

# Comprehensive Creative Technologies Project: Simulating the Effects of Climate Change on a Game Environment

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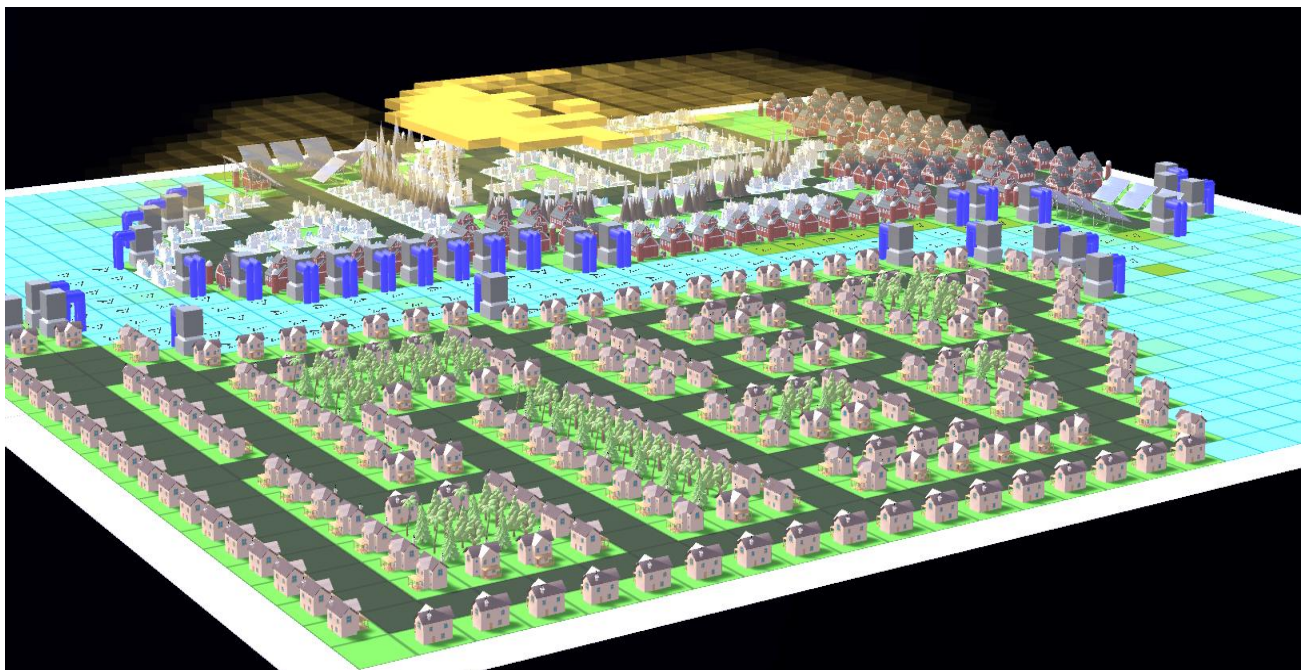
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## Abstract

This project is a simulation that aims to teach the user about how climate change can affect the environment, the city, and its population. This was achieved through the medium of a game where the user controls a city and their decisions have an impact on the environment around them. If polluted water is drunk, the population becomes ill and is unable to work, reducing productivity and overall gain of the city. Food production starts to fall, and the city becomes unable to support the local population. If pollution is left in the air, food production falls due to the Carbon-Nitrogen cycle, solar panels produce less electricity due to smog, and the population becomes ill from unclean air.

**Keywords:** Climate Change, carbon, nitrogen, simulation, city, builder, unity

## Biography

### How to access the project

#### 1. Introduction

Climate Change is an issue that affects everyone and nearly every aspect of daily life (Perry, 2007), and this project aims to simulate its effects on an environment within a game. For this project, a city-builder like design was chosen to give the user a more direct impact on the output of toxic and greenhouse gasses and how it affects their city.

The project originally started as a pure simulation, with the user being able to input values into a system and watch the effects over time. The decision was made to change it into a city builder to have the pollution effect something the user has built to make it more engaging and educational.

The project explores how pollution will affect a population within a city and its components, such as farms, solar panels, and water sources. An example of how the pollution will affect the population is if the water becomes contaminated and is then fed into the city's water system. This will cause residents to become ill and unable to work, affecting work efficiency and food production in the farms. This is indicative of Flint, Michigan (Zahran, 2018) and the Legionnaires disease outbreak that occurred due to the local government beginning to supply the residents with polluted water from the river (Denchak, 2018).

