Facilitating Climate Emergency Response Policy for Stevenage Borough Council

Report by

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26th April 2022

Introduction

Stevenage Borough Council (SBC) established contact with Prof Jankovic of the University of Hertfordshire's Zero Carbon Lab (UH ZCL) in October 2021 when they approached him about taking part in the Council's Scrutiny Committee as an expert witness in a review process of their Climate Emergency Response. Whilst arrangements for this expert review process were being made, an opportunity arose in November 2021 for a short term project to look into SBC's climate emergency response, to be funded by the University's Allocation of QR Strategic Priorities Funding 2021/22. The funding between 1st December 2021 and 31st March 2022 enabled Prof Jankovic as Principal Investigator and Dr Rebecca Onafuye as Research Assistant to investigate interventions for gradual reduction of carbon emissions at SBC to zero. This report explains the process and the outcomes.

First, an initial desk-based research of SBC documents was carried out with the main findings as follows:

- a baseline of 351.8 kt CO2 carbon emissions was established
- the SBC approach was well structured, consisting of 8 themes: People, Biodiversity, Transport, Energy & Water, Business, Homes, Construction & Region, Waste & Recycling, and high level actions within these themes
- there was no quantification of how zero emissions would be achieved within the above themes.

Whilst it was found that SBC were heading in the right direction for reducing carbon emissions, it became clear that there was a need to rigorously quantify a range of interventions that would ultimately result in achieving zero emissions.

Aims, objectives and research questions

The overall aim is to for the team at Zero Carbon Lab of the University of Hertfordshire was scrutinise of the current Climate Emergency Response by the Council. The specific objectives were:

1. To investigate qualitative and quantitate information to be obtained from the Council in order to establish their overall carbon footprint and its future trajectory.
2. To develop carbon emissions reduction scenarios in order to inform the Council's Climate Emergency Response Policy.
3. To inform SBC's Climate Emergency Response Policy.

In response to the above, the main research questions that followed were:

1. What adjustments to the baseline emissions may be required?
2. What will be the effect on internal temperature reduction in domestic sector on carbon emissions?
3. What will be the effect of insulating domestic sector buildings on carbon emissions?
4. How can emissions reduction from transport electrification be quantified?
5. How can emissions reduction from purchasing renewable electricity be quantified?
6. What is the effect of PV generated electricity on emissions reduction?
7. What is the effect of tree planting on emissions reduction?
8. How can gradual increase of baseline emissions be quantified?
9. What is the effect of individual and combined interventions arising from the above on gradual reduction of carbon emissions?
10. What will be ultimately required to achieve zero emissions and by when?

Methodology

The starting point for analysis was the emissions baseline data provided by SBC, as shown in Table 1.

Table 1 Carbon emissions baseline data

Category	**Emissions (t CO2)**
Industry	45,734
Transport	119,612
Commercial	63,324
Public Sector	24,626
Domestic	98,504
Total	**351,800**

It was noted that the baseline data did not include carbon sequestration from existing trees, and information about the existing trees was subsequently obtained from SBC, as shown in Table 2. In this table, descriptions of mature, semi-mature etc. were allocated age profiles on the basis of further information from SBC.

Table 2 Existing trees in Stevenage

Description	**Percentage of the total**	**Total number**	**Age profile**	**Age alignment to 2022**
Mature	50.70%	16477.5	45 - 135 years old	90
Semi-Mature	37%	12025	15 - 45 years old	30
Young	12%	3900	Up to 15 years old	15
Veteran	0.30%	97.5	Over 135 years old	135
Total	**100.00%**	**32500**		

In order to allocate appropriate sequestration level for each age profile, age alignment to year 2022 was chosen to be a mid-range year for mature and semi-mature trees and the maximum year in the young and veteran trees. This alignment was made in the supplementary material spreadsheet under 'Stevenage trees data' tab.

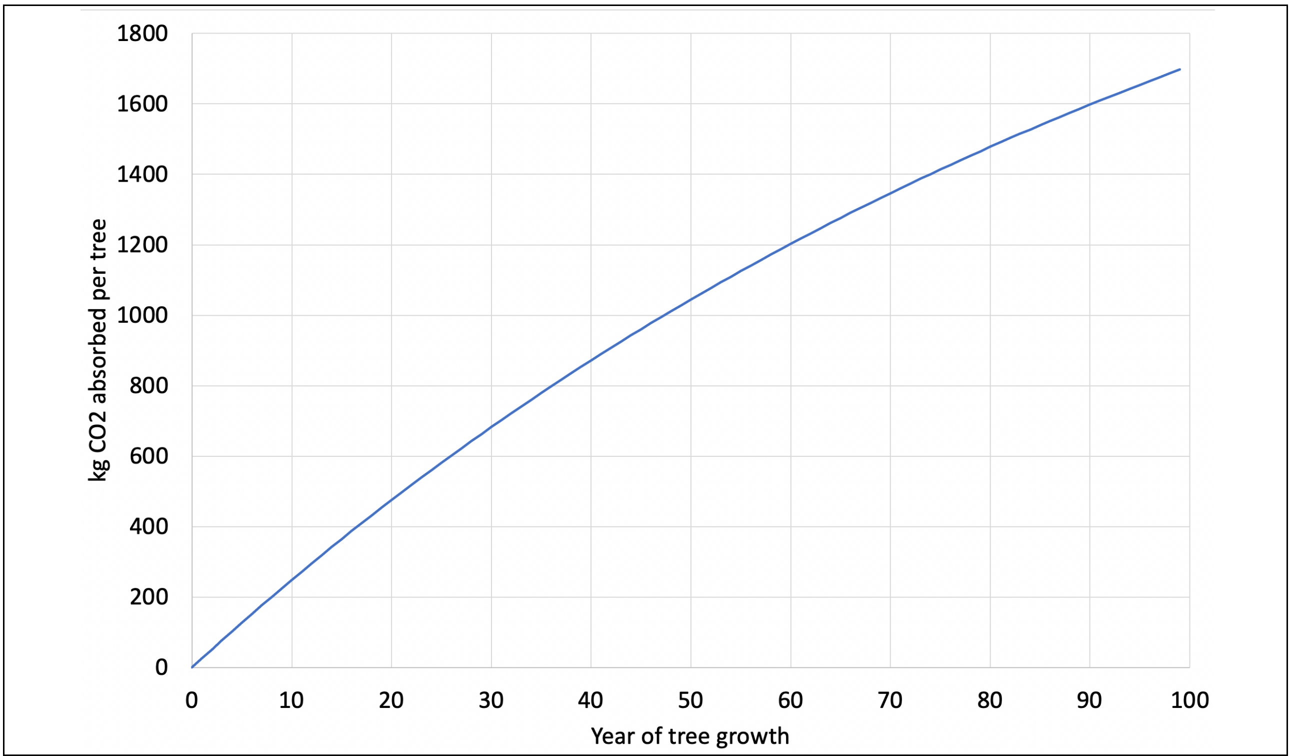


Figure 1 Sequestration approximation per single tree

The amount of carbon dioxide absorbed by a single tree is approximated on the basis of research reported by Lefebvre et al. (2021). That work shows that it takes approximately four years for a tree to absorb 100 kg of carbon dioxide. This information and the shape of the absorption curve published by the same authors was used to create a sequestration approximation curve as shown in Figure 1. Numerical values from this curve were then used in relation to the age alignment figures to year 2022 from Table 2 to calculate the baseline emissions adjustment that takes into account the existing trees.

After establishing this baseline adjustment, the following carbon emissions reduction measures were considered:

1. CO_2 reduction through internal temperature adjustment from 21 °C to 19 °C
2. CO_2 reduction from retrofit
3. CO_2 reduction from transport electrification
4. CO_2 reduction from purchasing renewable electricity
5. CO_2 reversal from PV electricity
6. CO_2 reversal from planting trees.

A gradual adoption of items 1 – 4 from the list above was assumed, and a gradual adoption over time was specified, as shown in Figure 2, so that 100% adoption/change occurs by 2030.

