Carbon emissions savings resulting from some common actions

When making changes in the home that may save energy and money it is also important from the climate change perspective to take actions that will reduce a household's carbon footprint. At its simplest this means cutting the emissions of carbon dioxide that arise from burning fossil fuels but it can include actions to absorb carbon or prevent emissions of greenhouse gases. We have estimated the relative impact of six actions that are frequently taken by WeCAN households. Three are more costly 'big ticket' items which come up only occasionally and three are actions that might be taken almost daily. Bear in mind that there are many other actions you can take to reduce your footprint, these are just the ones most commonly taken in WeCAN communities.

Big ticket items

Big ticket items, like a heat pump, an electric car (EV) or photovoltaic (PV) panels not only have associated operational emissions but also have significant embodied emissions arising from their manufacture, delivery and installation. Here the embodied emissions of the items to be replaced are discounted, because they have already been emitted into the atmosphere, **and in assessing the carbon impact of installing a heat pump or PV panels or buying an EV, just the embodied emissions of the new or replacement item are considered together with the operational emissions of the two items.**

- ### Installing an air source heat pump

We see a lot these days about installing a heat pump to replace a gas or oil boiler or even other forms of heating. Unfortunately, there is a lot of misinformation about heat pumps much of which has been debunked.[1,2] For example, heat pumps are not a new technology, they were invented well over 150 years ago and around 20 million have been installed throughout Europe, and modern ones are not noisy but almost inaudible. The big advantage of a heat pump is that it runs on electricity alone, in many cases this can be renewable electricity, and does not depend on burning a fossil fuel such as gas or oil. But a further advantage is that it extracts free heat from the surrounding air and in doing so uses around three times less energy than the equivalent fossil fuel boiler.[3] All this

[1] https://www.carbonbrief.org/factcheck-18-misleading-myths-about-heat-pumps/?utm_source=cbnewsletter&utm_medium=email&utm_term=2024-03-22&utm_campaign=DeBriefed+Red+alert+for+Earth+Heat-pump+myths+factchecked+Myanmar+s+rare-earth+mining+crisis

[2] https://us6.campaign-archive.com/?u=907cd0a631b66ec99f2e6f8f0&id=b0cb2072cb

[3] Ground source heat pumps are even more efficient because they extract heat from the ground which is a warmer source of heat in winter when the heat pump is working hardest.

means that, other than the embodied energy used in its construction, a heat pump can have a very low carbon footprint.

So, how do the carbon emissions of a heat pump compare with those of other heating appliances? Let's take a 2-3 bedroom house occupied by 2-3 people as an example. Ofgem estimates[4] that on average such a house with a gas boiler consumes 11,500 kWh annually which will produce 2.4 tonnes of CO2e.[5] An air source heat pump which is nominally three times more efficient is therefore likely to generate only around 0.8 tonnes CO2e.

However, the above sums ignore the embodied energy used up to the point of delivering the boiler or heat pump on site. A survey of heat pumps suggested the embodied energy of a 6 kW unit is around 1200 kg CO2e.[6] A similar figure was obtained independently.[7] Although I was unable to determine the embodied energy of a modern gas boiler the evidence is that this is much lower than that of a heat pump[8] and is assumed to be 15 kg CO2e.

In summary, **replacing a gas boiler in a 2-3 bedroom house by a heat pump can save between 1,150 and 1,300 kgCO2e per year depending on the coefficient of performance (assumed to be in the range 2.5 to 3.0) of the installation.[9] Similarly replacing an oil-fired boiler by a heat pump can save between 1,885 and 2,045 kgCO2e per year. After 15 years, the average lifetime of a heat pump, the net cumulative savings can be as much as 27.1 to 29.5 tonnes CO2e. The impact of the embodied emissions of the heat pump are offset by the operational savings made within the first year so it is clearly not worth hanging on to your gas or oil boiler however old it is. Larger savings will accrue for larger installations and vice versa.**

A final note of caution. Heat pumps contain a few kilograms of refrigerant which is used to extract heat from the air. Some refrigerants are very powerful greenhouse gases, more than 2000 times worse that carbon dioxide, whereas others are less than ten times worse. Avoid the most potentially damaging refrigerants which can damage the atmosphere if they leak during maintenance or when the heat pump is eventually scrapped.