The project aims to educate about the effects of climate change in an engaging way through a medium that is accessible to as many people as possible.

#### Project Objectives:

- Simulate effects of climate change in a city environment
- Educate users on how pollution will affect a city

#### Deliverable:

- A city-builder game that simulates climate change and its effects on the city built.

#### 2. Literature review

##### Literature review – 2.1 – Rice and Wheat production

An increase in global temperatures and CO<sub>2</sub> levels have raised numerous concerns about food

production and the consequences of climate change on farms. In a study conducted in Bangladesh, Amin (2015) found that certain types of rice, such as Aman Rice, became greatly influenced by climate conditions when rainfall amounts are changed and exposure to sunlight, along with temperatures, is both increased and decreased. These reduce both the yield and cropping area of the Aman rice, significantly affecting the total production of that type of rice.

However, in contrast, Aman rice is positively affected by humidity in terms of both cropping area and yield. Other types of rice, such as Boro rice and wheat is also affected by an increase in maximum temperature, however, both minimum temperature and sunlight exposure seemed to increase the yield of Boro rice significantly.

##### Literature review – 2.2 – Water pollution

Water pollution is harmful to both humans and the environment, as it is a prime breeding ground for diseases such as Legionella (Zahran, 2018) and Cholera (Frerichs, 2021) where several pandemics have taken place due to the deadly disease, and only being linked to dirty water in 1854 by Professor John Snow. These diseases are caused by the consumption of infected water, usually caused by pollution or dirty water sources. These diseases can be deadly to human, but water pollution also affects the aquatic animals and the ecosystem, with some fish becoming unable to find food or dying from illness, or plants unable to photosynthesise due to pollution blocking sunlight (See Fig. 1 below).



**Fig 1:** Pollution in a Lake (Sourced from History.com)

The vast majority of sea life that people rely on is also affected, with one being coral reefs (Gibson et al., 2008) and the bleaching effect climate warming is having on them, where the corals slowly start to lose colour and eventually die, leaving fish without shelter or reliable food sources and subsequently destroying the ecosystem.

### Literature review – 2.3 – Wildlife & Habitation

Humans rely on animals and wildlife for a large percentage of our agricultural resources (Ritchie, 2017) at around 80%. During 2019 and into the start of 2020, an Australian wildfire during the wildfire season grew out of control, leaving a devastating trail of burnt forests and fields, and killing or displacing nearly 3 billion animals (Slezak, 2020). Many links have been made about the start of the bushfires and why they spread so quickly to climate change and its effects on Australian weather. On average, the “fire season” in Australia has been 1C hotter than usual and set a new record of 41.9C (BBC, 2019)

The wildfires also released an estimated 300 million tonnes of CO<sub>2</sub> into the atmosphere (Lee, 2019), which can contribute to global warming and other issues, such as around 450 people died because of smoke emissions from the bushfires (Hitch, 2020).

### **3. Research question**

#### Research Question - 3.0 – Overall question

What effects will simulating Climate Change have on a game environment?

#### Research Question – 3.1 – Water

When trying to answer the overall question, it can be split into smaller questions for each part of the project. The first will be:

- What effects will pollution have on water?

This question can also include:

- What will the effects of the polluted water be on the user?

As water is an important part of a city, furthermore water is one of the most affected aspects by climate change in the world.

#### Research Question – 3.2 – Agriculture

Another important section is agriculture, and how the project can show its effects through the medium:

- How will pollution affect food growth?

- What effects will this have on the city and the player?

Food growth is essential when building a city, and keeping its populace happy, and these questions can link to the previous questions involving water pollution, as some places in the world rely heavily on fishing for food sources and in some cases, is a large part of the economy.

#### Research Question – 3.3 - Air

Climate change is primarily caused by air pollution from gasses like CO<sub>2</sub>, where it is causing our planet to warm each year, having unpredictable effects on all aspects of life:

- How will air pollution affect the game environment?
- What effects can air pollution have on the city?

Air pollutants can often cause breathing problems and can even cause death in extreme cases, all the while heating the oceans causing sea levels to rise.