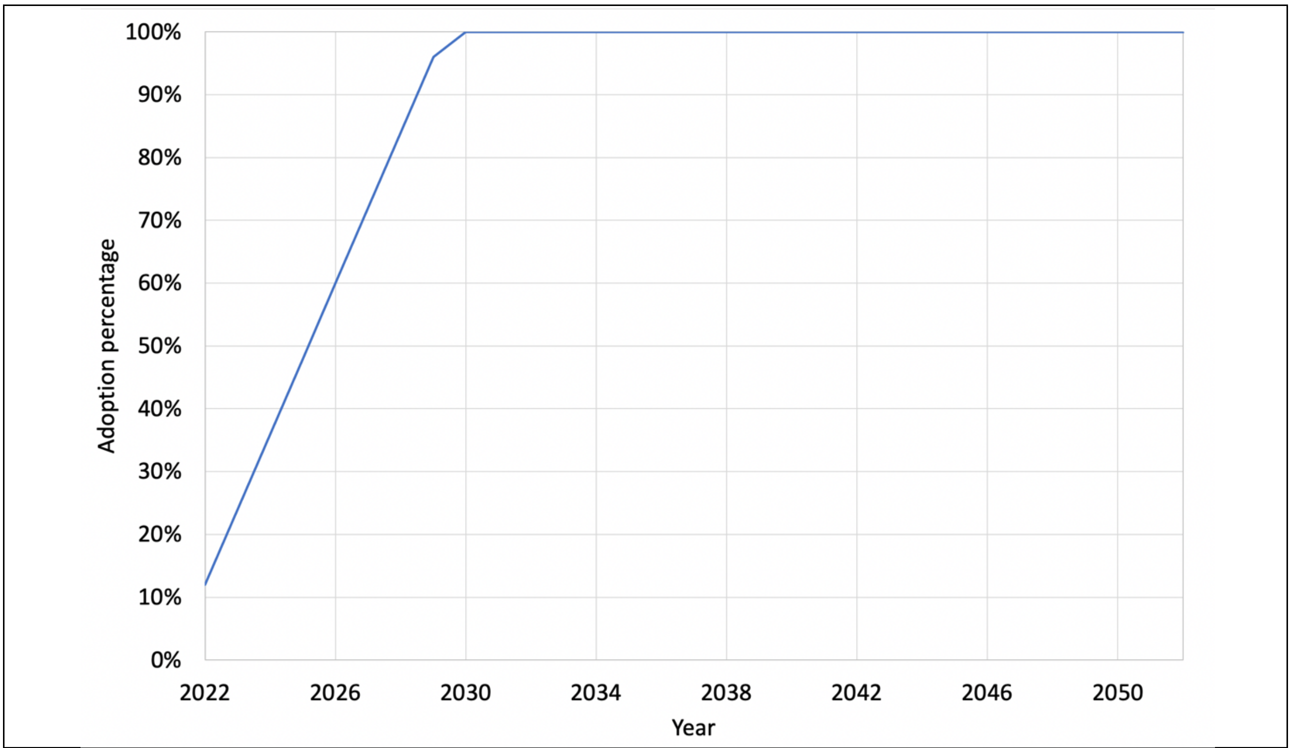


Figure 2 Assumption of gradual adoption of internal temperature reduction from 21 °C to 19 °C, retrofit, transport electrification and purchasing renewable electricity

1. **CO2 reduction through internal temperature adjustment from 21 °C to 19 °C** was calculated using dynamic simulation of a building slice with dimensions of 1m wide, 2.6m high and 6m deep. The widow to wall ration was set to be WWR = 0.3. The front surface of this slice was north facing and in direct contact with external air, and the remaining five surfaces were set to be adiabatic in the computer model, and therefore heat transfer through these surfaces was set to zero (Figure 3). This made the slice representative of an inner floor of either a house or a multi-storey building and it facilitated a simulation of carbon impact of the internal set temperature reduction.

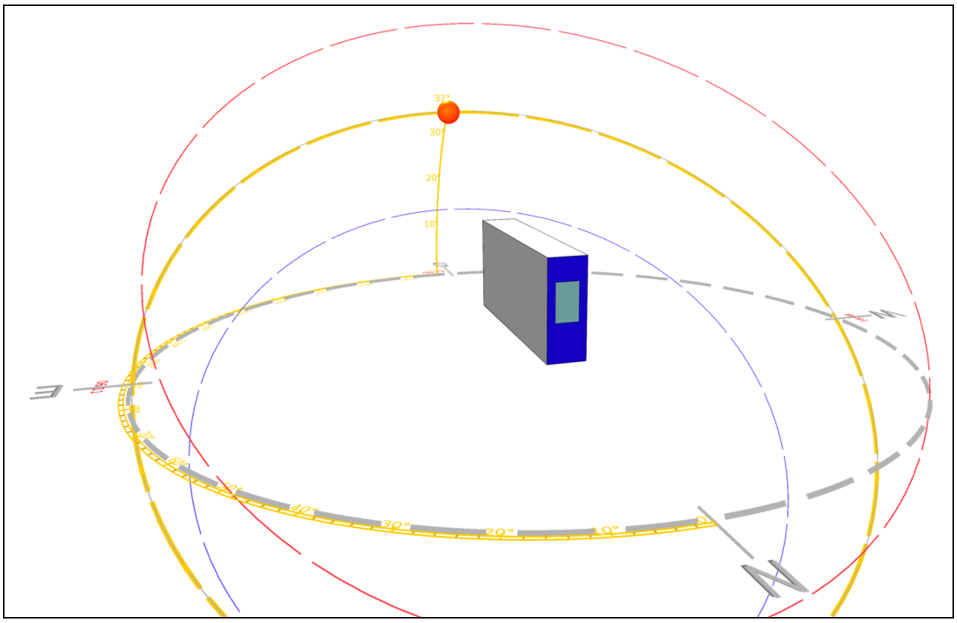


Figure 3 Simulation model for establishing emissions reduction arising from adjustment of internal set temperatures and from increasing thermal insulation through retrofit

The building occupancy was set to 07:00-23:00 hours in the model. The control of the electric lighting was based on daylight sensitive switching using sensor reading values calculated in RadianceIES (IES, 2021). Thus, the lights were switched on during occupancy hours when the daylight sensor reading was below 150 lux. The simulations were carried out using IES Virtual Environment 2021 (IES, 2021). The carbon emissions reduction from temperature adjustment is summarised in Table 3. As it can be seen from this table, there is approximately 10% reduction of carbon emissions per each degree centigrade of reduction of internal air temperature setting. This reduction will be applied gradually on the domestic emissions from Table 1, using gradual adoption curve from Figure 2.

Table 3 CO2 reduction through internal temperature reduction

Set temperature	**Emissions (kgCO2/m²)**	**Emissions reduction**
21	41.00	
20	37.00	-9.76%
19	33.00	-19.51%

2. **CO2 reduction from retrofit** was calculated using the same simulation model of the building slice as above (Figure 3), by changing thermal transmittance of the wall from poorly insulated (0.45 W/(m²K)) to well insulated wall (0.15 W/(m²K)) using 150 mm of mineral fibre insulation. The results are shown in Table 4. This reduction will be applied gradually on the domestic emissions from Table 1, using gradual adoption curve from Figure 2, and applying it to 99% of the housing stock, assuming that 1% of the stock is newbuild, and it is consistent with real life retrofit experience of houses by the Author of this report.

Table 4CO2 reduction from retrofit

Emissions before retrofit (kg CO2/m²)	**Emissions after retrofit (kg CO2/m²)**	**Emissions savings (kg CO2/m²)**	**Percentage savings**
5.50	3.5	-2.00	-36%

3. **CO2 reduction from transport electrification** was calculated using transport emissions from emissions figure from Table 1, and applying gradual adoption curve from Figure 2.

4. **CO2 reduction from purchasing renewable electricity** was calculated using domestic emissions from Table 1, and applying gradual adoption curve from Figure 2, to purchase renewable electricity and switch from gas heating to electricity heating in the domestic sector.

5. **CO2 reversal from PV electricity** was calculated on the basis of annual simulation of one square metre of monocrystalline PV panel of 20% efficiency, with south orientation and 35° inclination from the horizontal plane. It was found that annual reduction of carbon emissions from each square metre of the PV panel is -96 kgCO2/(m²,year). This figure will be subsequently used in the scenario analysis, where different PV surface areas will be multiplied by it to produce the total CO2 reduction/reversal from newly installed PV systems.

6. **CO2 reversal from planting trees** was calculated using sequestration approximation curve per single tree from Figure 1 and multiplying the values from this curve by a number of planted trees in different scenarios. When a tree is planted, it does not absorb much carbon, but the amount of absorbed carbon increases gradually with the age of the tree. The curve from Figure 1 provides cumulative carbon absorption according to the age of the tree, and that is reflected in the cumulative effect of carbon reduction as result of tree planting.

In addition to the combined carbon reduction from the measures 1 to 6, an assumption was made that the base line emissions will also increase year on year by 1%. That gradual increase is represented with a line in Figure 4.

The overall carbon balance is then calculated as follows:

Emissions running total = Baseline emissions x annual increase – reduction through internal temperature adjustment from 21 °C to 19 °C – reduction from retrofit – reduction from transport electrification – reduction from purchasing renewable electricity – reversal from PV electricity – reversal from planting trees.

This was the basis for exploring several different scenarios in the next section.