• Installing PV panels

Especially in the southern UK photovoltaic solar panels (PV panels) are an attractive proposition if a home has sufficient unshaded roof or land space in a suitable

[4] https://www.ofgem.gov.uk/average-gas-and-electricity-usage
[5] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2024
[6] https://www.cibsejournal.com/technical/embodied-energy-the-whole-picture/
[7] https://www.raponline.org/blog/why-i-replaced-my-new-gas-boiler-with-a-heat-pump/
[8] https://les.mitsubishielectric.co.uk/the-hub/carbon-embodied-operational-and-whole-life-cycle
[9] The coefficient of performance is the ratio of the heat energy output of a heat pump to the actual electrical energy consumed by the pump in operation.

orientation although the actual output of an installation will depend on the specific circumstances.[10] Whether or not you use any PV generated electricity at home or export it to the national grid you are potentially saving carbon emissions. This is because electricity from the grid, generated by a combination of renewable energy sources and fossil fuel power stations, currently has a carbon intensity of 0. 207 kgCO2e/kWh[11] whereas electricity from your PV panels has zero intensity, at least until the carbon footprint of the installation is factored in.

Although PV panels can be used in combination with other equipment such as batteries, a heat pump, a hot water tank or an EV this will not affect the emissions savings that are directly related to generating electricity from the panels. What matters is simply the kWh coming from the panels which will displace kWh from the grid.

The embodied emissions of a PV installation comprise emissions from the manufacture, supply and installation of the panels as well as of ancillary equipment

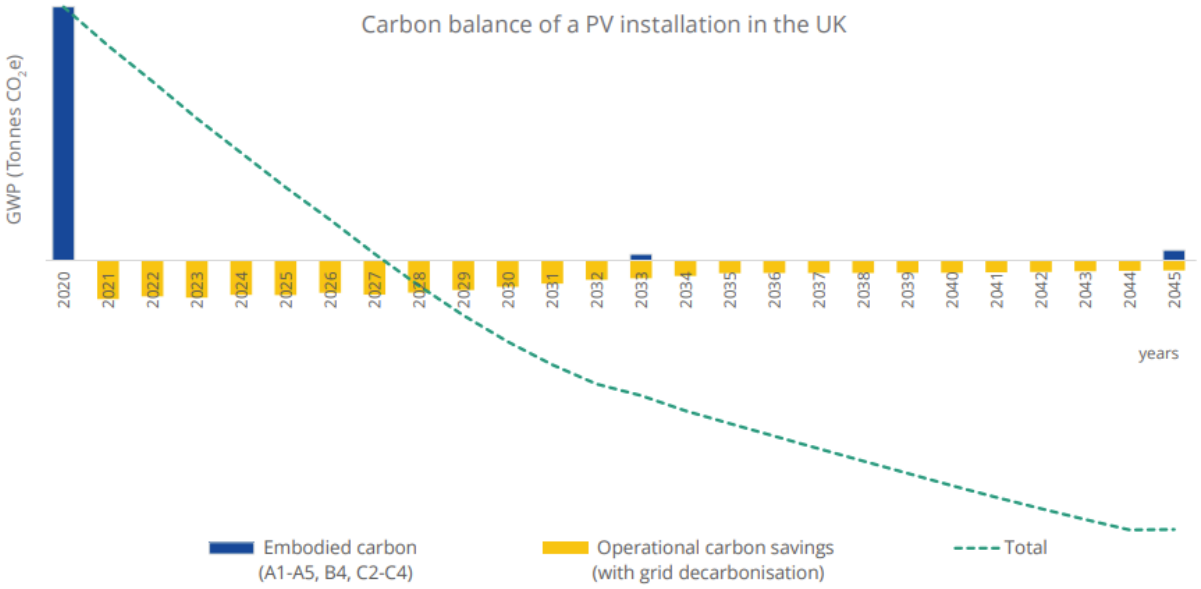


Figure 1. Schematic of whole life carbon balance of a typical large scale (non-domestic) PV installation. Note the very small operational carbon saving by 2045 when PV panels will be far less attractive from the emissions saving perspective even though they continue to supply free energy (ref.11).

such as an inverter. The following is extensively based on a report published by Hamot et al in 2022.[12] These authors assume the use of 15-20% efficient monocrystalline panels in contrast to polycrystalline panels which are 14-16% efficient.

