Carbon Emissions Education

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Introduction

The proposed application will immerse the user in a virtual world where they will be able to select residential construction materials, vehicles, appliances, and plant trees. The embodied and operational carbon footprint of these choices will be displayed in a UI element (bar) existing in world space, attached to the user's arm. Below the bar will be a button, upon pressing the button a particle effect will simulate the amount of carbon released by their decisions, compressed into the size of the average Australian house. The amount of time the user would be able to survive in this environment will be displayed on the screen.

Being immersed in a virtual space will allow the user to weigh quantitative (amount of carbon released) and qualitative (aesthetic preferences) information at the same time. Additionally, the simulation will allow the easy comparison of this multi-variate data set. The application of the particle effect will humanize the often-abstract concept of cubic meters of carbon.

The application will be a powerful tool for educating both customers embarking on a construction project and construction professionals engaged in the industry.

Description of the Application

The application is proposed to allow users to select different residential building materials and household utilities. Live feedback on the impact these decisions make on the embodied and operational carbon footprint will these decisions imply be embedded in a UI bar. This net carbon footprint will then be the basis for a visual representation of carbon used if these choices were to be implemented in a real-life scenario. This visual representation will be a particle effect, the density of which will be calculated based upon m^3 of carbon used if compressed to the size of the virtual area. This will then notify how long the user would be able to survive in this environment.

The complexity of a home system and the number of these decisions make tracking these decisions in a traditional spreadsheet sub optimal. As elements of a house grow, shrink or are substituted data must be entered, re-calculated and re-interpreted, making comparison of options cumbersome. Additionally, this method also does nothing to engage the user on qualitative information, that of aesthetics.

Our proposal will allow the user to see aesthetic changes in the virtual world. These decisions can be weighed up against their carbon impact. A UI which updates and reacts in real time to design decisions will allow people to engage with the complexity, and volume of data presented in a more meaningful way.

Additionally traditional measures of carbon usage (m^3) are abstract in nature. These measures can be difficult to comprehend due to their vast volume. By compressing what can often be an inhuman volume to a more meaningful scale, that being the average Australian property block (232m^2, Australian Buero of Statistics, 2019) Then relating it to the human desire to continue to live is intended to leave a lasting impact on the user. This implementation is significantly more impactful than traditional methods of conveying this information.

Description of the Interface Solution

The application is required to enable the substitution of numerous materials on numerous building structures, for instance:

Roof	corrugated iron		
Interior wall	hempcrete	Plaster, paint & insulation	Wood & insulation
exterior wall	concrete	wood & paint	masonry (bricks)
driveway	concrete	masonry	gravel
kitchen bench	wood	engineered stone	
floor	carpet	polished concrete	wood

Additionally, the user will have to be able to substitute several home appliances:

Vehicle	large	small	bicycle
Heating	Fire	electric	heat pump
Lighting	LED	conventional	
Solar Panels	Yes	No	

The user will also have the opportunity to plant several trees on their virtual property to see the impact that it will have on their overall carbon footprint.

To accommodate the wide variety of selection the application intends to exploit Virtual Reality's inherent ability to enable the user to directly interact with environments as opposed to having these interactions mediated by complex user interfaces. The user will be encouraged to make these interactions through instructions embedded in picture frames in the world space. These will prompt the user to use the poke interaction to cycle through materials and appliances. These interactions and instructions being embedded in the world space removes the need for cumbersome UI elements which take up both screen real estate and user mental bandwidth. Removing these ensures the user focuses on the information being conveyed by the program.