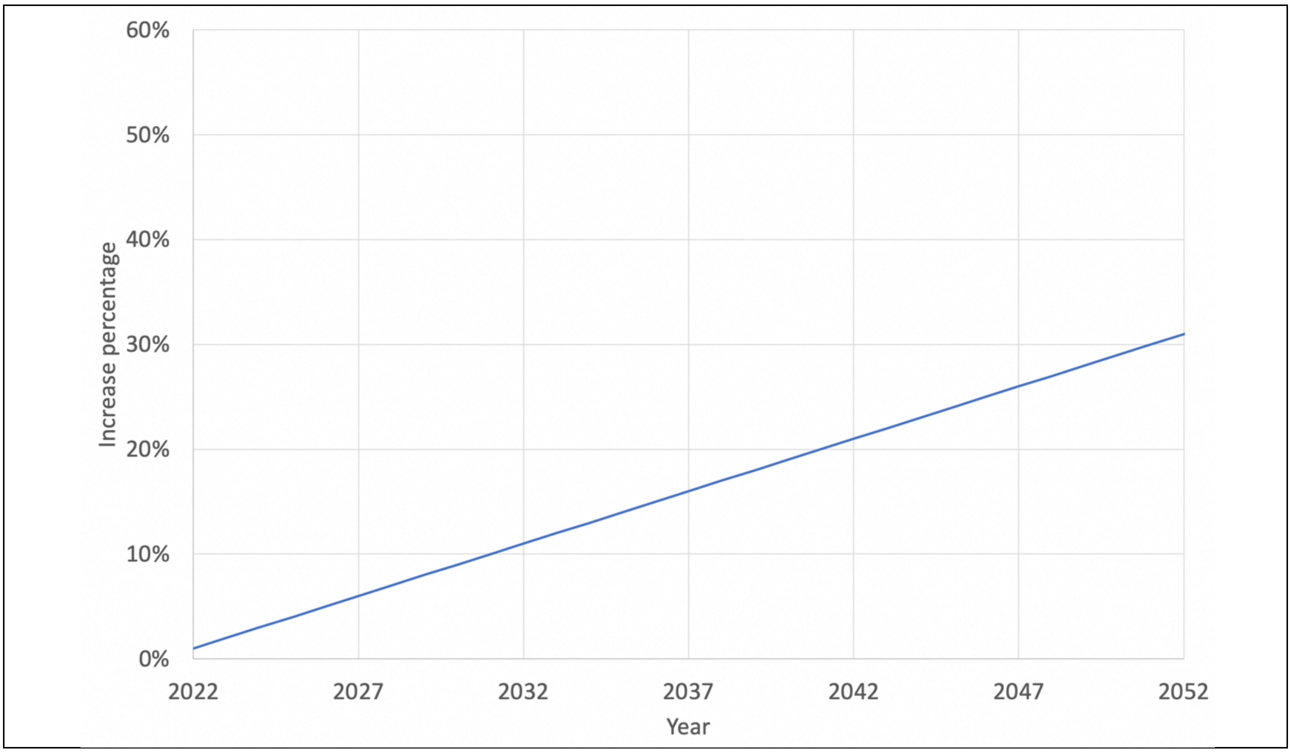


Figure 4 Assumption of annual increase of baseline carbon emissions

Emissions scenarios

The **first scenario** is business as usual, with no reduction interventions and with no increase of the baseline. This is shown in Figure 5. Whilst the top line does not show any changes, the bottom line that takes into account the existing trees shows a gradual decline, however that decline would not be sufficient to reach zero emissions any time within this century.

The **second scenario** includes the baseline and its annual increase, as shown in Figure 6. In this scenario, emissions are increasing year on year and there is no prospect of reaching zero.

The **third scenario** includes the baseline and its annual increase, as well as reduction of internal temperatures from 21 °C to 19 °C (Figure 7). Whilst total emissions remain stable until 2030 caused by the gradual adoption of the measure, they start rising from 2030 onwards, and there is no prospect of reaching zero under this scenario on its own.

The **fourth scenario** includes gradual retrofit of 99% of the domestic sector, assuming that 1% is newbuild (Figure 8). In this scenario, there is a sharper decrease of total emissions until 2028, levelling off until 2030 and then a gradual increase from 2030 onwards. Under this scenario on its own there is no prospect of reaching zero emissions.

The **fifth scenario** includes gradual transport electrification (Figure 9). In this scenario, there is a sharper decrease of total emissions until 2028, levelling off until 2030 and then gradual increase from 2030 onwards. Under this scenario on its own there is no prospect of reaching zero emissions.