Typically a PV panel system is considered to have a lifetime of at least 25 years. Over this time period the embodied emissions of the installation are gradually offset by the

[10] Solar Wizard is an online tool to check your property's suitability for installing PV panels.
[11] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2024
[12] Whole Life Carbon of Photovoltaic Installations Report Released - Elementa Consulting

emissions saved by not using the grid. However, the timespan is so long that the expected gradually increasing 'greening' of the grid may have to be taken into account, meaning that annual emissions savings will decrease over time, as well as replacement of the inverter after 12.5 years (Figure 1). Similarly, the efficiency of monocrystalline PV panels decreases by 0.6% per year. Even if the grid is eventually based on renewables alone it will still have some transmission and distribution losses which would give onsite PV panels an advantage. These details are not accounted for here.

The estimated embodied emissions of monocrystalline PV panels is very variable but appears to have been decreasing in recent years. 400 kgCO2e/kWhp is towards the top end of the best currently available panels and is used here.

In summary, it is estimated that **the embodied emissions of a 3-8 kWp installation in southern England will be cancelled out by the emissions saved by the panels within 2.5 years. The net savings over the 25-year lifetime of such an installation will range from 11 to 34 tonnes CO2e.**

• Switching to an electric car (or going entirely car free)

Road transport causes 22% of the UK's emissions of CO2 and 82% of vehicles are cars.[13] So one's choice of car and annual mileage driven are obviously important. For example, a petrol/diesel car emitting on average 340 gCO2/mile and which has been driven 6,600 miles per year will emit 2.2 tonnes of CO2 (UK average figures[14]). The easiest way to avoid these emissions when getting around is clearly to give up driving altogether and to use public transport instead, which has a much lower carbon footprint per passenger, but this does not suit everyone nor is it necessarily always feasible.

Electric cars (EVs) are an attractive prospect from the climate change viewpoint especially when we are told that they have zero tailpipe emissions. However, an EV's effective emissions also depend on the source of the electricity they use to charge their battery and their embodied emissions. In the UK, electricity from the national grid has a carbon intensity of 0.207 kgCO2e/kWh.[15] It is estimated that an EV driven for 6,600 miles will emit only around 255 kgCO2 (ref.14) which is about 12% of a petrol/diesel car's emissions!

Like other Big ticket items, because of the materials and processes involved in their construction, we must also consider an EV's embodied emissions. These are especially high because the battery they contain requires mining, or at least sourcing, some rare

[13] https://www.torfaen.gov.uk/en/Related-Documents/Pollution-Control/PollutionControl-IdlingVehicles/Car-Pollution-Booklet.pdf

[14] How clean are electric cars? | Transport & Environment (transportenvironment.org) Emissions per mile averaged over 225,000 km based on the annotated graphs.

[15] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2024

elements and heating to high temperatures during production. A useful online tool compares the total emissions of petrol/diesel cars and EVs.[16] These results show that although a medium sized EV has embodied energy of 10.7 tonnes CO2e, over 50% more than a similar sized petrol/diesel car, an EV's cumulative operational emissions soon become less than the cumulative emissions of the latter because of its much lower emissions per mile from using electricity.

So, when should you swap your petrol/diesel car for a new EV? The arguments are quite complicated.[17] For a start, the calculation becomes much simpler if one assumes that the embodied emissions of your current car can be ignored, because they are long since emitted. One should also consider how much longer one's current car might reasonably remain viable (on average in the UK petrol/diesel cars are scrapped after 14 years[18]). Therefore, I compare the emissions during the remaining lifetime of your present petrol/diesel car, should you hang on to it, with the emissions over the same period which would result if you replaced it now with an EV.

It turns out that, because of the high embodied emissions of an EV, **only if your present car is younger than 8.6 years, i.e. it nominally has at least 5.4 years of life left in it, will you save emissions by replacing it with an EV. Otherwise, you should hang on to it. This assumes an annual mileage of 6,600 miles. For 4,000 miles/yr you should replace your car before it is 5 years old and for 8,000 miles/yr the age is 9.5 years.**

However, an even better solution for the environment is to buy a second-hand EV. In this case the emissions "saved" up to when the first car would have been scrapped at the end of its life are always positive (see Table 1).

