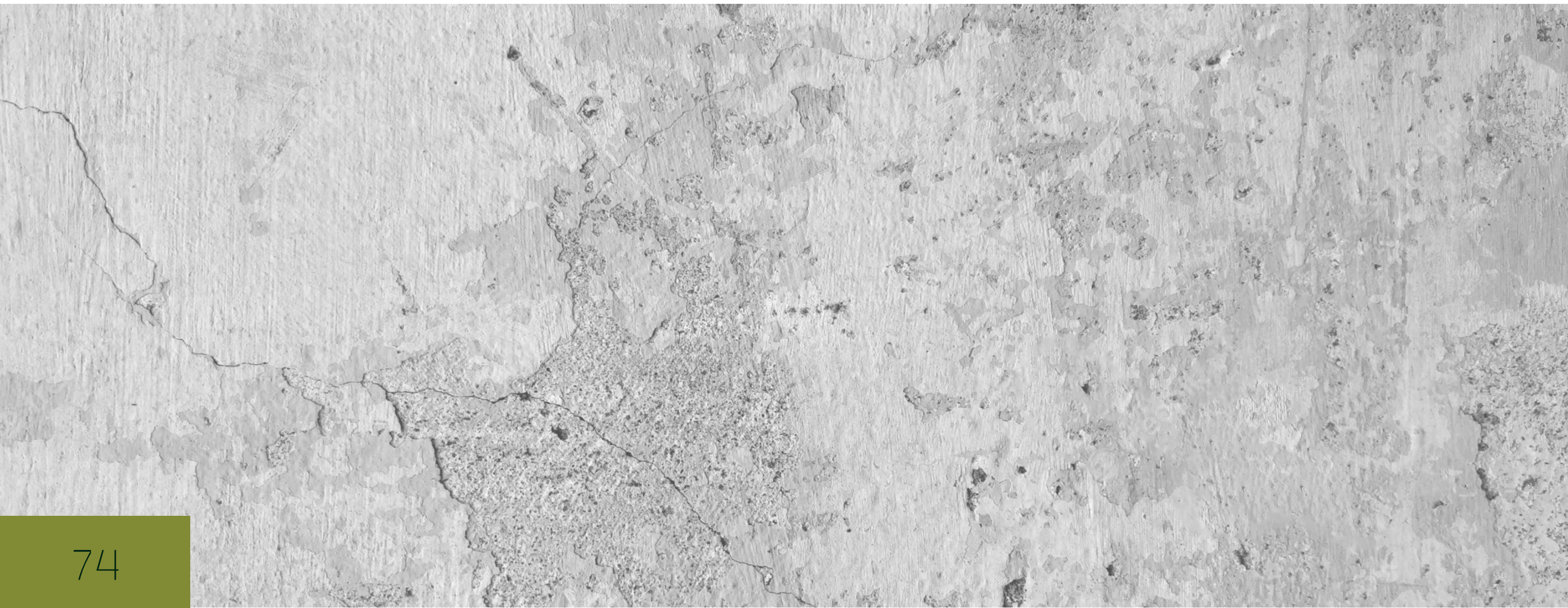

CARBON IMPACTS OF CONCRETE
CHEMICAL REACTION CO_2
FOSSIL FUEL CO_2
1,400-2,000° C
INGREDIENTS:
LIMESTONE
SILICA
ALUMINA
GYPSUM
CO_2
CO_2
CO_2
CO_2*
CO_2*
or
1. MINING RAW MATERIAL
2. CEMENT MANUFACTURING
3. MIXING CONCRETE
4. TRANSIT
5. USE
6. END OF LIFE
END OF LIFE:
Concrete can be ground up at the end of its useful life to make aggregate for new concrete.
* If exposed to air, concrete will absorb some CO_2
AIR
+
CEMENT
+
WATER
+
AGGREGATE
COMPONENTS OF CONCRETE