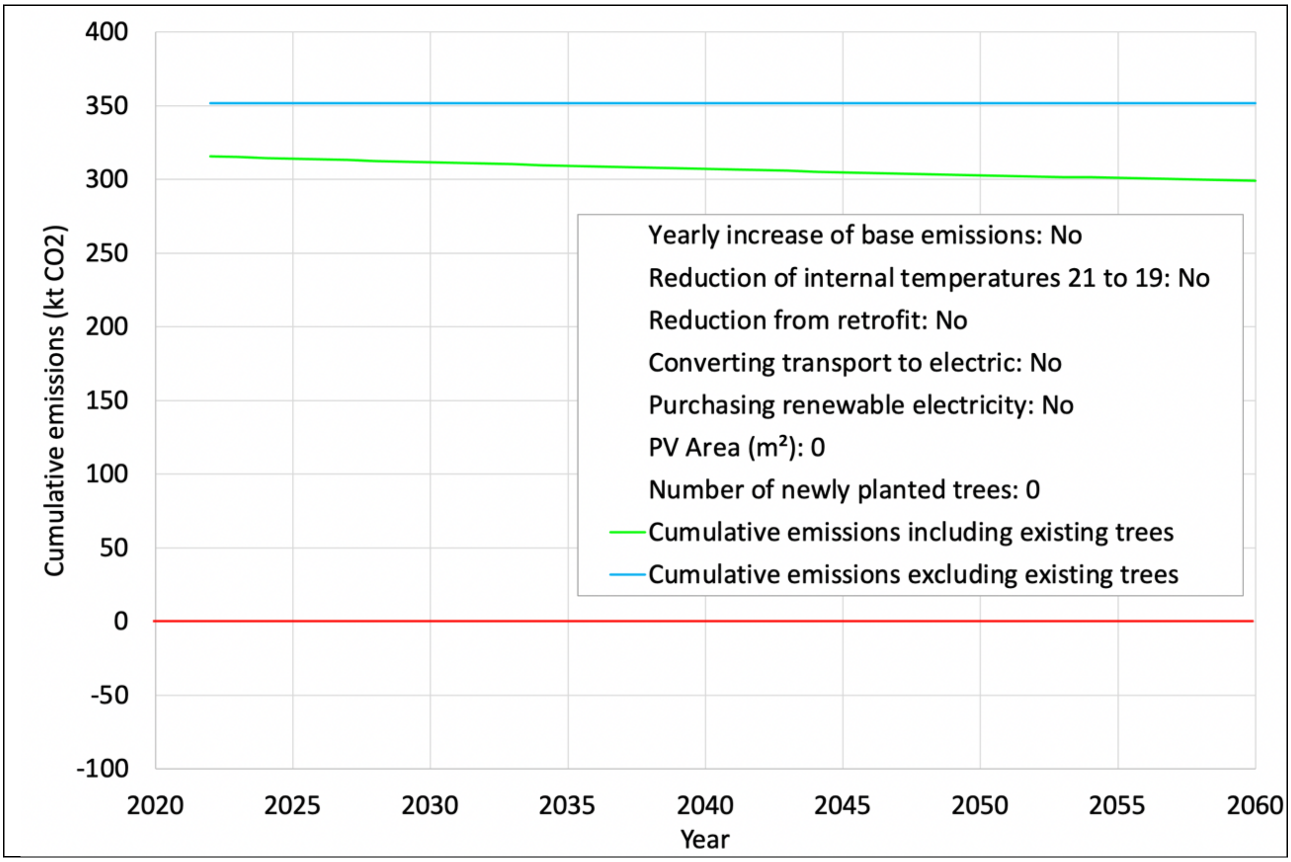


Figure 5 Business as usual without change of baseline

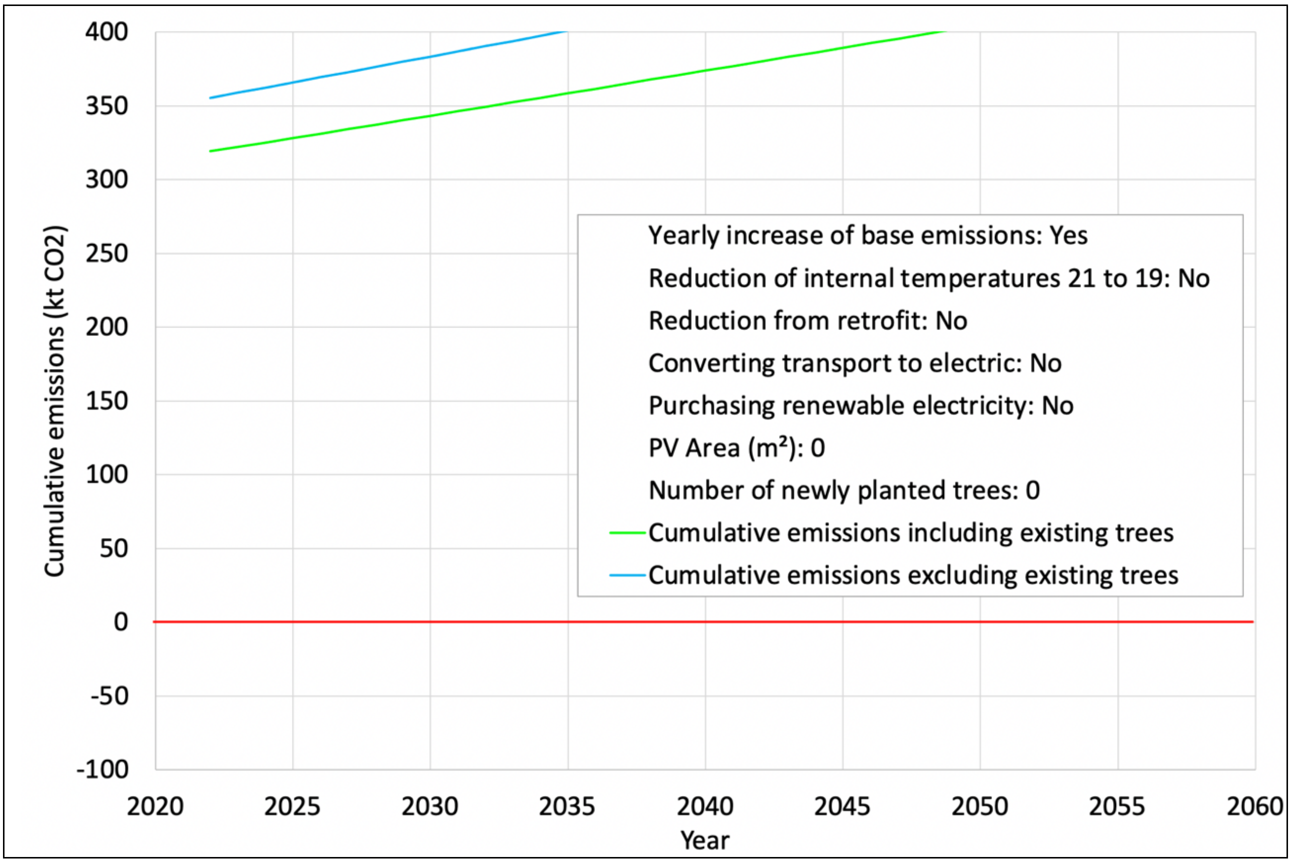


Figure 6 Business as usual with increase of baseline

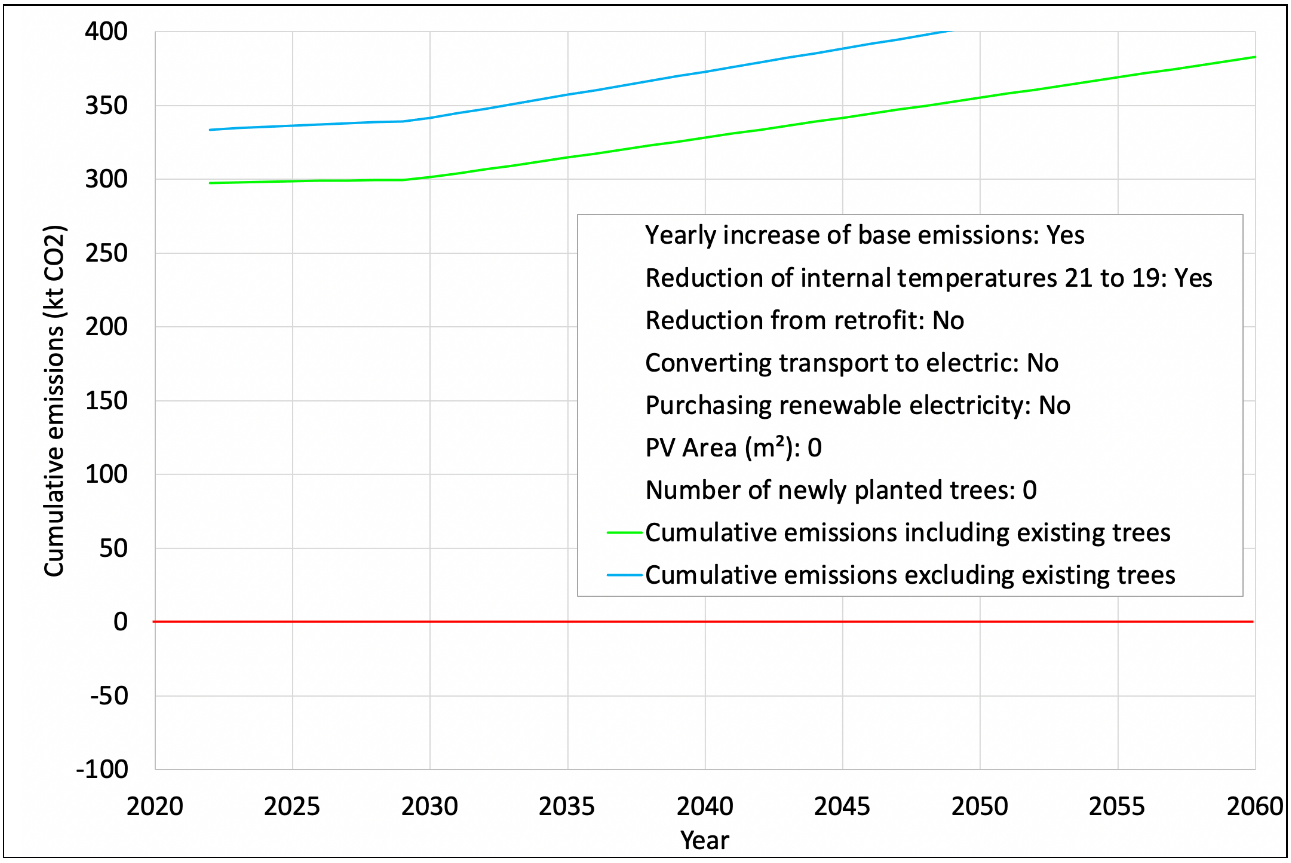


Figure 7 As the case in Figure 6 but with gradual internal temperature reduction

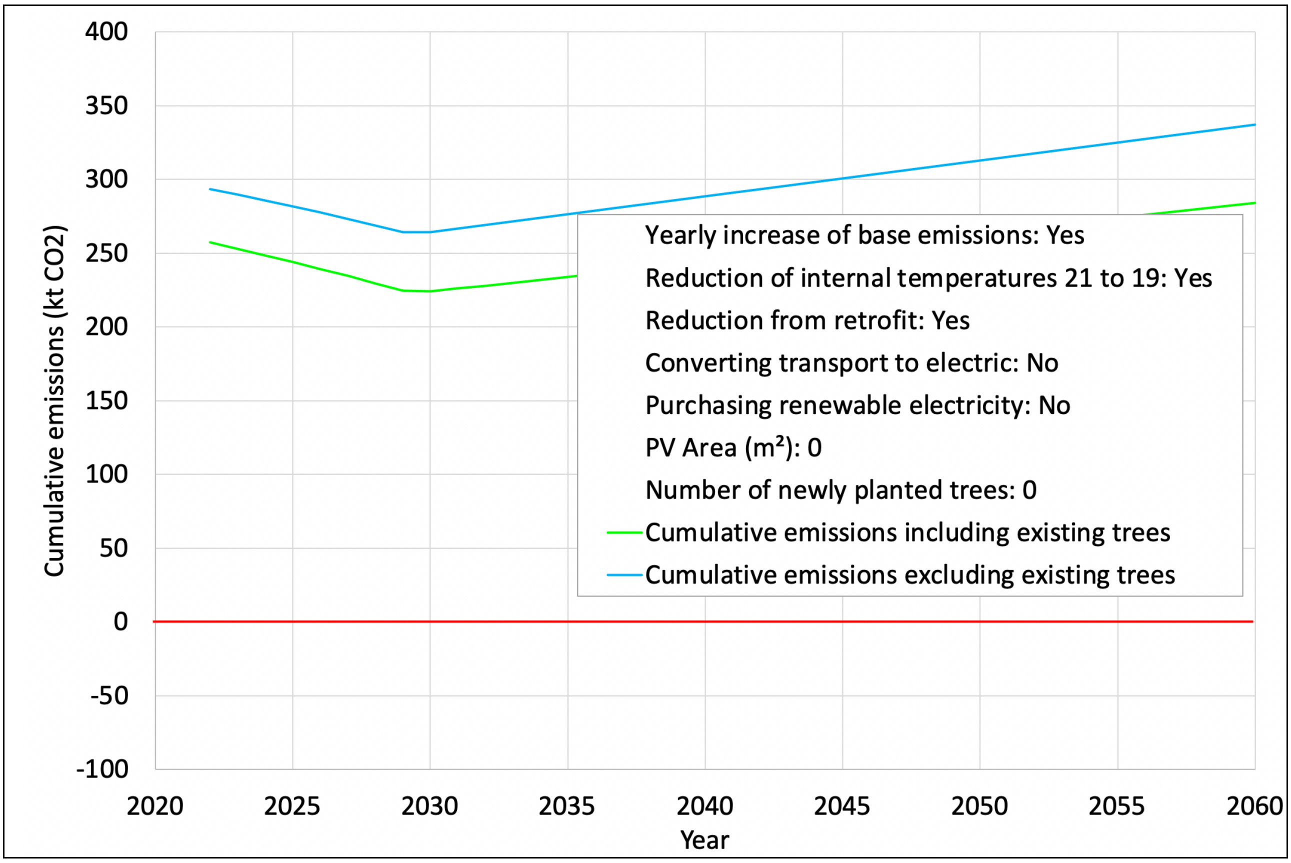


Figure 8 As the case in Figure 7 but with gradual retrofit of the domestic sector