### **4. Research methods 400w**

### **5. Ethical and professional principles 350w**

### **6. Research findings 600w**

### **7. Practice**

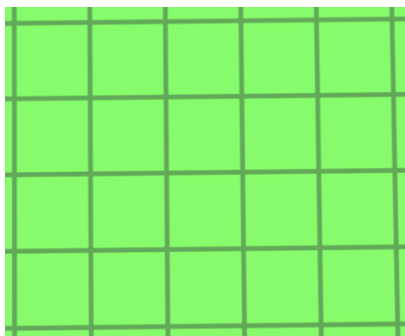
The project was created in Unity, as the scripting interface was thought to be the best method to creating a city-builder like game. Previous games, such as Cities: Skylines (Paradox Interactive, 2015) were also developed using Unity, as Unity can support a significant number of objects on screen at one, beneficial for playability and stability.

#### **Practice – 7.1 – Player Control**

##### Practice – 7.1.0 – Dividing the world

For the user to be able to place buildings in the world, the world is divided up into squares that are 1x1 in size along a 2D plane. This was achieved through the use of `Mathf.CeilToInt`, which rounds the position of the mouse to the nearest integer, and having the scale of the tiles by 1 by 1 using Unity's position system, creates a grid-like system where the player is only able

to place buildings on each tile, where each tile is a visual indication of the grid.



**Fig 2:** The tile-in-grid system

```
public Vector3 GetCurTilePosition()
{
    plane = new Plane(Vector3.up, Vector3.zero);
    ray = cam.ScreenPointToRay(Input.mousePosition);

    if(plane.Raycast(cam.ScreenPointToRay(Input.mousePosition), out rayOut))
    {
        newPos = ray.GetPoint(rayOut) - new
        Vector3(0.5f, 0.0f, 0.5f);
        return new Vector3(Mathf.CeilToInt(newPos.x),
        0f, Mathf.CeilToInt(newPos.z));
    }

    return new Vector3(0, -99, 0);
}
```

Using the code above, a placement indicator is then moved around the map to indicate where the player wants to place a building.

#### Practice - 7.1.1 - Placing buildings

To place buildings, a prefab system was decided upon to store individual properties about the buildings themselves, for example: how many people can live in it, how much food it produces etc.

A scriptable object was created and was made so that it can be accessed from the asset viewer, this allowed for building pre-sets to be created using prefabs and individual values to create the object in the game. Using the grid, buildings are placed using a selector object to select a square in the grid to place in the scene. One issue that arose from this was that buildings were able to be placed on top of one another, leading to the possibility that a square can contain an entire city worth of buildings. To circumvent this, buildings were added to a dictionary with their location (Vector3) as the key.

```
public Dictionary<Vector3, GameObject>
buildings = new Dictionary<Vector3,
GameObject>();
```

When placing a building, the dictionary is queried as to whether or not it contains the desired

location for a new building to be placed, and if it does not, the building can be placed on the tile provided the tile does not contain water and the tile is within the city limits.

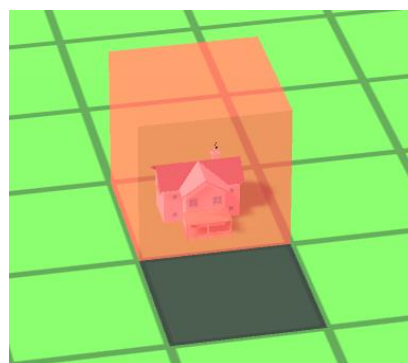
#### Practice - 7.1.2 - Limiting building locations

Due to the choice of how the map is structured, and considering city limits, buildings should only be able to be built on ground tiles. When placing a building, a series of checks take place to make sure whether or not the building can be placed on the desired tile. The player must have enough money, and the building must not be placed over the border or the water. This is again achieved through the use of Dictionaries, where each tile is set into a dictionary at the start of the game and is then accessed through the use of a singleton that oversees different aspects of the city.

Originally, this was done by a ray-cast from the user's cursor to detect a ground tile, this proved to be inefficient later on due to other aspects of the project requiring the dictionaries that contain the different tiles, so the ray-casts were removed out of performance consideration and replaced with dictionary checks.

#### Practice - 7.1.3 - Removing buildings

When planning for later features, such as buildings being abandoned if requirements are not met, these buildings will need to be removed. Using the same script as the placement, if a button is pressed on the tool-bar, the indicator becomes red and then whichever buildings are clicked are removed, this was achieved with the same method to check if there is a building on a square – by querying the dictionary and returning the corresponding GameObject at that location.