Finally, these results depend on using a number of average figures so they give only an indication of what to do. More exact results will depend on individual cases.

Be aware that the Committee on Climate Change recently (July 2024) recommended to the UK government that "The share of electric vehicles (EVs) out of all new vehicles sold needs to increase … to between 80% and 100% for cars and between 70% and 100% for vans by 2030".[19] The previous government wished to stop sales of new petrol and diesel cars by 2035 but this date may now change.

Table 1. Table of emissions savings for a mid-sized car as a function of when a petrol/diesel car is replaced by an EV during the car's 14-year lifespan and for annual

[16] How clean are electric cars? | Transport & Environment (transportenvironment.org)
[17] https://www.zerocarbonguildford.org/post/should-i-buy-an-electric-car#:~:text=This%20report%20estimates%20the%20embodied,carbon%2C%20about%2014%20tonnes%20CO2e
[18] Best ways to make your car last longer | RAC Drive
[19] https://www.theccc.org.uk/publication/progress-in-reducing-emissions-2024-report-to-parliament/

mileages of 4,000 and 8,000. The negative numbers indicate that it is too late to replace the car by an EV after it reaches 13-years old.

Replacement car	Emissions saved (tCO2e)			
Age of petrol/diesel car when replaced (year)	1		13	
Annual mileage (miles)	4000	8000	4000	8000
New EV	4.9	20.5	-9.5	-8.3
Second-hand EV	15.6	31.2	1.2	2.4

Daily activities

- ### Cycling and walking for short journeys including e-bikes

Many trips that are frequently made, including those for shopping, commuting to work and going to school, are actually quite short. 26% of all trips are less than 1 mile and 71% are shorter than 5 miles. Even so 16% of trips less than a mile and 67% of trips less than 5 miles are made by car or van. So, it is worth considering what emissions would be saved by walking or cycling for distances up to 5 miles.[20]

The average petrol/diesel car emits 340 gCO2/mile (ref. 14; electric vehicles (EVs) are considered under Big ticket items) whereas cyclists and walkers clearly burn some energy but do not directly produce carbon dioxide. However, if we also account for the emissions in making the car and the bicycle, and the emissions from producing the food the cyclists and walkers 'burn', the figures are worse. Surprisingly cycling emits less than walking, because walkers are said to need to eat more, and e-bikes emit least of all (see Table 2).[21] Advice on choosing a bike is available here.[22]

Table 2. Table comparing annual emissions of different modes of transport over short distances and showing emissions savings made compared to a car.*

Mode of transport	Total emissions (g CO2 per mile)	Emissions saved by 200 commutes of 5 miles one-way relative to a car (kg CO2)
car	434	0
e-bike	23.7	800
bicycle	33.6	820
walking	89.6	240**

*From a very thorough life-cycle assessment report on Europe-wide transport emissions, published in 2011 and now possibly outdated; figures are only used for comparison purposes in this section.[23]
** actually for 175 school trips of 2 miles one-way

[20] https://www.gov.uk/government/statistics/national-travel-survey-2022/national-travel-survey-2022-mode-share-journey-lengths-and-trends-in-public-transport-use
[21] How much carbon can you save by cycling to work? | Cycling UK
[22] Eco-friendly bicycles & E-bikes | Ethical Consumer
[23] ECF_BROCHURE_EN_planche.pdf

So, for example, a commuter choosing to cycle or e-cycle 5 miles to work and back 200 days a year would save very substantial emissions of 800 kg of CO2 (and pro rata for shorter distances). This should also be good for the cyclist's fitness, general health and well-being. Each trip will take the cyclist about 20-23 minutes whereas a car in traffic might take 15 minutes; isn't it worth a few minutes a day to help 'save the planet'?

- ## Composting food waste

A shocking statistic is that 4.7 million tonnes of food, excluding inedible parts, is wasted annually in UK households. This amounts to about 170 kg per household which is around one sixth of what we buy.[24] This is not just a food waste issue, it is also a waste of land, water, labour, energy, and even contributes to methane emissions, a potent greenhouse gas.[25] But here we are concerned just with what happens to food that you have in the home but is wasted because, although it is fit for human consumption, it isn't eaten. Either it's been left to go off or has been prepared for a meal but thrown away (hopefully not because it's just passed its 'best before' date).