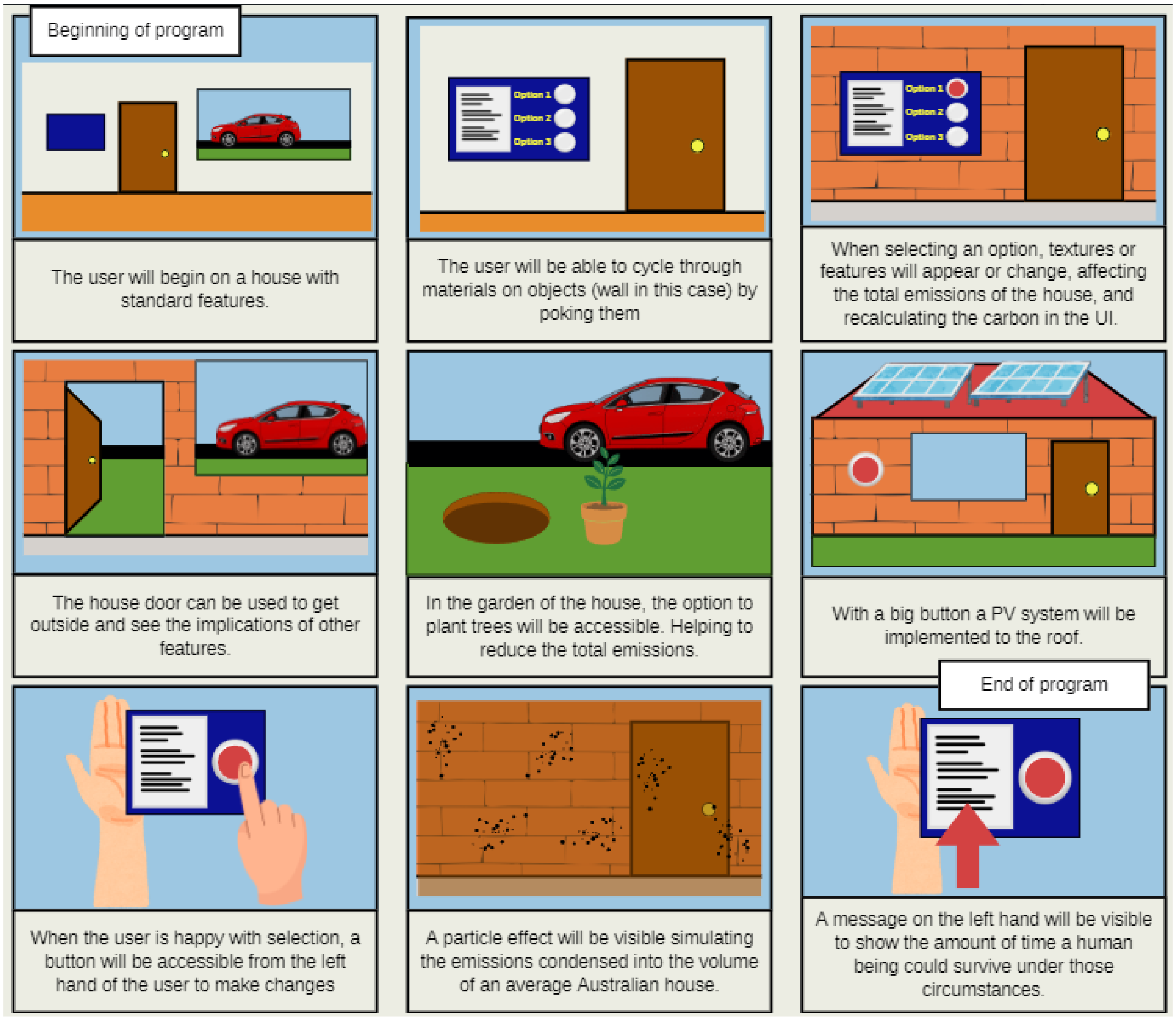
The planting of trees will be conducted with a grab interaction on a sapling. When placed in a designated area (hole) the sapling will grow into a tree. This is an intuitive interaction, simulating the real-life experience of floral cultivation, again removing the need for user bandwidth required for application interaction.

These interactions will ensure the user interface remains minimal, reducing the cognitive load required for engaging with the application. The user interface will be confined to world space, located on their wrist allows the user to be in control of how often they engage with the carbon footprint information. Allowing them cognitive space absorb aesthetic information before being presented qualitive data.

This cognitive space is accentuated by the user being able to explore the virtual world at their will. Additionally, the user being in control of when the final tally of carbon, and the particle effect is executed ensure they are prepared for the display of the final, and most important information.

Being immersed within an atmosphere of compressed carbon will create a claustrophobic environment. This would not be able to be conveyed by conventional means, either digital or analogue.

Interaction Design



This application will contain several VR specific interactions, including pokes, grabs, and interacting with world-space UI.

Firstly, the user will be placed in a small game scene containing the house. Locomotion will be a requirement to traverse this environment as many of the other interactions points in the scene will be separated distance.

Secondly, the various interaction points found across the scene (pokes, grabs, buttons) are necessary to effectively highlight how different materials can influence a household's carbon footprint. Often, information regarding carbon emissions is presented in tables and figures with no real bearing on the average individual's experiences. Therefore, the types of interactivities that VR provides will be critical in grounding this high-level data into a more informationally accessible format.