**Fig 3:** The delete indicator over a building

Buildings are removed from the game via the Destroy function and are then removed from the dictionary in the case that it is queried on if that GameObject still exists, where it would return an error.



### Practice – 7.1.4 – Building orientation

Originally, buildings could be placed anywhere with only one rotation possible (the rotation of the prefab). A choice was made to have buildings be required to face roads, where buildings can be rotated using the building placer, and a visual indicator on which way the building is facing is provided. When a building is placed, the dictionary containing all buildings is queried, and it checks for the current position + 1 in the direction that the building is facing.

This was originally implemented as a ray-cast and set to only collide with road objects. After the dictionaries were introduced, it was thought to be best practice to change to a dictionary search to match the rest of the project.

## **Practice – 7.2 - Pollution**

### Practice – 7.2.0 – Creating pollution

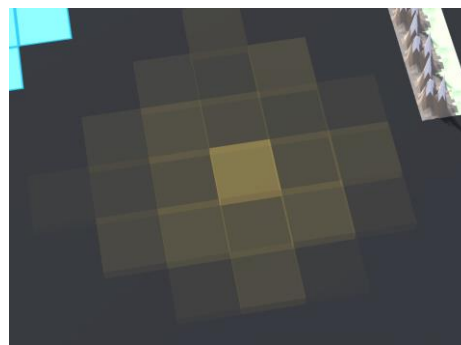
To visualise pollution, using particles to create a fog effect was an option that was considered, however it proved to be too taxing towards the performance of the project and was difficult to have spread in the desired manner.

Thus, using the Unity 3D object “cube” to represent pollution above the tiles on the map. This, however, set up a roadblock where the original idea was to change the transparency of the block via applying a material to each cube and editing it. This caused every block with the material to change transparency at the same rates.

```
_renderer.GetPropertyBlock(mpb);
mpb.SetColor("_Color", new Color(0.9f, 0.7f, 0.2f,
currentPollution / maxPollution));
_renderer.SetPropertyBlock(mpb);
```

To be able to set each individual block its unique material properties, such as transparency, the direct use of the renderer is required, where the renderer is called and returns the material property block of the object. This creates an instance of the material that can be edited to be given its unique transparency value. It is then passed back to the renderer and each block can have unique transparency.

Pollution tiles are made as children of the map tile they represent, this choice was made to simplify accessing other components from within the pollution, this is especially useful when polluting the water via air and rain. Pollution also moves with the wind, where the wind direction is generated between every 7 and 10 turns and is random. The pollution will slowly move in the direction of the wind, and if the wind is still, it will slowly spread out to the surrounding tiles.

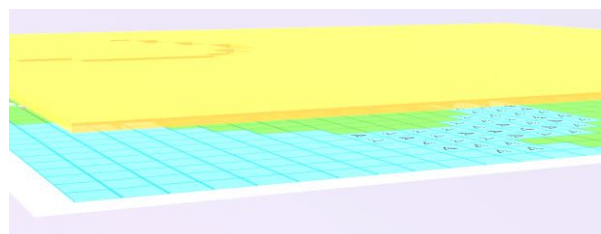


**Fig 4:** Showing the pollution spread to other tiles (ground tiles disabled to help visibility)

After discussion with the supervisor, mountains were added as a way to prevent pollution from spreading over them. This was in consideration for playability and planning. The mountains can be seen in Fig 4 in the top right and their effect can be seen in Fig 5 on the left where there is a gap in the pollution layer.

### Practice – 7.2.1 – Interacting with pollution

Having the pollution interact with the world, the total pollution for a tile had to be given a value. During the creation of the material in 7.2.0, the maximum value of 256 was decided upon due to the material using values of 0-255 for R, G, B, A in the editor. Although, when translated to scripts, the engine preferred a float between 0 and 1. This is again seen in section 7.2.0 where the colours are set as 0.9f, 0.7f, and 0.2f to create a brown-yellow colour.



**Fig 5:** The pollution clouds above the map.

A maximum value allows for the division  $\text{currentPollution} / \text{maxPollution}$  to give a float value between 0 and 1. This is then used to interact with the map and buildings. An example is when a solar panel has a large amount of pollution above it, where it can decrease efficiency by up to half depending on the density of the pollution above.

$$\text{Efficiency} = \text{maxProduction} / (1 + ((\text{currentPollution} / \text{maxPollution}) / 2))$$

Pollution will also affect the growth of food from farms, where a similar formula to that which is shown above is applied. This is to represent the findings of Amin (2015), although exaggerated for the purpose of the project and its target goal.