Where food waste can be separated from other household waste this prevents contamination of other waste which could be usefully recycled. It also ensures that food waste can be sent to anaerobic digestion facilities rather than needlessly lost to landfill or burnt, as in Hampshire, to help generate electricity.[26] The real problem with food waste is that if it decomposes where air (oxygen) is limited it will produce the strong greenhouse gas methane which, over 20 years, causes 86 times more warming than CO2. An anaerobic digester collects methane and burns it but in many landfills the methane is allowed to escape to the atmosphere. So, clearly we should avoid wasting food in the home at all costs. However, if you do end up with food waste, including the inedible parts, it is better to compost uncooked food waste at home either in a compost heap or in a special food waste container that allows air to enter.

Composting for just one year is said to save global warming gases equivalent to all the CO2 your kettle produces annually (73 kg CO2)[27], or your washing machine produces in three months (14 kg CO2).[28,29]

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[24] https://www.wrap.ngo/resources/report/food-surplus-and-waste-uk-key-facts-updated-november-2023
[25] https://www.epa.gov/snep/composting-food-waste-keeping-good-thing-going#:~:text=In%20addition%2C%20composting%20lowers%20greenhouse,in%20the%20presence%20of%20oxygen.
[26] https://www.gov.uk/government/news/new-295m-for-councils-to-introduce-weekly-food-waste-collections
[27] https://www.carbonfootprint.com/energyconsumption.html
[28] https://www.recyclenow.com/how-to-recycle/home-composting#Why-compost
[29] https://www.which.co.uk/news/article/change-this-laundry-habit-and-help-cut-co2-pollution-by-400000-cars-aVQXA7B7HxFx

Food, once cooked, should always be eaten even if at a later meal. Other food leftovers, if inedible, should be composted. The resulting compost, once fully rotted down, can be used to improve your soil.

- ## Planting a tree

There's a lot to be said for planting trees especially if one is replacing a tree that was recently cut or blown down. Trees cool and purify the air and, especially if they are native species, support ecosystems. But most importantly, trees sequester (store up) carbon very slowly over their lifetime and recent research has discovered that tree bark absorbs methane as well.[30] A young tree absorbs only 5.9 kg CO2 per year (and a sapling perhaps much less).[31] On average a fully grown tree takes up between 10 and 40 kg of CO2 per year by photosynthesis but this amount depends on numerous factors including the species of tree.[32] Trees can also grow for many years; initially, when relatively small, they grow fast but as they mature, over decades or even centuries, they grow more slowly whilst still absorbing carbon.

A mature tree can contain a tonne or more of stored up carbon but from the climate point of view the eventual fate of the tree is absolutely key to its impact on global heating. If it succumbs to fire, storm, disease, drought or flood the carbon so gradually stored away for many years is easily and quite quickly returned to the atmosphere. Only if a tree is grown for timber and that timber is then incorporated into buildings, furniture or other uses is the carbon prevented, at least for a while longer, from returning to the atmosphere. So planting trees can be seen as a useful and practical way now of slowly absorbing carbon from the atmosphere but it has to be recognised that in the majority of cases that carbon inevitably returns as carbon dioxide from whence it came.

Trees help to mitigate global heating now but it is almost impossible to say how much carbon dioxide any individual tree will successfully absorb over its uncertain lifetime in the coming decades.

Summary

The above results are summarised in the following two figures; Big ticket items in Figure 2 and Daily activities in Figure 3.

Figure 2 shows the range of likely lifetime emissions savings for heat pumps, PV panels and electric cars over a period of 14 or 15 years (the PV panel figures were adjusted pro

[30] https://www.theguardian.com/environment/article/2024/jul/24/tree-bark-vital-role-removing-methane-atmosphere-climate#:~:text=Microbes%20in%20the%20bark%20of,atmosphere%20for%20a%20shorter%20time.
[31] https://www.carbonpirates.com/blog/how-much-carbon-do-trees-absorb/
[32] https://ecotree.green/en/how-much-co2-does-a-tree-absorb#:~:text=A%20tree%20absorbs%20approximately%2025kg%20of%20CO2%20per%20year&text=But%20really%20a%20tree%20absorbs,let's%20start%20breaking%20it%20down.