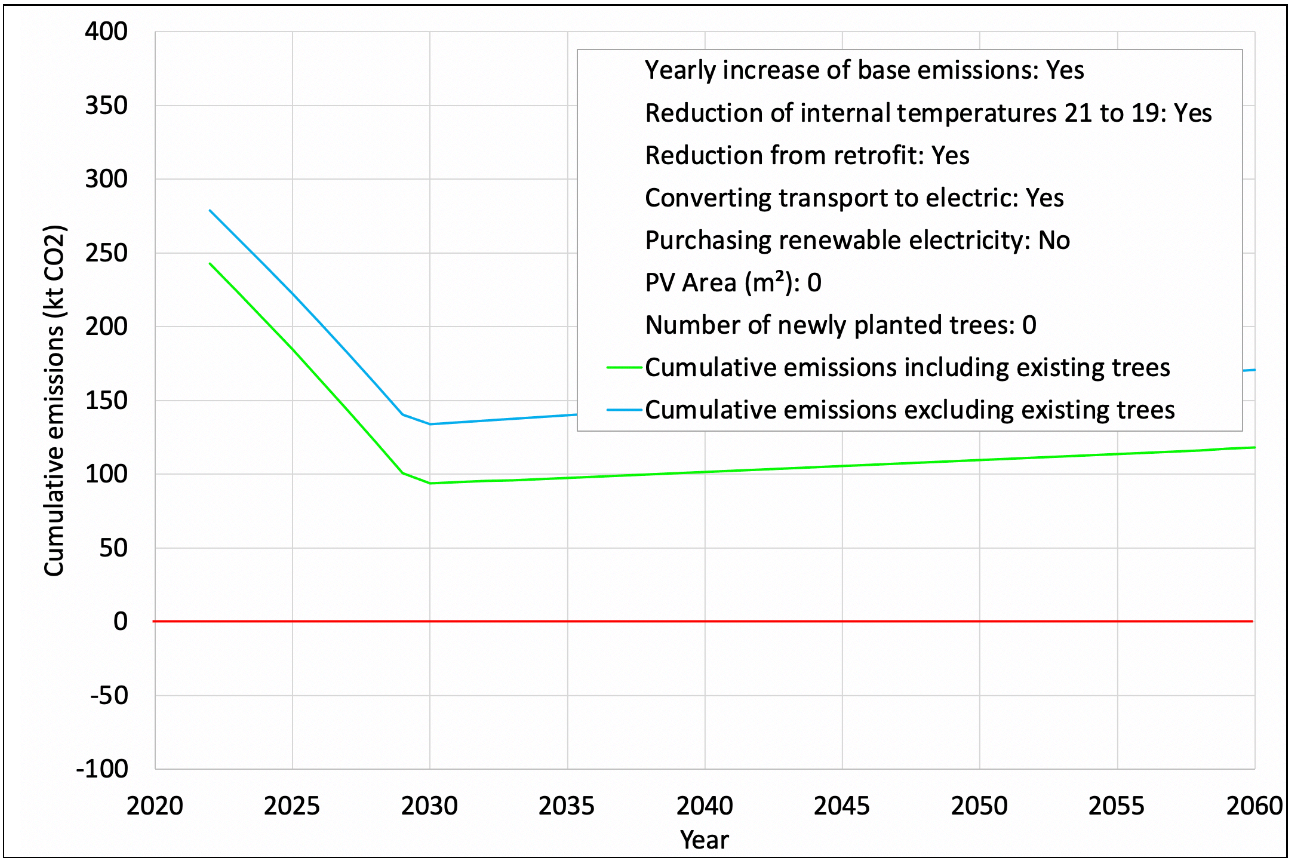


Figure 9 As the case in Figure 8 but with gradual transport electrification

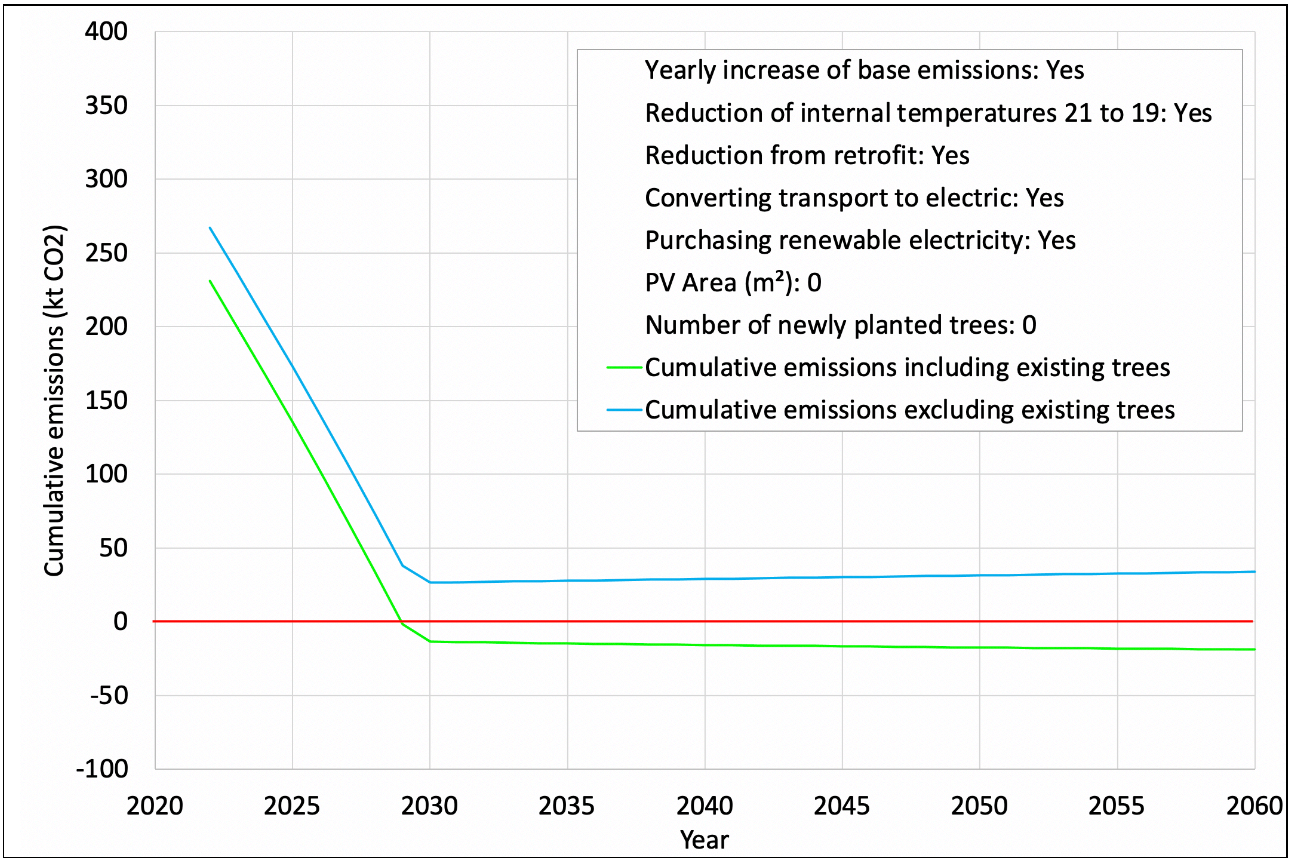


Figure 10 As the case in Figure 9 but with gradual purchasing of renewable electricity

The **sixth scenario** includes gradual purchasing of renewable electricity and switching from gas heating to electricity heating (Figure 10). Under this scenario, zero emissions are reached by 2028.