### Practice - 7.2.2 – Water pollution

In order to capture how pollution moves through a body of water, each water was given an enum containing 5 values; north, south, east, west, and still. These values determine the direction of flow for the water and how pollution will move throughout the body of water. For example: if a tile is set to “still”, the pollution contained within that tile will slowly spread to each neighbouring tile, unlike a tile set to “south” where pollution will only move to the tile to the south.

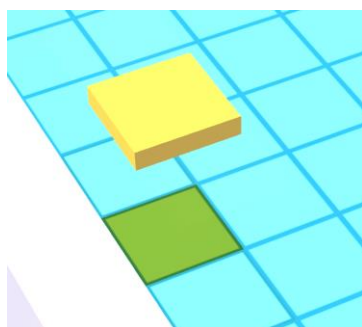
Visualising that a water tile contains pollution is set up in a similar fashion to how the air tiles display pollution – using the renderer and material property blocks.

```
g = 1.0f - (currentPollution / (maxPollution / 4.0f));
if (g < 0.5f)
{
    g = 0.5f;
}

b = 1.0f - (currentPollution / (maxPollution / 8.0f));
if (b < 0.0f)
{
    b = 0.0f;
}

_renderer.GetPropertyBlock(mpb);
mpb.SetColor("_Color", new Color(r, g, b, 1.0f));
_renderer.SetPropertyBlock(mpb);
```

The code above is slightly different when compared to the code used for air pollution, also both share the same principle of editing the material property block at runtime. Air pollution uses a material and sets its transparency, whereas the water material has a colour change applied to it to visualise pollution on that tile. Checks are also made to make sure that the B and G values do not go below certain values, for B this is to keep the colour at a more distinguishable level, whereas for G this prevents the value for the colour going into the negative which produced some undesired effects.



**Fig 6:** A water tile with pollution compared to surrounding tiles to highlight the change in colour.

For air tiles to pollute water, if an air tile contains sufficient pollution a check is made to see if it is currently above a water tile. This is achieved by checking if there is a component in the parent of

the air tile that matches “Water”, and pollution is then transferred to the water tile from the air tile.

Two other methods that were explored early on during the creation of the project were polluting water from nearby factories and a sewage outlet for waste from buildings. These proved difficult to add and were unreliable when trying to find the tiles that they were required to pollute. These originally used ray-casts to find the object, thought would occasionally return null and cause an error, or would select the wrong tile. After switching to the dictionary system, this could be reexplored in further development of the project.

### Practice – 7.3 – Key aspects of the project

#### Practice – 7.3.0 – The City

Most values for the city are calculated at the end of each turn. The decision to have the project a “turn-based” simulation eases the demand on hardware and also allows for more emphasis on the parts of the project that focus on pollution and climate change.

The city itself is created as a singleton object within the game manager, where the dictionaries for tiles and buildings used within other scripts are stored and accessed. This allows for all of the values to be accumulated at the end of each turn, and for resources to be distributed amongst each building. Each key value is displayed to the user through a HUD (Heads Up Display).

One flaw with this design is that resources are distributed between buildings in the order in which they are added to the dictionary. An example of this is if the city does not have enough water, buildings placed most recently will always run out of water first, regardless of the distance between them and the water pump. The ideal design would be for buildings furthest away from the water pumps to run out of water first, and the closest last.

#### Practice – 7.3.1 – The City’s interactions

Each building has its own needs, such as water and electricity. Houses also require clean water and food, and if these needs are not met a warning indicator appears above the building.

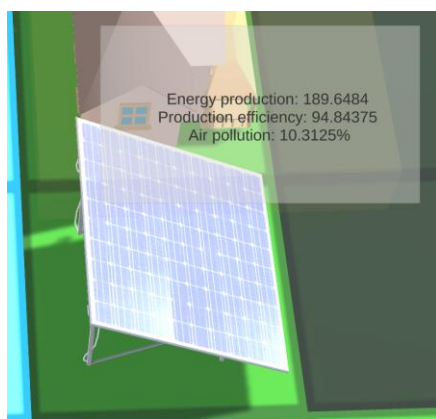


**Fig 7:** Warning symbols above buildings

If the needs are not met within a certain time (currently 20 turns), the building becomes abandoned and does not generate any resources for the city. Likewise, if a house is provided with dirty water, the population of that house slowly becomes ill and unable to work, reducing income for the city. Dirty water is collected through water pumps that are facing polluted water, where the amount of polluted water they accumulate depends on how polluted the water tile is.