rata from a lifetime of 25 years). Potentially the biggest savings are made by giving up the use of a car altogether followed by buying a second-hand electric car (EV). The range of savings for EVs are down to considering annual mileages of 4000 to 8000 miles driven for 14 years (the average lifetime of a petrol/diesel car). The relatively small differenece between giving up a car and buy a second-hand EV is simply down to the very low operational emissions of an EV. Next, replacing an oil boiler with a heat pump makes a very significant saving. The smaller saving from replacing a gas boiler reflects the smaller carbon intensity of gas with respect to oil. The range of values is caused by considering coefficients of performance (COP) from 2.5 to 3.0. The smallest savings are made by installing PV panels. The range of savings covers installed capacities of 3 to 5

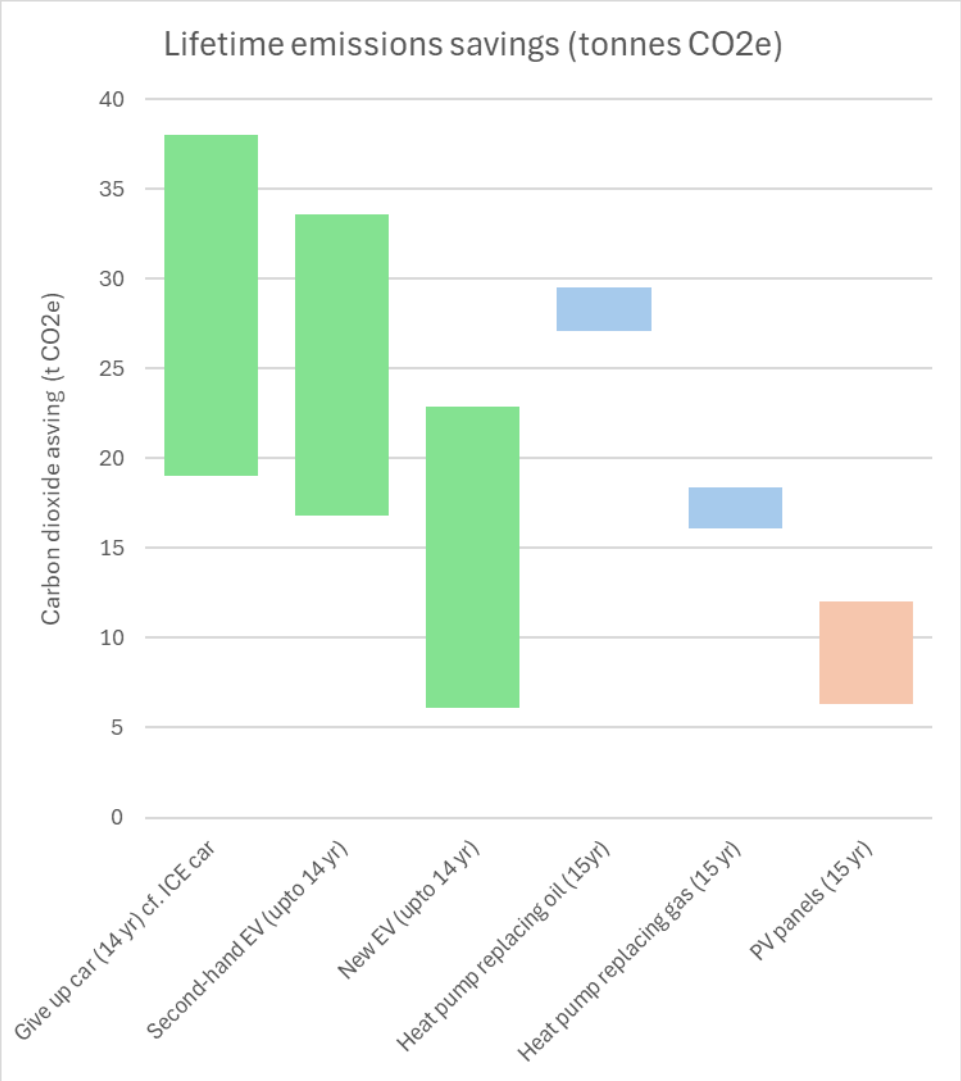


Figure 2. Potential carbon dioxide emissions savings from adopting some Big ticket items.

kWp.