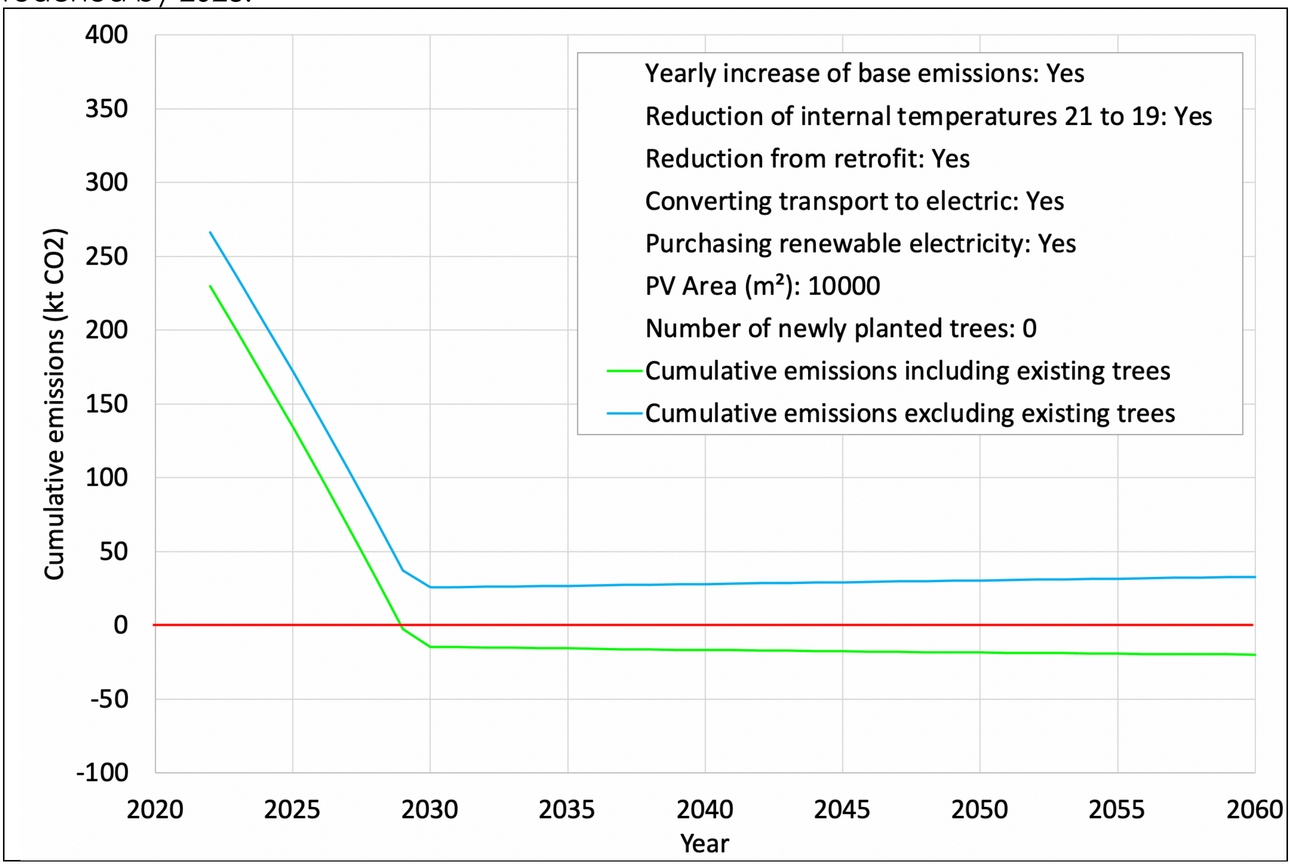


Figure 11 As the case in Figure 10 but with 10,000 m² of PV installed

The **seventh scenario** includes 10,000 m² of new PV installed in the area (Figure 11). There is no significant difference between this and the previous scenario in reducing carbon emissions.

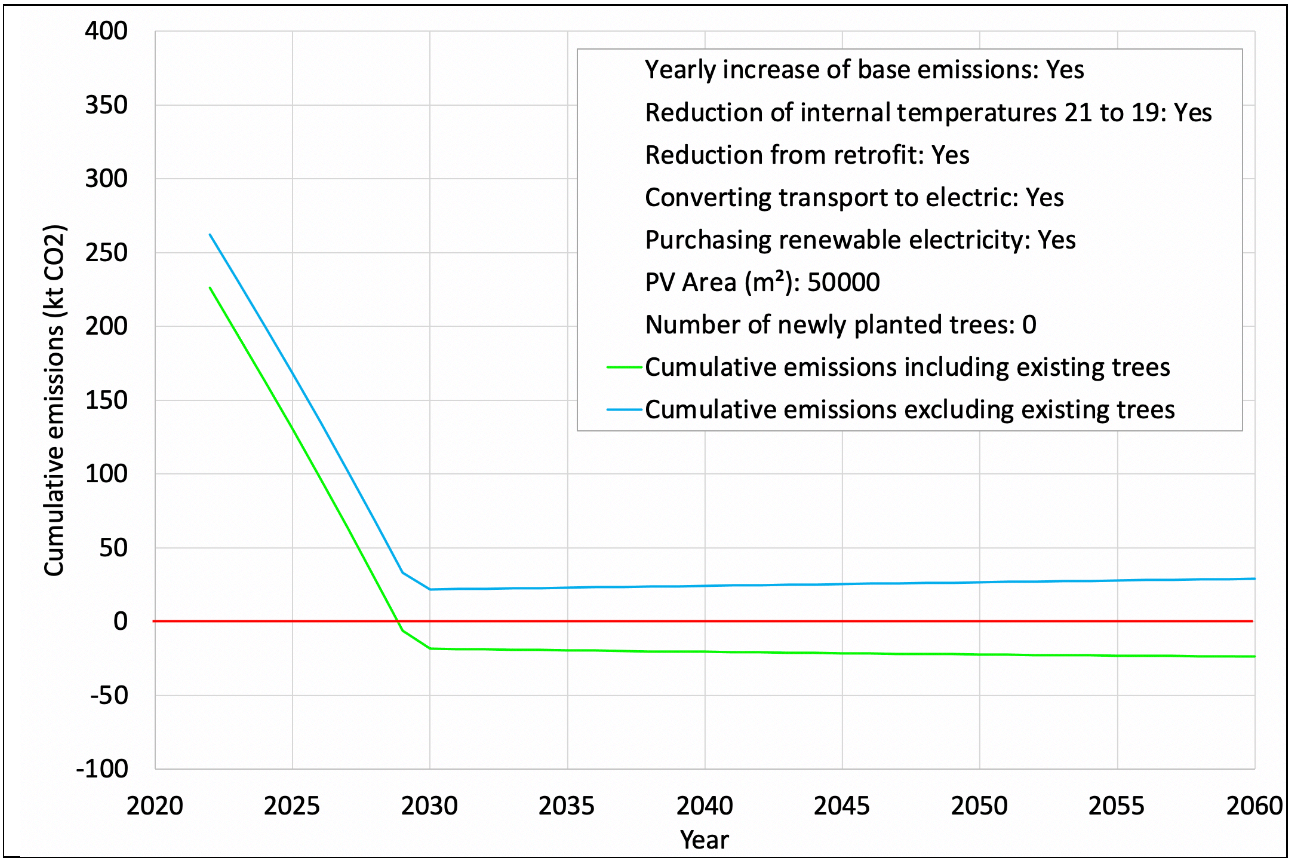


Figure 12 As the case in Figure 11 but with 50,000 m² of PV installed

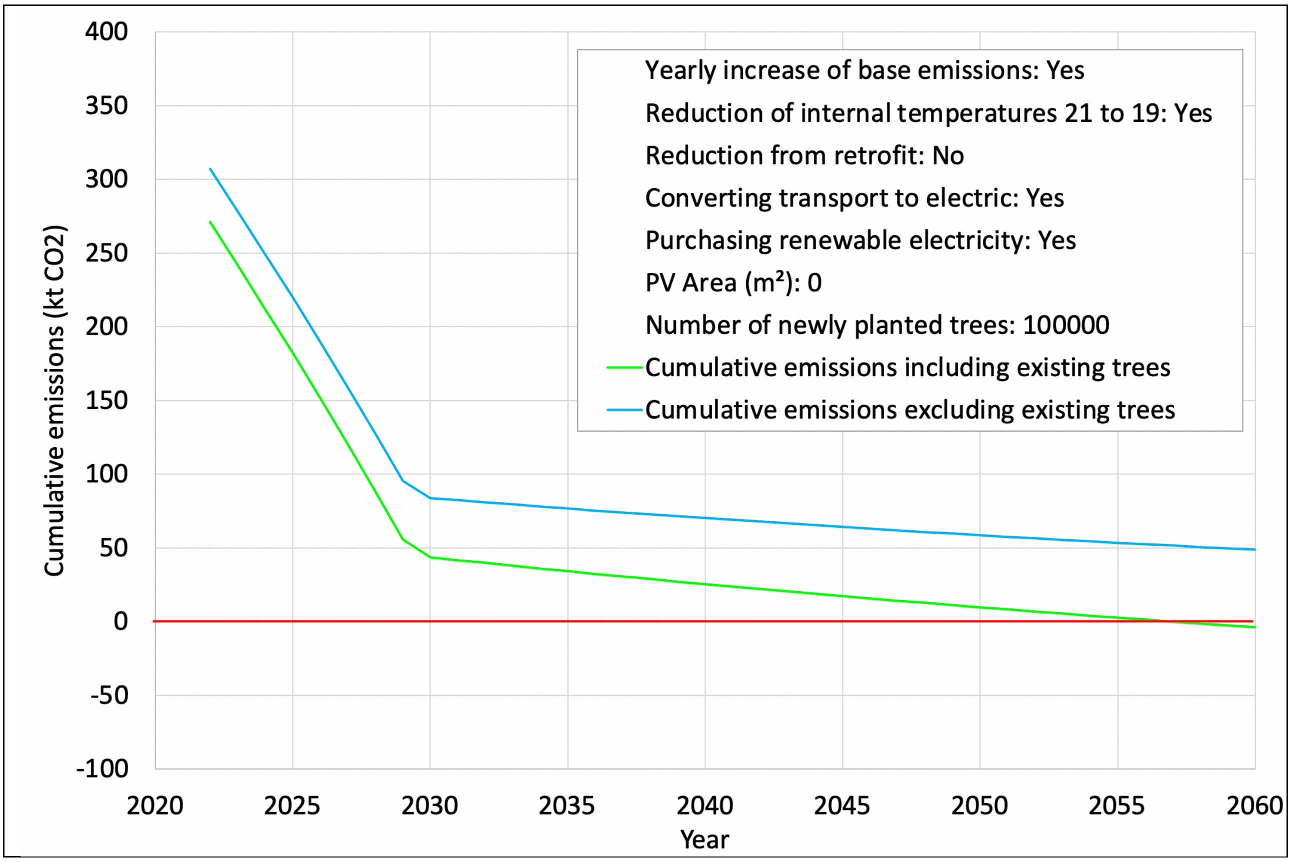


Figure 13 As the case in Figure 12 but without retrofit and with 100,000 newly planted trees

What would be the effect of increasing the surface area of newly installed PV? As shown in the **eighth scenario** (Figure 12), after increasing the PV surface area to 50,000 m², there is only a marginal difference from the previous scenario.