### Practice – 7.3.2 – Tile information

To make the project more interactive for the user, a function to retrieve and display certain information about a tile was added to the project. Using the middle mouse button (pressing the scroll wheel), the user can bring up a panel that displays the information gathered about a tile. Through string.format, the info panel retrieves information about the object through the use of a ray-cast from the tile the cursor is over depending on what building or tile there is.



**Fig 8:** Displaying information about the solar panel tile.

Fig 8 shows the information panel displaying the energy production of the solar panel along with the current pollution over that tile. As discussed in 7.2.1, the pollution affects the overall energy production of the solar panel.

$$\text{Efficiency} = 200 / (1 + (0.103 / 2)) = 189.6$$

This is displayed as a percentage efficiency instead of showing the loss in production. This is the same as showing pollution for a tile as a percentage rather than a flat value as it provides a more accurate representation of the data for a tile and is easier for the user to understand.

## **8. Discussion of outcomes**

The initial concept for the project was to have it as a simulation where the user can change specific values, such as temperature offset and CO2 pollution in the air, where each value would affect

specific parts of the simulation. After the initial build, it was decided that the best path for the project would be to turn it into a game environment with the player being able to directly influence aspects through their decisions.

The end product took the path of a city builder project with climate change and pollution aspects in and have the effects of their decisions and building choices show over time. This makes the project more engaging and investing for the user, although some degree of authenticity is lost as certain parts, such as the effects on farms, have to be emphasised more than real world examples (Amin, 2015) to engage the user more within the game environment.

### Discussion of outcomes – 8.1 – Objectives

The projects primary goal was to answer the question stated in 3.0. To achieve this, the goal was split into smaller milestones such as water, agriculture, and air pollution. The project itself explores all 3 categories to the extent where each aspect can be affected by the user's choices and playstyles and have those effects tie back in with the core gameplay loop.

Air pollution, being the first problem tackled, fit into the theme of the project well, where each individual grid tile has its own unique values and has the ability to spread pollution towards other tiles. This was a feature discussed with a supervisor in the early stages of the project, though initial methods struggled to produce desired results, as the project progressed the move from using ray-casts to using dictionaries helped greatly in organisation, reliability, and resource management.

Overall, air pollution seems to have achieved its target in both visual and practical effects, where the user can clearly see the pollution of a tile through both visual indication and the tile information panel. Air pollution also interacts with components of the world and the city, such as water tiles and solar panels in the desired way, although exaggerated for the purpose of the project.

Similar problems began to arise with water pollution and setting up the orientation with stream tiles. Using ray-casts, it was difficult to reliably return a desired tile, as both the ground and water tiles consist of plane objects which have no value on the height, which made ray-casts occasionally miss their target and return tiles that were not intended. This was circumvented by once again using a dictionary, however there are other (possibly more efficient) ways to achieve this goal.

Water pollution was eventually achieved and produces desired effects on the population of the

city, such as drinking dirty water makes residents ill. In the original plan for the project, water pollution had a significantly greater impact on how the player interacts with the body of water. One example of this was the attempt to add coral reefs and fishing dependencies for the city, where water pollution would affect the total output and would eventually kill off the coral reefs reducing sea population and food income (Gibson, 2008).

The effects of pollution on the agricultural aspects were achieved, though became difficult to balance and represent in a turn-based city-builder. Whilst the overall growth and gain from farms was affected based on the amount of people working at said farms and the pollution above farms, it had to be over-exaggerated quite extensively to fit into the balance of the game and have its effects impact the user more severely. This decision was made based on research conducted by Amin (2015) where they saw an annual decrease of yields of around 2-3%.

When looking at the agricultural aspect, it is clear it achieved the desired outcome in a manner that effects the user based on their decisions. However, it could be tweaked further to more accurately represent how pollution and climate change actually affect farming and agriculture, though it will be a difficult task to balance it within the game environment.