FIGURE #65



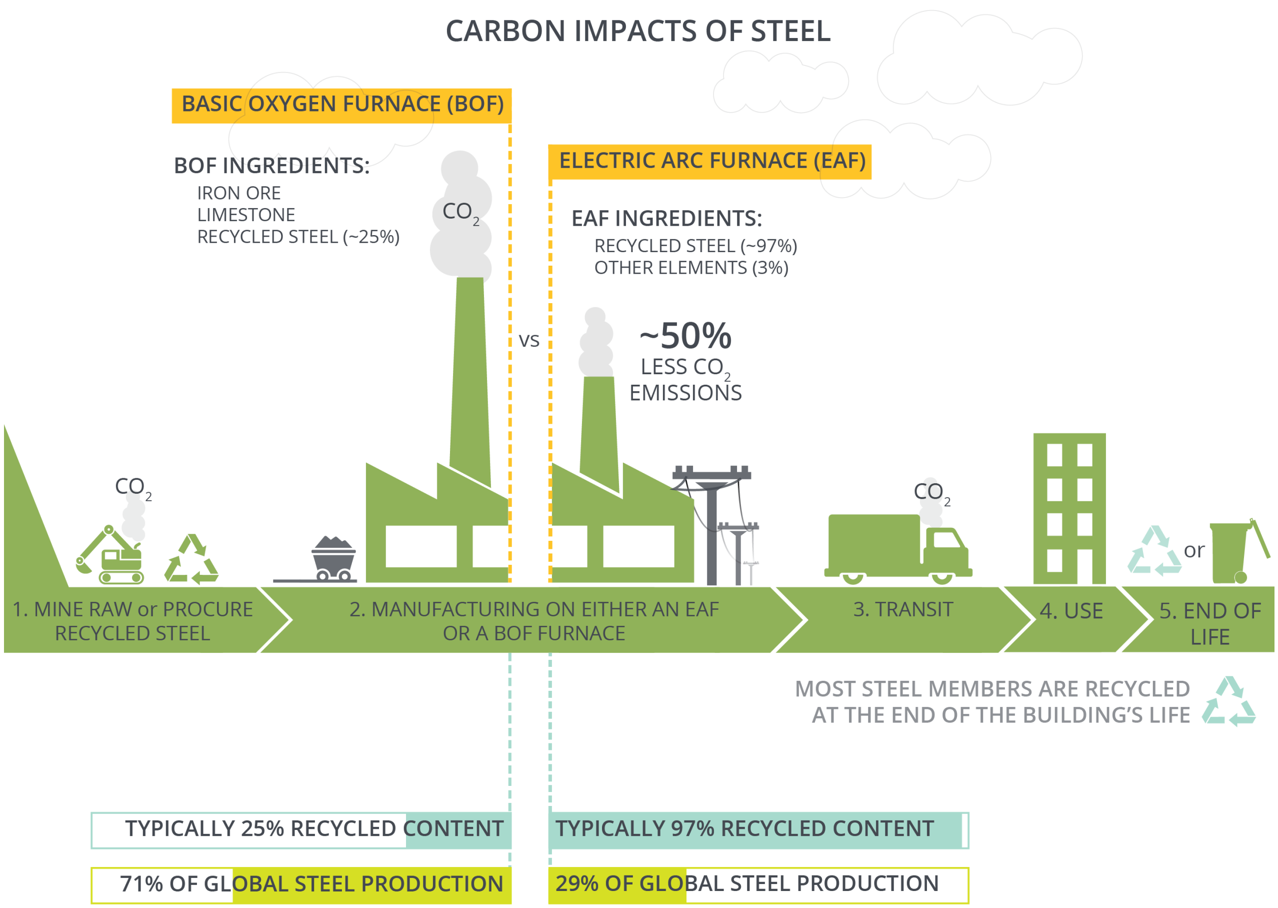

CARBON IMPACTS OF STEEL
BASIC OXYGEN FURNACE (BOF)
BOF INGREDIENTS:
IRON ORE
LIMESTONE
RECYCLED STEEL (~25%)
CO_2
VS
ELECTRIC ARC FURNACE (EAF)
EAF INGREDIENTS:
RECYCLED STEEL (~97%)
OTHER ELEMENTS (3%)
~50%
LESS CO_2
EMISSIONS
CO_2
CO_2
or
1. MINE RAW or PROCURE RECYCLED STEEL
2. MANUFACTURING ON EITHER AN EAF OR A BOF FURNACE
3. TRANSIT
4. USE
5. END OF LIFE
MOST STEEL MEMBERS ARE RECYCLED
AT THE END OF THE BUILDING'S LIFE
TYPICALLY 25% RECYCLED CONTENT
TYPICALLY 97% RECYCLED CONTENT
71% OF GLOBAL STEEL PRODUCTION
29% OF GLOBAL STEEL PRODUCTION