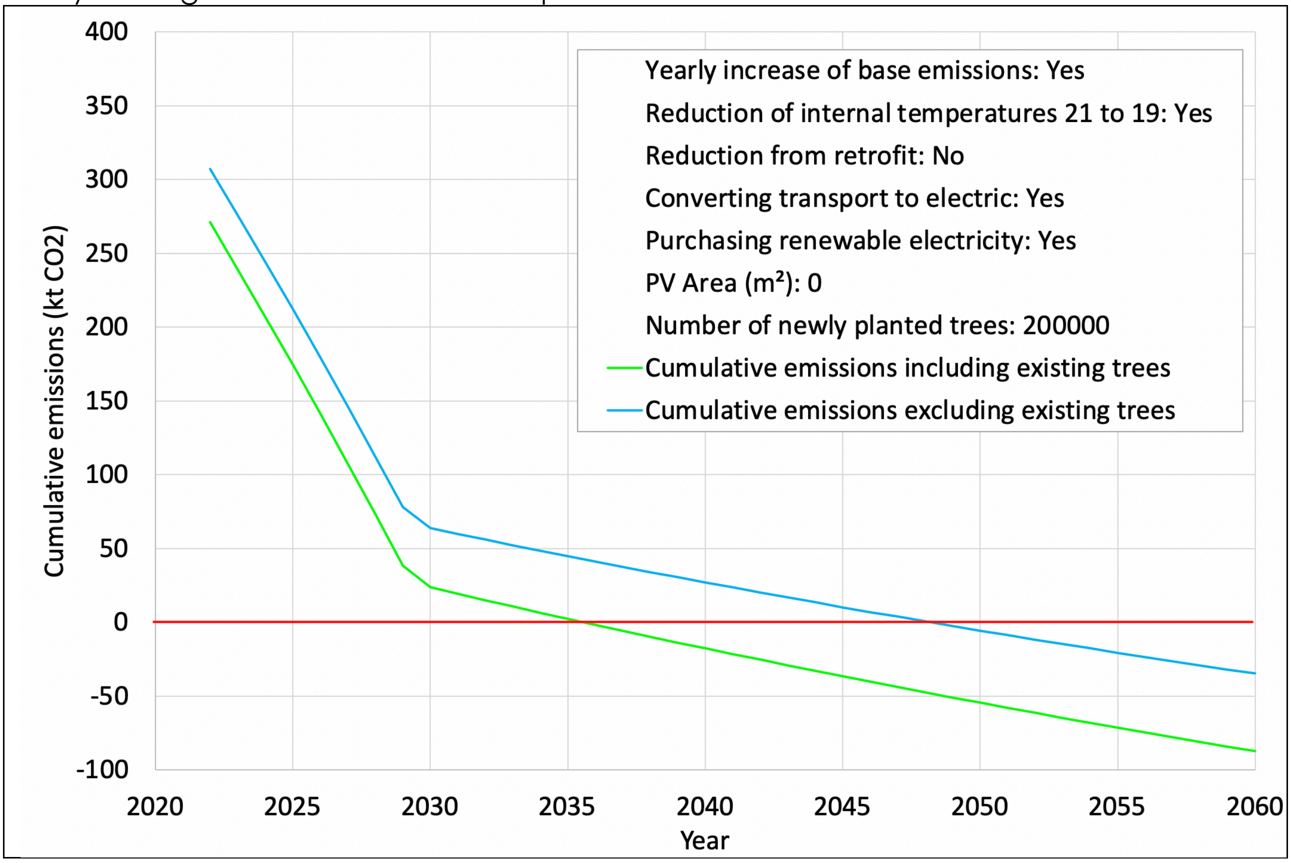


Figure 14 As the case in Figure 13 but with 200,000 newly planted trees (excludes retrofit)

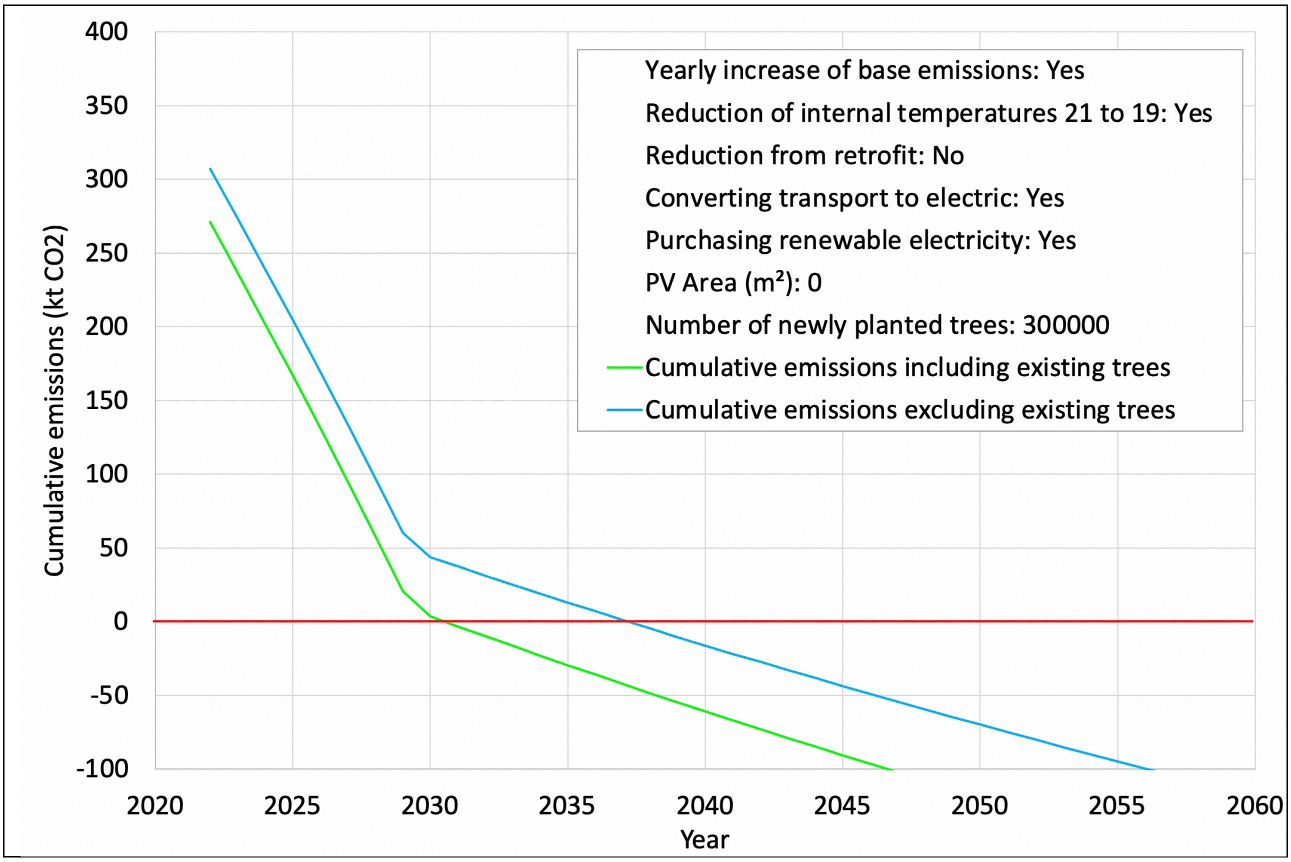


Figure 15 As the case in Figure 14 but with 300,000 newly planted trees (excludes retrofit)