Finally, the user's ability to activate a visual "simulation" of the abstracted physical representation of carbon as gas and its resulting effects is critical to tie together the other components of the application. Presenting information in this format drives home the physicality of the average household's carbon footprint in a way that would not be possible in the real world without a high risk to personal safety.

Technical Development Planning

This application will be developed in Unity version 6000.0.5f1, utilizing the Meta XR SDK for VR integration. Planned supported hardware includes Meta Quest 2 and 3. To accommodate effective collaboration, Git and GitHub will be used for version control.

The house, all assets and materials will be contained in a house class. This class will contain classes for each asset, e.g. interior walls. These classes have attributes of volume, and material. Materials being scriptable objects. The building will inherit the attributes and scriptable objects of the child classes and will thus be able to access them, for example, House.interior_walls.embodied_carbon.
Each time a material is substituted the UI element, the bar on the right will be called to re-calculate carbon by accessing the members of the building class. This figure will then be displayed.

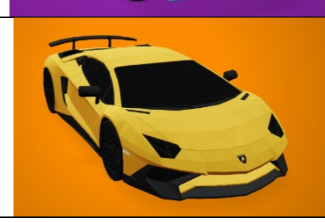
3D Models

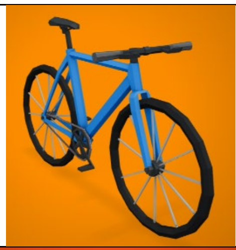
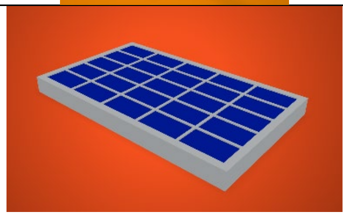
This project focuses on reducing emissions by implementing various 3D models that offer users different options for measuring their carbon footprint. The interface will allow users to select from a range of vehicles, each with distinct emission levels based on their characteristics. It's important to note that a standard car will have different emissions compared to a high-performance vehicle, and a bicycle will have zero emissions.

Similarly, the carbon emissions generated by different housing materials, such as wood, concrete, or others, will be considered. This is crucial since each material undergoes a distinct process that results in varying levels of CO2 emissions. Additionally, the integration of renewable energy sources will be addressed, with the option to install solar panels on the roof, reducing the home's overall carbon footprint. Lastly, the proposal includes the option to plant trees in the exterior area, encouraging homeowners to take this action and highlighting the large-scale positive impact it can have.

For the 3D models, assets were primarily sourced from the website Poly.pizza. This site provides a wide variety of 3D models that are easy to import and have low processing requirements, significantly reducing the time needed for rendering and optimizing the scene before running the program. This efficiency is especially valuable for projects that require quick iterations or operate on limited computational resources, as it minimizes the overhead typically associated with rendering high-poly assets.

The specific 3D models used in our space's creation are listed below, with all corresponding links to these assets provided in the references section. These models were instrumental in creating a cohesive and detailed environment that met the project's requirements without sacrificing performance or increasing processing time. By utilizing readily available assets from Poly Pizza, we were able to streamline the development process and focus on refining other elements of the design.

Name of 3D model	Description	Image
Home blocks home	A group of 3D objects that can be used in various ways to create a virtual space.	
Road Piece Straight	Straight road piece with double yellow lines used for the street.	
Car	Standard car with an internal combustion engine.	
Car Model	High performance car which increases the usage of gas.	

Bicycle	Zero-emission transport for short distances.	
Solar Panel	Implementation of renewable energies which helps to reduce emissions from electricity production.	
Trees	Trees for planting, demonstrating how this action has large-scale and long-term benefits.	

Conclusion

In conclusion, this application aims to provide an experience that encapsulates the abstract concepts of carbon emissions into an easily understood format. This will be achieved by providing the user with various points of interaction designed to inform how changes to aspects of a household affect their carbon footprint. Virtual reality provides the means to convey this information in both a more consumable and pragmatic format, that may not be achievable in other mediums.