FIGURE #66

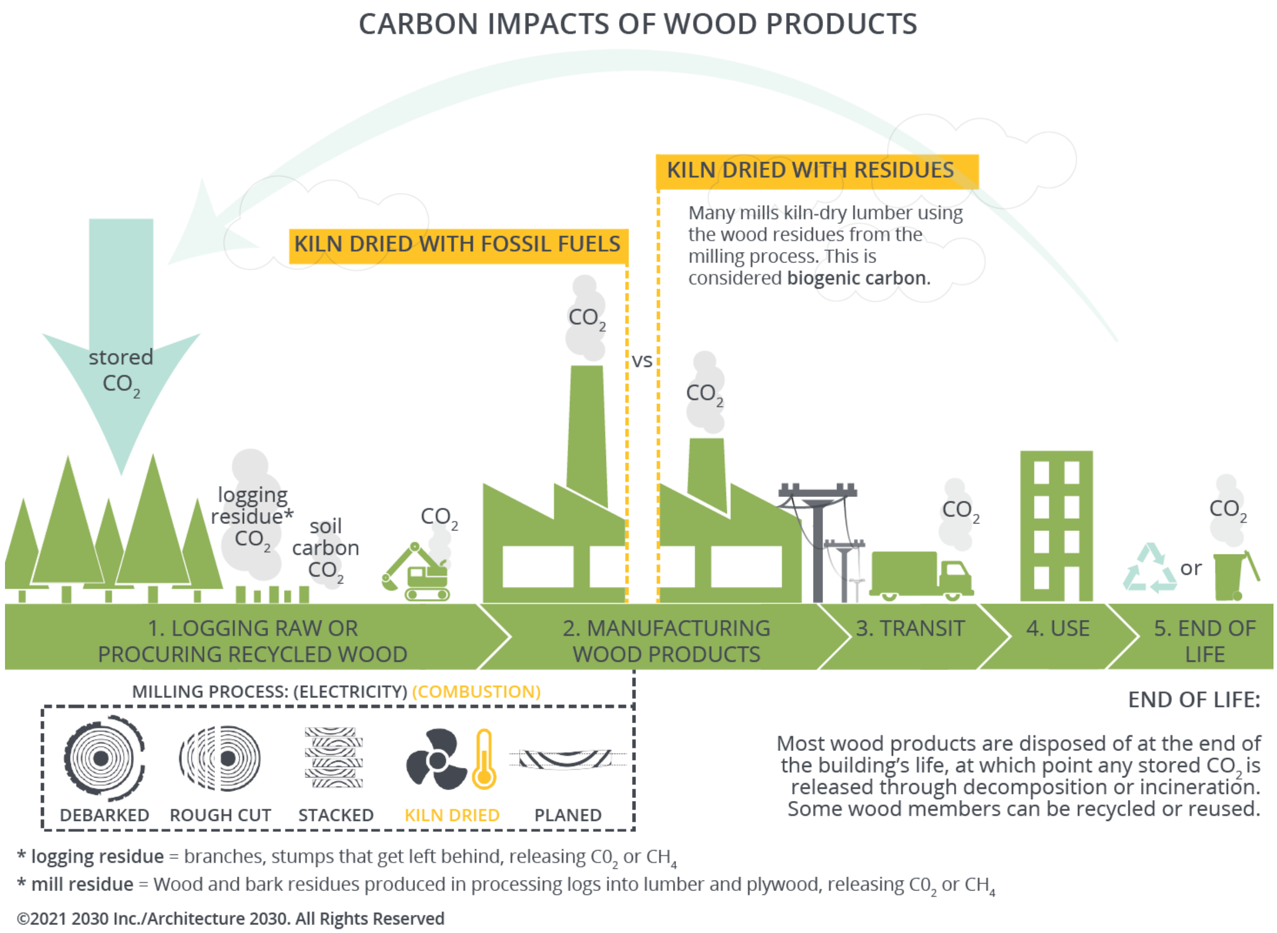

CARBON IMPACTS OF WOOD PRODUCTS
KILN DRIED WITH FOSSIL FUELS
KILN DRIED WITH RESIDUES
Many mills kiln-dry lumber using the wood residues from the milling process. This is considered **biogenic carbon**.
stored CO_2
logging residue* CO_2
soil carbon CO_2
CO_2
vs
or
1. LOGGING RAW OR PROCURING RECYCLED WOOD
2. MANUFACTURING WOOD PRODUCTS
3. TRANSIT
4. USE
5. END OF LIFE
MILLING PROCESS: (ELECTRICITY) (COMBUSTION)
DEBARKED
ROUGH CUT
STACKED
KILN DRIED
PLANED
END OF LIFE:
Most wood products are disposed of at the end of the building's life, at which point any stored CO_2 is released through decomposition or incineration. Some wood members can be recycled or reused.
* **logging residue** = branches, stumps that get left behind, releasing $C0_2$ or CH_4
* **mill residue** = Wood and bark residues produced in processing logs into lumber and plywood, releasing $C0_2$ or CH_4
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FIGURE #67