Figure 3 shows the annual emissions savings made from active travel, tree planting and composting. These savings would mostly be less than those of the Big ticket items even in the unlikely event that they would be conducted continuously over 15 years. As for the Big ticket items making changes to one's travel arrangements, in this case adopting active travel for each of two different scenarios, has the biggest impact. The differences between the two tree planting scenarios simply reflects that it takes years for a small sapling to grow enough to absorb significant amounts of carbon.

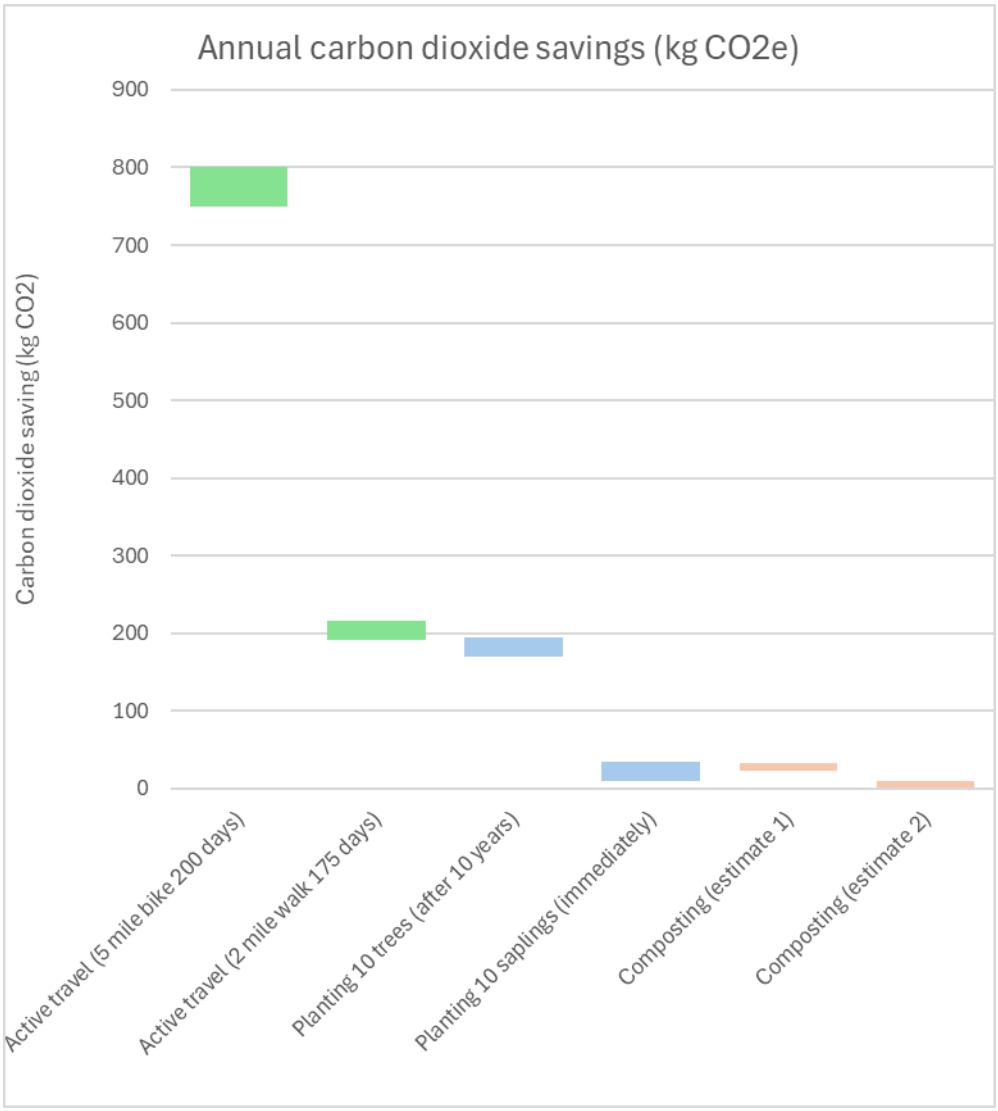


Figure 3. Carbon savings from adopting some different daily habits.