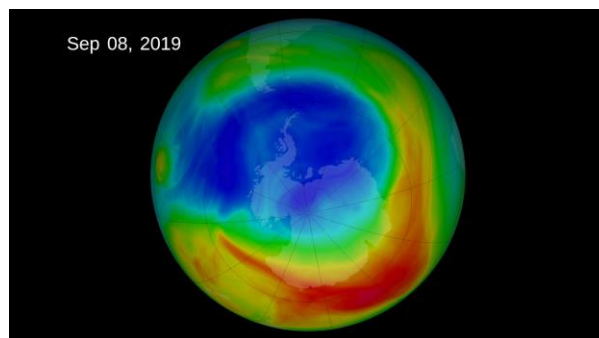
#### Discussion of outcomes – 8.2 – Future improvements

To expand and improve further upon the project, there are many different aspects that can be changed, added, and adjusted to provide a better learning experience for users.

#### Discussion of outcomes – 8.2.1 – Air pollution

In a discussion with the supervisor, it was brought up that there could be different types of air pollution that have effects on different aspects of the project.

CFCs (chlorofluorocarbons) is one such pollutant discussed, where a hole in the ozone is caused by the chlorine when separated from the CFC, the chlorine then breaks the O<sub>3</sub> (ozone) down into CH<sub>3</sub> and O<sub>2</sub>, depleting the ozone. This is harmful to humans as the ozone helps protect against harmful UV light from the sun. One way this could be added to the project is as a separate layer above the pollution layer, where a hole will begin to open if the buildings use CFCs. This poses a new choice to the user, whether to let the ozone deplete and risk the health of the citizens or try to reduce the use of said CFCs.



**Fig 9:** An image showing the density (red – high, blue low) of ozone over the Antarctic. (Sourced from Nasa.gov)

Another potential candidate is smog, where smog can cause potential breathing and health problems, and in some cases lead to death in the case of Ella Adoo-Kissi-Debrah (BBC, 2020).

When adding to the project, smog can have multiple effects such as affecting citizens health and their ability to work, as well as clarity and solar panels ability to generate energy from the sun.

#### Discussion of outcomes – 8.2.2 – Water pollution

During the initial proposal of the project, there were several aspects to water pollution that were discussed but not added to the final project.

Coral Reefs are a large part of why water pollution is a growing problem, with coral bleaching (Gibson, 2008) becoming even more of an issue. The initial idea was to add coral reef tiles to the bodies of water and have the player able to build fishing colonies along the beach and waterfront.



**Fig 10:** Coral bleaching over the course of a year (Sourced from oceanactionagenda.org)

Fig 10 shows the events of coral bleaching, and how it can affect huge bodies of water due to rising temperatures. To be an impactful addition to the project, food sources can be derived from the coral reefs and oceans, where the amount of food produced would decrease as the coral bleaches over time due to pollution and temperature increase.



## 9. Conclusion and recommendations

The project along with this paper shows that it is possible to simulate the effects of climate change within a game environment, where each aspect can be altered and has its own effect on the environment and is all caused by the players decisions. As it stands, data is not accurately represented through the project as in a game environment, it is difficult to capture real world data and turn it into an engaging experience through the game. Some values had to be over-exaggerated, but the overall point and message of these issues is presented to the user with the project. For the purpose of the project, the over-exaggerated numbers and figures help engage the user within the environment and provide obstacles that the user must consider.

There are many improvements to be made to the project, where different types of pollutions and their effects can be displayed and represented, giving a broader image of the impacts of climate change. These changes can help the delivery of the message that this project is trying to present and how climate change can impact daily life.

Currently, there are a few examples of games that deal with the issue of climate change and present them as issues through gameplay, such as Civilization VI from Firaxis Interactive (2016) or Fate of the World from Red Redemption (2011), where these games deal with scenarios that can be altered by the players decisions towards climate change.

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## 11. Bibliography

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## Appendix A: Project Log

## Appendix B: Project Timeline

## Appendix C: Assets used within the project

Solar panel asset: [Fabuan van Dorst](#) using CC Attribution  
 Factory asset: [Bunfar](#) using CC Attribution  
 Farm asset: [Quaternius](#) using CC Zero  
 Power station asset: [Mykhailo Ohorodnichuk](#) – Indicated royalty free

House asset: [CoralsStudio](#) – Indicated royalty free

Tree assets: [Ada King](#) – Indicated royalty free

Mountain asset: [olcaytoibili](#) – Personal use license (non-commercial)