CARBON IMPACTS OF CARPET

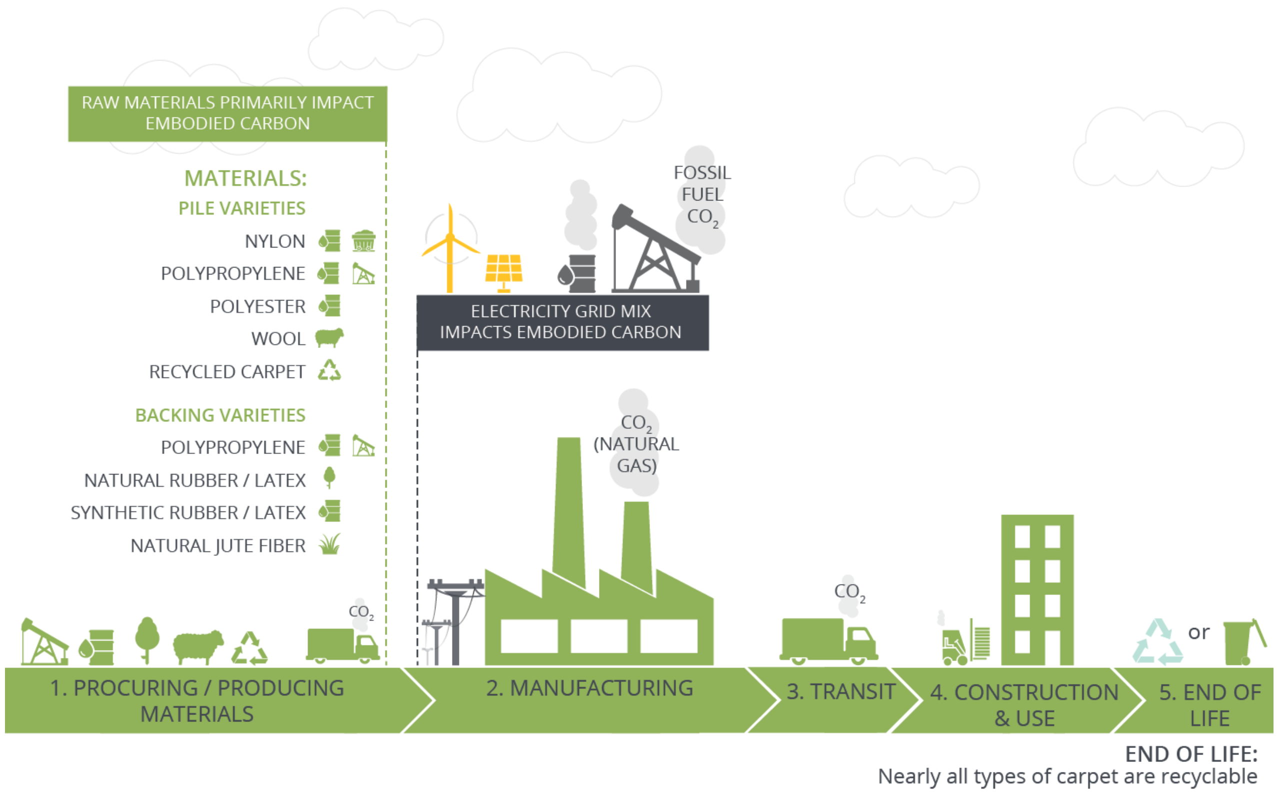


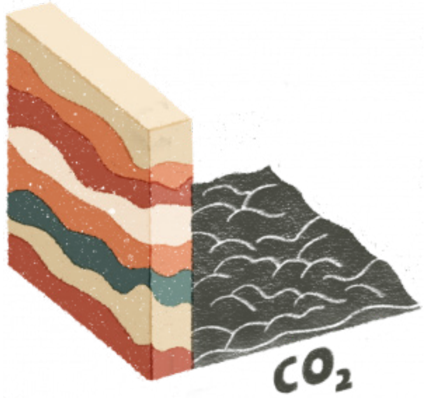
FIGURE #68

AVERAGE EMBODIED CARBON PER CUBIC METER

FIGURE #69

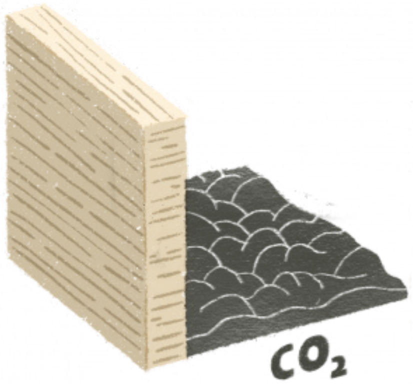
RAMMED EARTH

48 KG



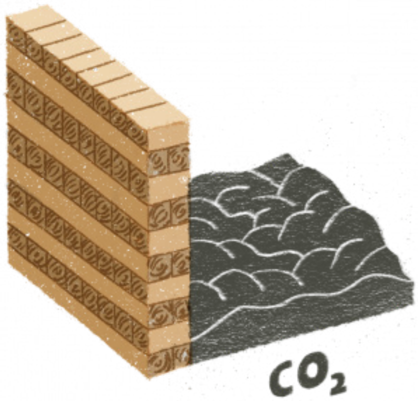
SOFTWOOD TIMBER

110 KG



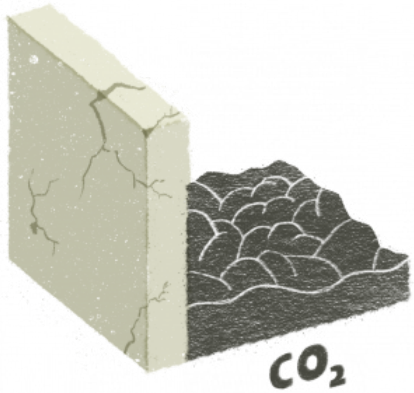
CROSS LAMINATED TIMBER

219 KG



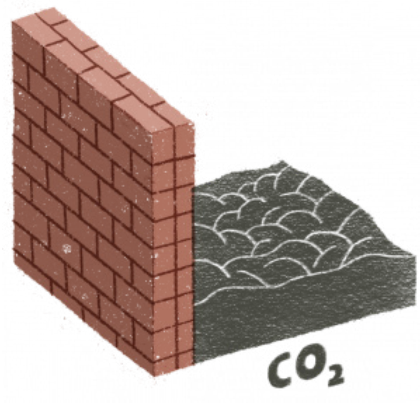
STONE

237 KG



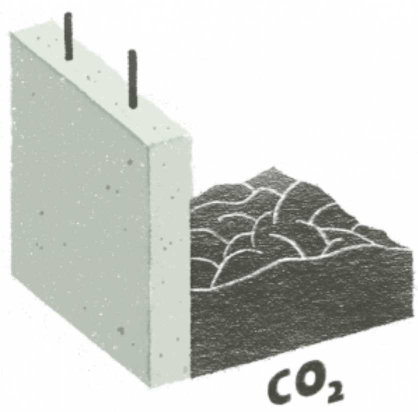
CLAY BRICK WALL

345 KG



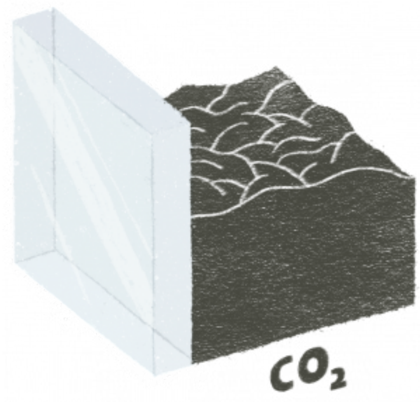
REINFORCED CONCRETE

635 KG



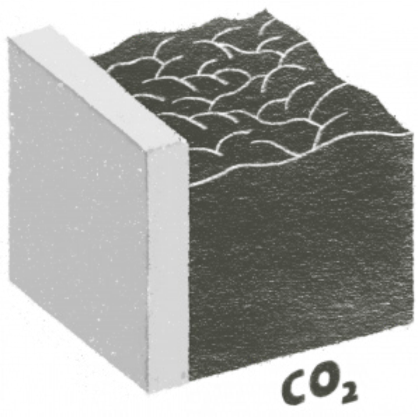
GLASS

3,600 KG



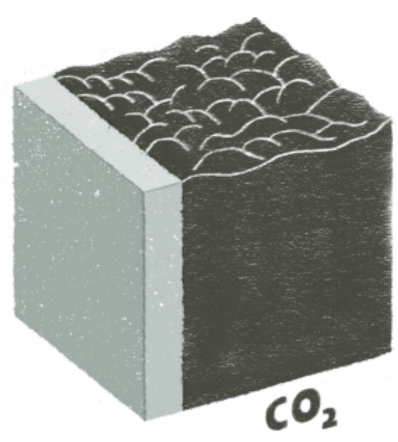
STEEL SECTION

12,090 KG



ALUMINUM

18,009 KG