Appendix 1 References:

Assets:

Low poly bricks:

https://assetstore.unity.com/packages/2d/textures-materials/texture-pack-bricks-n-blocks-180041

Concrete material options:

https://assetstore.unity.com/packages/2d/textures-materials/concrete/yughues-free-concrete-materials-12951

https://assetstore.unity.com/packages/2d/textures-materials/concrete-plaster-textures-4k-179120

https://assetstore.unity.com/packages/2d/textures-materials/concrete/clean-concrete-texture-37028

House assets:

https://poly.pizza/m/bvLXsDt9mww

Trees:

https://assetstore.unity.com/packages/3d/vegetation/trees/free-trees-103208?aid=1100liZev

Vehicle options:

CAR Model - Free 3D Model By Ignition Labs - Poly Pizza

Car - Free 3D Model By Poly by Google - Poly Pizza

Bicycle - Free 3D Model By Poly by Google - Poly Pizza

https://poly.pizza/m/4qjS9tFhsJg

Road:

Road Piece Straight - Free 3D Model By Zaw Imagineering - Poly Pizza

Embodied carbon DB:

https://circularecology.com/carbon-footprint-calculators-for-construction.html

ABS average floor plan:

https://www.abs.gov.au/articles/average-floor-area-new-residential-dwellings

Standard Kitchen Bench:

https://theinteriorsaddict.com/australian-kitchen-dimensions-standard-sizes-for-every-last-detail

Australian Average Driveway:

https://sqmarchitects.com.au/standard-driveway-width-in-australia/

Appendix 2 Volumetric Calculations:

Exterior Wall:

$$\text{Given the Australian new build floor plan (ABS), the area is:}$$
$$A = 232.3 \text{ m}^2$$
$$\text{To find the side length (s) of a square with this area:}$$
$$s = \sqrt{A} = \sqrt{232.3} \approx 15.24 \text{ m}$$
$$\text{Now, calculate the perimeter (P) of the square:}$$
$$P = 4 \times s = 4 \times 15.24 \approx 60.96 \text{ m}$$
$$\text{Therefore, the side length of the square is approximately (15.24 m),}$$
$$\text{and the perimeter is approximately (60.96 m).}$$

presuming $4m$ high walls and $30cm$ wide the cubic volume of the exterior walls is.

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$$\text{Volume} = \text{length} \times \text{height} \times \text{depth}$$
$$V = 60\,\mathrm{m} \times 4\,\mathrm{m} \times 0.3\,\mathrm{m}$$
$$V = 72\,\mathrm{m}^3$$

Roof:

$$\text{Presuming a } 20^\circ \text{ pitch}$$
$$A_{\text{roof}} = \frac{A}{\cos(\theta)}$$
$$A_{\text{roof}} = \frac{232}{\cos(20^\circ)}$$
$$A_{\text{roof}} \approx \frac{232}{0.94} \approx 246.8\,\mathrm{m}^2$$

Surface area of roof $246.8m^2$

Internal Walls:

$$\text{if the internals have 4 walls and the perimeter:}$$
$$P = 6 \times 15.24 \approx 92.4m$$

$$\text{with a volume of 90mm:}$$
$$\text{volume} = 92.4 \times 0.9$$
$$\text{volume} = 83.16m^3$$

Kitchen Bench:

$$\text{Assuming average dimensions, given:}$$
$$\text{Depth} = 600 \text{ mm}, \quad \text{Height} = 40 \text{ mm}, \quad \text{Width} = 1200 \text{ mm}$$
$$\text{Dimensions to meters:}$$
$$600 \text{ mm} = 0.6 \text{ m}$$
$$40 \text{ mm} = 0.04 \text{ m}$$
$$1200 \text{ mm} = 1.2 \text{ m}$$
$$\text{Calculate the volume } V \text{ in cubic meters:}$$
$$V = \text{Depth} \times \text{Height} \times \text{Width} = 0.6 \text{ m} \times 0.04 \text{ m} \times 1.2 \text{ m}$$
$$V = 0.0288 \text{ m}^3$$
$$\text{Therefore, the volume is:}$$
$$V = 0.0288 \text{ m}^3$$

Drive Way:

$$\text{Assuming average dimensions, given:}$$

$$\text{Width} = 3 \text{ m}, \quad \text{Thickness} = 125 \text{ mm}, \quad \text{Length} = 7 \text{ m}$$

$$\text{Thickness to meters:}$$

$$125 \text{ mm} = 0.125 \text{ m}$$

$$\text{Calculate the volume } V \text{ in cubic meters:}$$

$$V = \text{Width} \times \text{Thickness} \times \text{Length} = 3 \text{ m} \times 0.125 \text{ m} \times 7 \text{ m}$$

$$V = 2.625 \text{ m}^3$$

$$\text{Therefore, the volume is:}$$

$$V = 2.625 \text{ m}^3$$