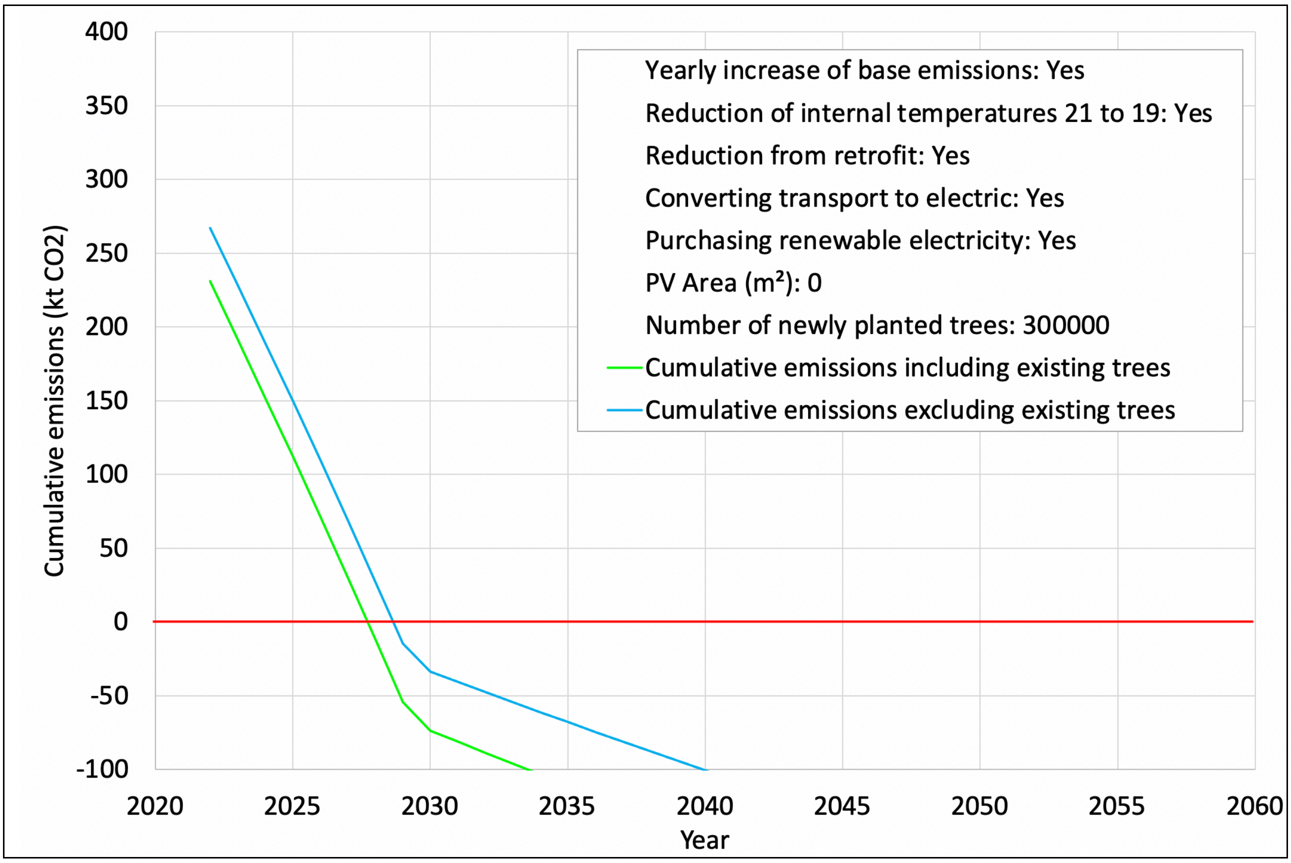


Figure 16 As the case in Figure 15 but with retrofit included

For this reason, it appears that PV does not make a noticeable difference to carbon emissions, as it has immediate annual effect but not cumulative effect. In the next, **ninth scenario**, PV is reset back to zero, retrofit is excluded, and 100,000 new trees are planted (Figure 13). As the trees appear to have a cumulative effect on emissions, considering that their volume and therefore sequestration grows year on year according to a curve in Figure 1, cumulative emissions reach zero by 2057.

Increasing the number of newly planted trees to 200,000 in the **tenth scenario** (Figure 14) achieves zero total emissions just after 2035.

A further increase of newly planted trees to 300,000 in the **eleventh scenario** (Figure 15), achieves total zero emissions just after 2030.

If retrofit is subsequently enabled in the **twelfth scenario** (Figure 16), zero is reached by 2028.

The lessons learnt from these scenarios will be discussed in the next section.

Discussion

The first thing that can be said about these scenarios are that they are based on a set of assumptions. Although the assumptions made are deemed to be realistic, a different set of assumptions will reach different outcomes of the scenarios.

However, what we can learn from the scenarios as presented here is that the measures that include CO_2 reduction through internal temperature adjustment from 21 °C to 19 °C, CO_2 reduction from retrofit, CO_2 reduction from transport electrification, and CO_2

reduction from purchasing renewable electricity, when combined together, will be sufficient to reach zero total emissions before 2030 (Figure 10).

Another somewhat surprising result is that solar generated electricity does not make much difference to the baseline and to the overall carbon emissions reduction (Figure 11and Figure 12). This is explained by its instant rather than cumulative effect on the baseline reduction.

However, it is encouraging to see that planting trees has a significant effect on the baseline reduction and that zero emissions can be reached sooner or later, depending on how many trees are planted. This is because carbon sequestration in trees is proportional to the tree mass and age, and therefore it has cumulative effect on carbon emissions reduction.

If no retrofit is carried out, then planting of 300,000 trees will be required to reach by 2030 (Figure 15). If retrofit is carried out, then zero can be reached by 2030 by combining all of the other measures except PV installation and planting trees (Figure 10).

Conclusions and future work

This document reports on a short term project funded by University of Hertfordshire's Allocation of QR Strategic Priorities Funding 2021/22, which focused on helping SBC with the scrutiny of their Climate Emergency Response.

A number of interventions for reducing baseline carbon emissions were identified. These were presented as a series of 12 quantified scenarios. It was found that different interventions had varying degree of success in carbon emissions reduction. Interventions such as internal temperature adjustment from 21 °C to 19 °C, retrofit of the domestic sector, transport electrification and purchasing renewable electricity were sufficient to achieve zero emissions if combined all together. Installation of PV systems provided minor annual reductions with no cumulative effect. Three planting provided a cumulative effect on gradual reductions over time. Trade-offs can be achieved between tree planting and retrofit in order to plan zero emissions by a specified year.

The results of this work are based on a series of assumptions. If these assumptions are changed, the results will also change. For that reason, the University research team is providing SBC with a detailed spreadsheet of assumptions and scenario calculations as supplementary material, in order to enable SBC to interrogate and evolve the Climate Emergency Response over time. Technical reference for this supplementary material is provided in the Appendix.

A more in-depth study is required in order to address details of many of the high level actions that could not be addressed as result of the short term nature of this project. This includes but it is not limited to construction of all new homes to net zero with immediate effect; accounting for emissions embodied in building materials and construction process; retrofitting of non-residential buildings; quantifying the effects of water savings; quantifying the effects of waste recycling and others.

It is recommended to continue the collaboration between SBC and University of Hertfordshire, and to seek strategic funding for developing methods and tools for real time management of Stevenage carbon emissions using digital twin technology. A Digital Twin is a process-based and physics-based digital replica of a building, an estate or an area, connected to live data sources that enable evaluation of energy and carbon emissions performance in the real time. This would be an integrated approach to low-carbon energy generation, storage and management. It would cover domestic and commercial buildings, heating and cooling systems, demand management, energy networks and energy storage, power purchasing collaborations, grid flexibility and other local conditions. The approach would aim at ensuring a realistic representation of the current performance, identifying any inefficiency and opportunity for operational savings, using the data uploaded at the start, as well as the live data feeds. By ‘pushing and poking’ such digital twin model, carbon emergency response policy could be strengthened and fine-tuned on the fly, facilitating the best match to the changing landscape of carbon emissions over time.

References

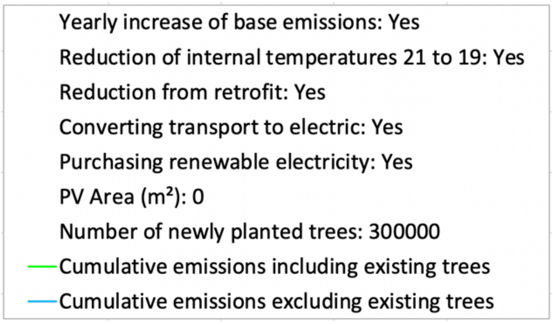
IES, 2021. VE 2021 [WWW Document]. URL https://www.iesve.com/VE2021 (accessed 11.8.21).

Lefebvre, D., Williams, A.G., Kirk, G.J.D., Paul, Burgess, J., Meersmans, J., Silman, M.R., Román-Dañobeytia, F., Farfan, J., Smith, P., 2021. Assessing the carbon capture potential of a reforestation project. Sci. Rep. 11, 19907. https://doi.org/10.1038/s41598-021-99395-6

Disclaimer

Appendix – Supplementary content

The scenarios investigation spreadsheet named: **SBCEmissionsScenariosByUniversityOfHertfordshireZCLab.xlsx** is submitted as supplementary content with this report. This Appendix gives an outline of the spreadsheet tabs and information within the corresponding worksheets under each tab.

Tab Name (exactly as they appears)	**Description**
About	Title, author, background and disclaimer information tab. Password protected.
Baseline	Baseline emissions data obtained from SBC
Scenarios data	Data used to generate scenarios, as per Methodology section. Cells C3-C8 are used for switching individual on/off interventions. Cells B9 and B10 specify PV surface area and the number of newly planted trees respectively. Numerical data of the scenarios are in columns H-S.
Scenarios chart	Emissions scenarios chart, using 'Scenarios data' to generate the 12 scenarios as reported in the Emissions Scenarios section of this report. The first seven lines of the legend show the individual interventions chosen in the corresponding scenario. The last two lines of the legend show the colour codes for the curves on the chart. 
Savings from lower room temp	Summary results of dynamic simulations showing emissions reduction from reducing internal set temperature. Data used for calculations in 'Scenarios data'. Password protected.
Savings from retrofit	Summary results of dynamic simulations showing emissions reduction from retrofit. Data used for calculations in 'Scenarios data'. Password protected.
Stevenage trees data	Data on the total number of existing trees in Stevenage, their age profile and age alignment to 2022. It applies sequestration approximation calculations per age profile. Data used for calculations in 'Scenarios data'.
Sequestration approximation cur	Visualisation of 'Sequestration approx data'.
Sequestration approx data	Tree carbon sequestration quantities on the basis of research reported by Lefebvre et al. (2021)
Adoption curve chart	Visualisation of 'Adoption curve data'
Adoption curve data	Assumption of gradual adoption of internal temperature reduction from 21 °C to 19 °C, retrofit, transport electrification and purchasing renewable electricity
Increase curve chart	Visualisation of 'Increase curve data'
Increase curve data	Assumption of gradual increase of baseline emissions at 1% per year