CARBON SEQUESTRATION CALCULATING METHODOLOGY

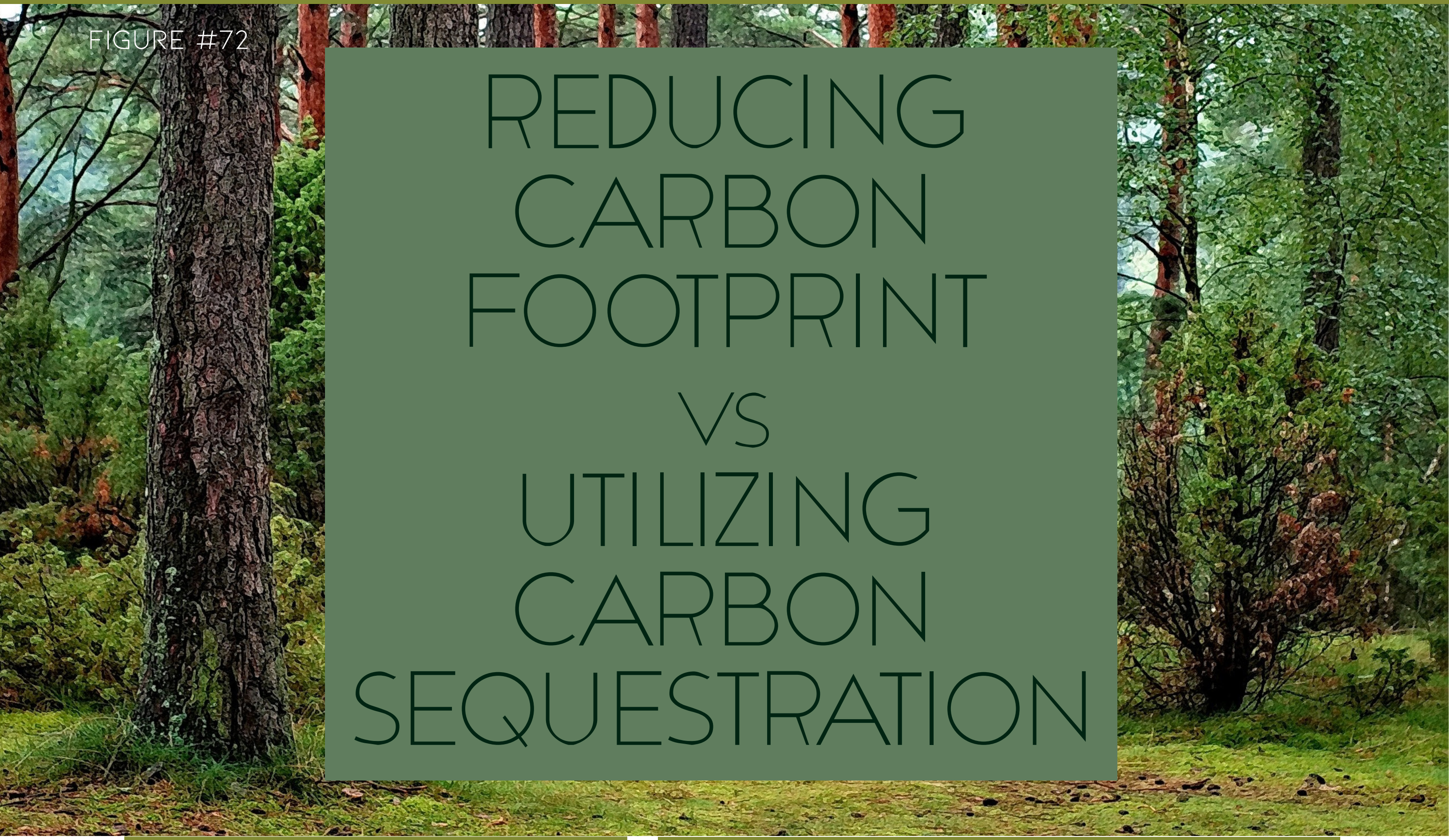
FIGURE #70

FIGURE #71

CARBON SEQUESTRATION IS THE TERM THAT IS USED TO DESCRIBE THE PROCESS OF CAPTURING, SECURING AND STORING CARBON DIOXIDE FROM THE ATMOSPHERE. THE IDEA IS TO STABILIZE CARBON IN SOLID AND DISSOLVED FORMS SO THAT IT DOESN'T CAUSE THE ATMOSPHERE TO WARM.

INTRODUCING MORE VEGETATION TO A SITE IS ANOTHER WAY OF HELPING TO REDUCE THE AMOUNT OF CARBON DIOXIDE AROUND THE SITE.

FIGURE #72



REDUCING CARBON FOOTPRINT VS UTILIZING CARBON SEQUESTRATION

CARBON FOOTPRINT

REDUCING CARBON FOOTPRINT REFERS TO REDUCING GREENHOUSE GAS EMISSIONS CAUSED BY HUMAN ACTIVITIES SUCH AS TRANSPORTATION, ENERGY PRODUCTION, AND INDUSTRIAL PROCESSES. IT INVOLVES REDUCING ENERGY CONSUMPTION, USING RENEWABLE ENERGY SOURCES, AND INCREASING ENERGY EFFICIENCY.

CARBON SEQUESTRATION

CARBON SEQUESTRATION IS THE TERM THAT IS USED TO DESCRIBE THE PROCESS OF CAPTURING, SECURING AND STORING CARBON DIOXIDE FROM THE ATMOSPHERE. THE IDEA IS TO STABILIZE CARBON IN SOLID AND DISSOLVED FORMS SO THAT IT DOESN'T CAUSE THE ATMOSPHERE TO WARM.

INTRODUCING MORE VEGETATION TO A SITE IS ANOTHER WAY OF HELPING TO REDUCE THE AMOUNT OF CARBON DIOXIDE AROUND THE SITE.

REDUCING CARBON EMISSIONS IS A PREVENTATIVE MEASURE - MAKING A CHANGE PRIOR TO CARBON BEING EMITTED WHEREAS CARBON SEQUESTRATION IS A POST EMITTED CARBON SOLUTION - CAPTURING AND TRANSFORMING EXISTING CARBON IN THE AT-MOSPHERE AND TURNING IT INTO OXYGEN.

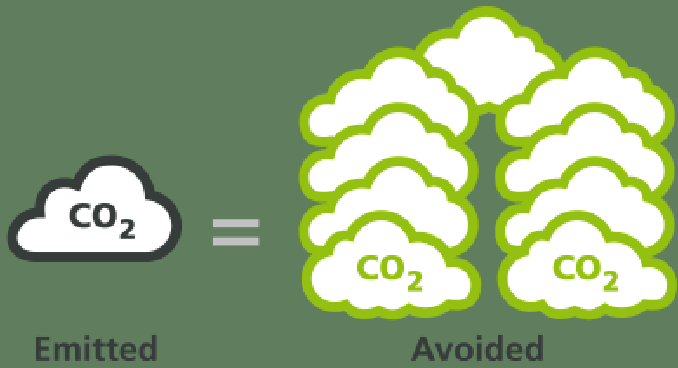


FIGURE #73

1

BIOMASS EQUATION

M = ADB

2

SPECIES SPECIFIC COEFFICIENTS

RESEARCH THE SPECIES SPECIFIC COEFFICIENTS

3

TREE DIAMETER

MEASURE TREE DIAMETER

4

CALCULATE DATA

INSERT DIAMETER (D) AND SPECIES SPECIFIC COEFFICIENTS (A&B) INTO EQUATION

5

CALCULATE CARBON

MULTIPLY BIOMASS BY 1/2, THEN MULTIPLY BY CARBONS WEIGHT - 3.67

FIGURE #74

BIOMASS EQUATION

1

M=ADB

M = ABOVE GROUND BIOMASS (KG) OF TREE

D = DIAMETER OF TRUNK AT BREAST HEIGHT

A & B = SPPECIES SPECIFIC COEFFICIENTS

FIGURE #75

CARBON SEQUESTRATION EQUATION RESULTS USING 4" DIAMETER TREES

WALNUT = .007 KGS OF CARBON

JUGLANS MANDSHURICA: M=0.0001*4^2.63 = 0.0038 KG

.0038 KG * 50% * 3.67= .007 KGS

ASH = .0068 KGS OF CARBON

FRAXINUS MANDSHURICA: M=0.0001*4^2.61 = .0037 KG

.0037 * 50% * 3.67 = .0068 KGS

PINE = .0062 KGS OF CARBON

PINUS KORAIENSIS: M=0.0001*4^2.54 = .0034 KG

.0034 * 50% * 3.67 = .0062 KGS

MAPLE = .00175 KGS OF CARBON

ACER MONO: M=0.0001*4^2.56 = 0.0035 KG

.0035 KG * 50% * 3.67= .00175 KGS

BIRCH = .00175 KGS OF CARBON

BETULA PLATYPHYLLA: M=0.0001*4^2.57= .0035 KG

.0035 * 50% * 3.67 = .00175 KGS

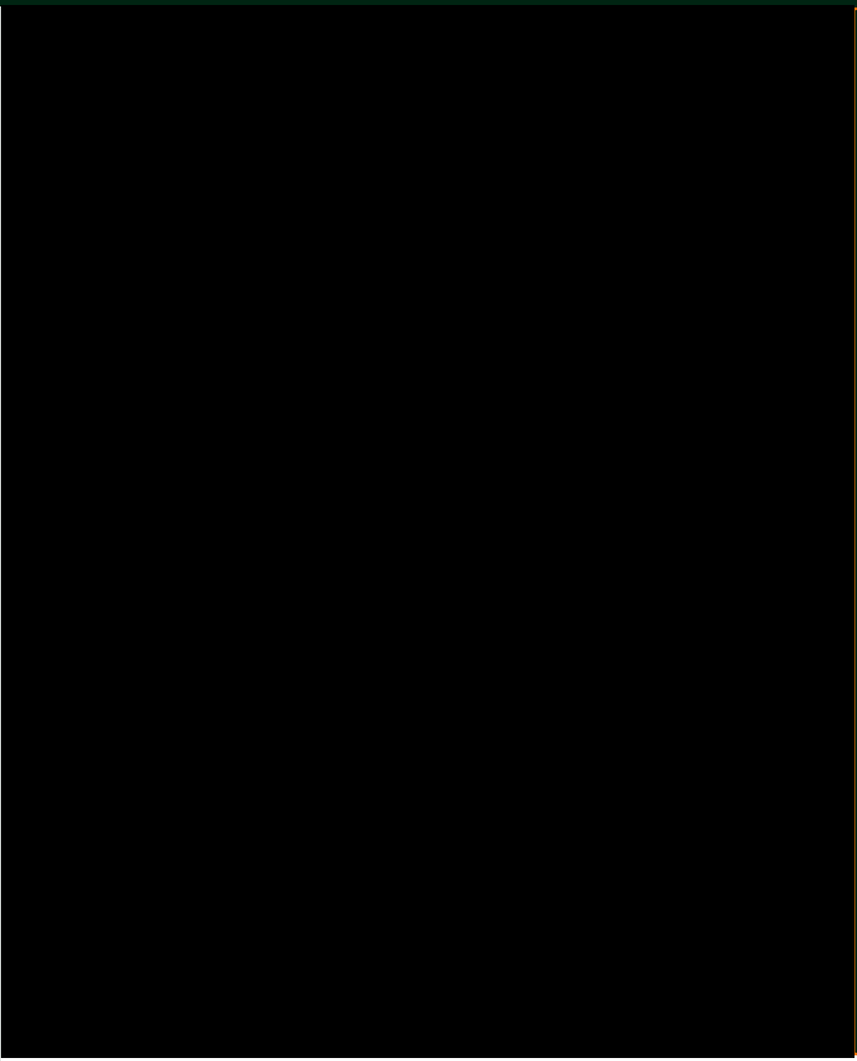
LARCH = .00175 KGS OF CARBON

LARIX GMELINII: M=0.0001*4^2.56 = .0035 KG

.0035 * 50% * 3.67 = .00175 KGS

FIGURE #76

APPENDIX



ABOUT ME

KAITLYN M. KANE

HOMETOWN: NEW YORK MILLS, MINNESOTA

I COME FROM A SMALL TOWN THAT VALUES A STRONG COMMUNITY AND GENEROSTITY. I SPEND MOST OF MY TIME WITH MY FIANCE AROUND HIS FAMILYS DAIRY FARM IN BULTER, MINNESOTA. WE ENJOY SPENDING TIME TOGETHER WHETHER THAT IS HOBBIES LIKE HUNTING, ICE FISHING, TRAPPING, FOUR WHEELER RIDES, AND HANGING WITH FRIENDS OR DOING FARM CHORES. I PREFER THE SIMPLE THINGS IN LIFE AND HOPE TO FIND A CAREER THAT WILL ALLOW ME TO CONTINUE SPENDING TIME WITH MY FAMILY AND LIVING OUTSIDE OF TOWN.

2ND YEAR

FALL 2019:
INSTRUCTOR - RON RAMSEY
ARCHITECTURAL DESIGN 1
BOATHOUSE PROJECT

SPRING 2020:
INSTRUCTOR - MILTON YERGENS
ARCHITECTURAL DESIGN 2
DWELLING PROJECT

3RD YEAR

FALL 2020:
INSTRUCTOR - BAKR ALY AHMED
ARCHITECTURAL DESIGN 3
XXXXX PROJECT

SPRING 2021:
INSTRUCTOR - EMILY GUO
ARCHITECTURAL DESIGN 4
XXXXXX PROJECT

4TH YEAR

FALL 2021:
INSTRUCTOR - CINDY URNESS
ARCHITECTURAL DESIGN 5
XXXXXXX PROJECT

SPRING 2022:
INSTRUCTOR - DAVID CRUTCHFIELD
ARCHITECTURAL DESIGN 6
DWELLING PROJECT

5TH YEAR

FALL 2022 - SPRING 2023:
INSTRUCTOR - GANAPATHY MAHALINGAM
DESIGN THESIS

ACKNOWLEDGMENTS

AS MUCH AS I WOULD LIKE TO TAKE CREDIT FOR EVERY PART OF THIS PROJECT, I KNOW THAT THERE IS NO WAY IT WOULD HAVE BEEN ACCOMPLISHED WITHOUT THE HELP OF MANY OTHERS:

FIRST, TO MY FIANCE,
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SECOND, TO MY FAMILY,
THANK YOU FOR UNDERSTANDING HOW LITTLE TIME I HAD TO TRAVEL AND VISIT YOU. I KNOW HOW MUCH YOU WOULD HAVE LIKED TO SEE ME, BUT YOU UNDERSTOOD THAT IT JUST WAS NOT POSSIBLE WITH MY SCHEDULE. ALSO, THANK YOU FOR ALWAYS SUPPORTING ME IN EVERYTHING I HAVE DONE. I AM LUCKY TO HAVE SUCH A GREAT FOUNDATION FOR LOVE AND WORK ETHIC.

THIRD, TO MY BOSS,
JIM, THANK YOU FOR ENCOURAGING ME TO SEEK MY MASTERS DEGREE. YOU HAVE TRULY MADE MY LAST YEAR OF SCHOOL A BREEZE WITH YOUR GENEROSTIY FROM FINANCIAL HELP, MORAL SUPPORT AND WORK SCHEDULE FLEXIBILITY. YOU HAVE PUSHED ME TO GO FURTHER THAN I THOUGHT I COULD.

FOURTH, TO MY THESIS ADVISOR,
GANAPATHY MAHALINGAM, THANK YOU FOR YOUR ENDLESS WEALTH OF INFORMATION AND HELP WITH THE COMPLICATED PARTS OF THIS PROJECT. YOU ASSITED ME WITH MY RESERACH AND TIMES OF TROUBLE WITH TECHNOLOGY. YOU MADE SURE IT WAS MY PROJECT, BUT YOU HELPED TO POINT ME IN THE RIGHT DIRECTION. I THANK YOU FOR BEING A SUPPORTER OF THE PROJECT AND NOT A CONTROLLER. I ALSO WANT TO THANK YOU FOR BEING WILLING TO TEACH ME REMOTELY. I APPRECIATE THE ADAPABILITY THAT YOU HAVE SO GENEROUSLY PROVIDED.

FIFTH, TO THE FACULTY IN THE ARCHITECTURE DEPARTMENT, THANK YOU FOR PREPARING ME FOR THIS YEAR. EACH ONE OF YOU HAS SHAPED THE DESIGNER THAT I AM TODAY AND WILL BE IN THE FUTURE. IT IS BECAUSE OF YOU THAT I WILL BE SUC-CESSFUL IN THE MY FUTURE.

FINALLY, TO MY CLASSMATES AND FRIENDS, THANK YOU FOR GOING THROUGH THIS JOURNEY WITH ME. I APPRECIATE EACH ONE OF YOU. YOU WERE ALWAYS THERE TO BOUNCE IDEAS OFF OF, KEEP ME ON TRACK, AND ALSO DISTRACT ME. WE HAVE BE-COME A FAMILY OVER THE LAST FIVE YEARS, AND NOW WE MUST ALL GO OUR OWN DIRECTION. I WISH YOU ALL GOOD LUCK AND A SUCCESSFUL FUTURE AND CAREER!

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